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Original Research Article

Postharvest quality during refrigerated storage of Nadorcott mandarin

ABSTRACT

Aims. The aim of this article was to study the suitable storage time and storage temperature of Nadorcott mandarin.
Study design: The experimental design used was the completely randomized design, in factorial scheme, and the factors two temperatures (4 and 8℃) and four storage periods (15, 30, 45 and 60 days), with four repetitions for each period, each repetition counting with 15 fruits.
Place and Duration of Study: The tangerines cv. Nadorcott used were from Rosário do Sul, Rio Grande do Sul. Fruits were harvested with commercial maturation, selected and transported to the laboratory of the Núcleo de Alimentos/Pós-colheita da Embrapa Clima Temperado in Pelotas-RS.
Methodology: Tangerines were stored for 15, 30, 45, and 60 days at temperatures of 4℃ and 8℃, with two days of marketing simulation of 20℃. The variables analyzed were: total soluble solids content; titratable acidity; the relationship between total soluble solids and titratable acidity; firmness; longitudinal diameter; mass loss; yield of juice; hue of the rind; percentage of rotting; antioxidant activity; total carotenoids; total phenolics compounds and vitamin C.
Results: At the end of the study, 9.97 and 11.52 of Ratio to 4℃ and 8ºC, respectively, was obtained. The biggest loss of mass (%) and rotting (%) occurred at 60 days of storage at 8℃, with 12.08% and 18.33%, respectively. The total phenol content and the vitamin C concentration had the highest reduction at 60 days of storage at 8℃, with 60.02 mg of gallic/100g of fresh fruit and 15.7 mg of ascorbic acid/100g of fresh fruit, respectively.
Conclusion: It was concluded that the Nadorcott mandarin cultivar maintains postharvest quality characteristics when stored up to 45 days at 4℃, with relative humidity between 90-95%, and commercialized for 2 days at a temperature of 20℃.

Keywords: storage temperature; citrus; conservation

1. INTRODUCTION

Citrus cultivation was introduced in Brazil still in the colonial period and, since then, it became of great importance in the consumption habits of ~~our~~ population [1]. Citrus fruits are among the most appreciated and produced in the world. Brazil stands out as the largest orange producer and the second largest producer of tangerines [2]. The increase in the consumption of "in natura" fruits and of natural juices is a global trend that can be used by Brazil as a way to encourage increased production and quality ~~of~~ [3]. Among tangerines, the Nadorcott cultivar has stood out because of its good ~~fruit~~ quality and high productivity [4].

The Nadorcott cultivar is a hybrid of “Murcott” tangor with male parental unknown, of high productivity which, depending on the growing conditions, can reach average annual production of 30 tons per hectare [5]. Fruit maturation is from mid to late season [5, 6]. In Rio Grande do Sul, harvest is carried out from July to August. The tangerines can remain in the trees for several weeks after the complete maturation, without significant loss of quality. The fruits are small to medium in size, weighing 90 to 120g; thin rind, a very attractive red-orange hue, being moderately easy to peel; intense orange pulp, with good amount of juice [5]

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The postharvest fruit conservation is of great importance so that it can reach the consumer without great alterations in quality, that is, keeping as much of its original nutritional value, appearance, and taste. To achieve this, it is necessary to provide good quality products at harvest, observing the degree of maturation of each species and knowing the resistance of each product to refrigerated storage [7]. The adequacy of the storage temperature contributes to the decrease in respiratory activity of fruit, since it decreases their metabolic activity and the ideal storage temperature will depend on the genotype, maturation stage and the time-temperature binomial [8]. Proper fruits storage also allows for longer marketing and consumption periods, which would lead to greater sales safety, usually with financial benefits [9].

The aim of this study was to determine the effect of temperature and adequate storage period to the quality of the Nadorcott mandarin cultivar.

2. MATERIAL AND METHODS

The experiment was conducted at the postharvest lab of the Núcleo de Alimentos da Embrapa Clima Temperado, Rio Grande do Sul, Brazil. The tangerines were produced in Rosário do Sul, in the region of Campanha Gaúcha, in plants with 8 years of age, conducted on rootstock Poncirus trifoliata, with spacing of 6 m x 3 m and average density of 555 plants per hectare. At harvest, the fruits were selected with respect to size, ripeness, and absence of defects and rotting. After that, the fruits were cleaned followed by the application with carnauba-based wax and vegetal resin. Later, the fruits were directed for storage in the postharvest laboratory.

The treatments consisted on fruits storage in two temperatures conditions temperatures (4 and 8℃) and four storage periods (15, 30, 45, 60 days). Each treatment had 4 repetitions, each repetition containing 15 fruits. Initially, the characterization of the tangerines was done, using the same number of repetitions as in the treatments. After each period of storage, the fruits were subjected to marketing simulation, with temperatures of approximately 20℃ and environment relative humidity for 2 days.

The parameters evaluated were: Titratable acidity (TA) by using ~~one~~ mL of juice and adding 90 mL of distilled water, the titration of the sample was made with the aid of a digital burette, Brand®, containing a solution of sodium hydroxide (NaOH) at 0.092 N until it reached pH 8.1. The result was expressed in grams of citric acid.100 g-1 of juice [10]. The total soluble solids content which was quantified using a digital refractometer, of the PAL-1, ATAGO model, by measuring the refractive index of the sample and with the results expressed in ºBrix [10]. The relationship between total soluble solids and titratable acidity (Ratio) was obtained by dividing the results of the levels of total soluble solids (° Brix) and the titratable acidity (% citric acid). The firmness of the pulp was obtained with the help of the texturometer of the brand Stable Micro Systems® using the compression nozzle P/75 with pre-test speed of 1.0 mm/s; test speed of 2.0 mm/s; post-test speed of 10.0 mm/s; 5 kg force, the results expressed in Newton (N). The loss of mass was obtained by calculating the difference between initial and final mass, with the result expressed as a percentage (%). The longitudinal Diameter was measured with digital caliper in the medium portion of the fruit, with the result expressed in millimeters (mm). The yield of juice was calculated by the difference between the mass of the juice and the mass of the pulp and rind, with the result expressed as a percentage (%). The percentage of rotting was done through the final count of healthy fruits after the two-day marketing simulation. The color of the fruit, measured with colorimeter Minolta CR-300, with system of reading CIE L*a*b*, proposed by the Comission Internacionale de I' Eclairage (CIE), and the hue or chromatic tonality represented by the Hue angle (Hº), through the arctangent formula b*/a*. The result was expressed in degrees, as seen in Minolta [11]. The antioxidant activity (DPPH) was evaluated using the methodology proposed by Rufino and co-workers [12], with some modifications. 250 µL of the sample was pipetted and left to react with 3750 µL of the solution of DPPH diluted in methanol for 24 hours in the dark. The absorbance was then obtained at 515 nm and calculated using a gamma linear calibration curve and the results expressed in mg of 100 Trolax/g of fresh fruit. The total carotenoids content was determined by the methodology proposed by Talcott and co-workers [13], and the result obtained was expressed in mg Equivalent β-carotene/100 g of fresh fruit. The total phenol content was determined with the methodology adapted from Swain and Hills [14]. For each test tube, 250 µL of sample was pipetted, 4 ml of ultrapure water and 250 ul of the Folin-Ciocalteau reagent (0.25N) were

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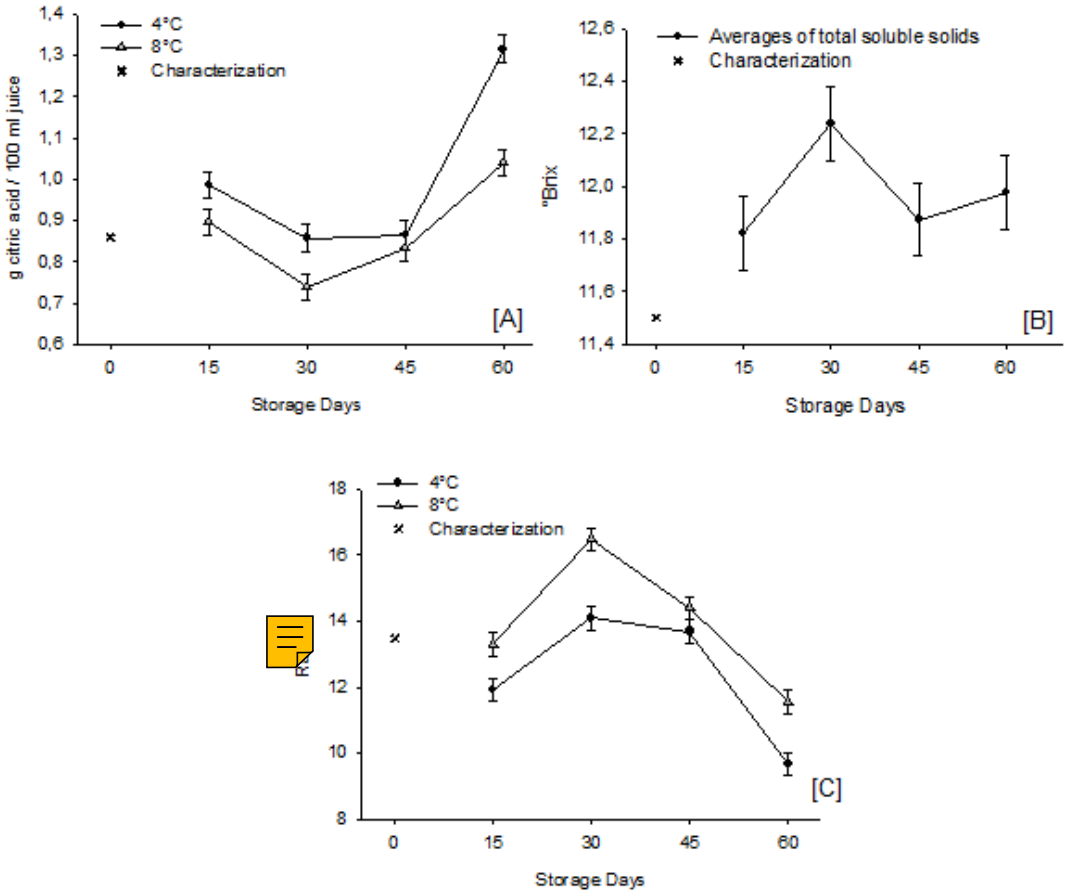
added, which was maintained for 3 minutes. After this time, 500 µl of sodium carbonate (1N) was added and the solution was maintained for 2 hours. The readings of the absorbances were done in a spectrophotometer with a wavelength of 725 nm, with the results expressed in mg of Gallic/100 g of fresh fruit. The vitamin C content was determined by means of spectrophotometry using the methodology proposed by Souza (2007), cited by Oliveira [15], with the result expressed in mg of ascorbic acid/100g of fresh fruit.

The experimental design used was entirely randomized, in factorial scheme, with factors, temperatures (4 °C and 8 °C), and storage periods (15, 30, 45 and 60 days). The experimental unit was composed of 15 fruits with four repetitions for each period. The results obtained were submitted to analysis of variance ($p \leq 0.05$) and, in the case of significance, submitted to the minimum significant difference test ($p \leq 0.05$).

3. RESULTS AND DISCUSSION

Figure 1 shows average values for titratable acidity, total soluble solids content, and ratio for mandarin cv. Nadorcott. The titratable acidity presented statistical significance only for the isolated factors of time and temperature (Figure 1). The total soluble solids did not present significant differences in relation to storage temperature, with significance occurring only when it comes to storage period (Figure 1 B).



Vertical bars: DMS test (p≤0.05)

Figure 1. Average titratable acidity (A), total soluble solids (B), soluble solids ratio and titratable acidity (C) of tangerines cv. Nadorcott in different storage periods. ~~Pelotas, 2017.~~

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It was observed that the temperature of 4℃ differed significantly from the highest values to titratable acidity during periods of 15, 30 and 60 days, differing not only at 45 days of storage, and, when related to the soluble solids content, it was observed that, at 30 days of storage, when the greatest concentration of soluble solids occurred, titratable acidity presented simultaneous decrease. It increased again when the soluble solids content decreased at 45 and 60 days. Similar behavior was observed by Brunini and co-workers [16] in oranges cv. Hamlin and Brunini and colleagues [17] with Pera sweet oranges. The researchers associated such performance with loss of water in the oranges. Vale and co-workers [9] associated this phenomenon with the use of soluble sugars as respiratory substrate by the fruit. The highest storage temperature can encourage degradative enzymatic processes, resulting in the consumption of sugars and organic acids used as respiratory substrate [18].

The ratio for tangerines cv. Nadorcott presented statistical significance for the isolated effects of time and temperature, in which the temperature of 8° C obtained the highest values in all storage period (Figure 1 C). The ~~relationship between total soluble solids and titratable acidity, which is called ratio,~~ is widely used in the evaluation of the quality of fruits. Also, according to the CEAGESP standards [19], for a good acceptance, the tangerines must present at least value 10 of ratio for Murcott cultivar and 9.5 of ratio for Ponkan. For the Nadorcott cultivar, the ratio was higher than those values, reaching 14.08 and 16.47 at 30 days in temperatures of 4℃ and 8℃, respectively. Jomori and co-workers [20] found values of approximately 16 in tangerines cv. Murcott stored up to 30 days at 5℃. Brunini and colleagues [16], with Hamlin oranges, found a ratio of approximately 14, when the oranges were stored up to 28 days at a temperature of 7℃.

Only at 60 days the fruits stored at 4℃ presented a value inferior to those of Murcott and Ponkan cultivars. The ratio corresponds to the balance between the total soluble solid contents and the titratable acidity that, beyond determining the maturation index, is the component that grants the sweet and acid flavor to the fruit [21]. During the maturation of the fruits, this relationship tends to increase due to decrease of acids and the increase of sugars [22]. This occurred up to 30 days of storage. Its decrease after this period may be related to the increase of titratable acidity and the consumption of sugars during respiratory activity.

In Figure 2 the averages for firmness, mass loss, longitudinal diameter, yield of juice, percentage of rotting, and hue of the rind to tangerines cv. Nadorcott are ~~represented~~. Interaction between factors of treatment for all variables represented occurred. Pacheco and co-workers [23] found in their study the importance of the physical attributes of the fruit for marketing purposes. That happens because most consumers, when it comes to the purchase of citrus fruits, take into consideration these attributes.

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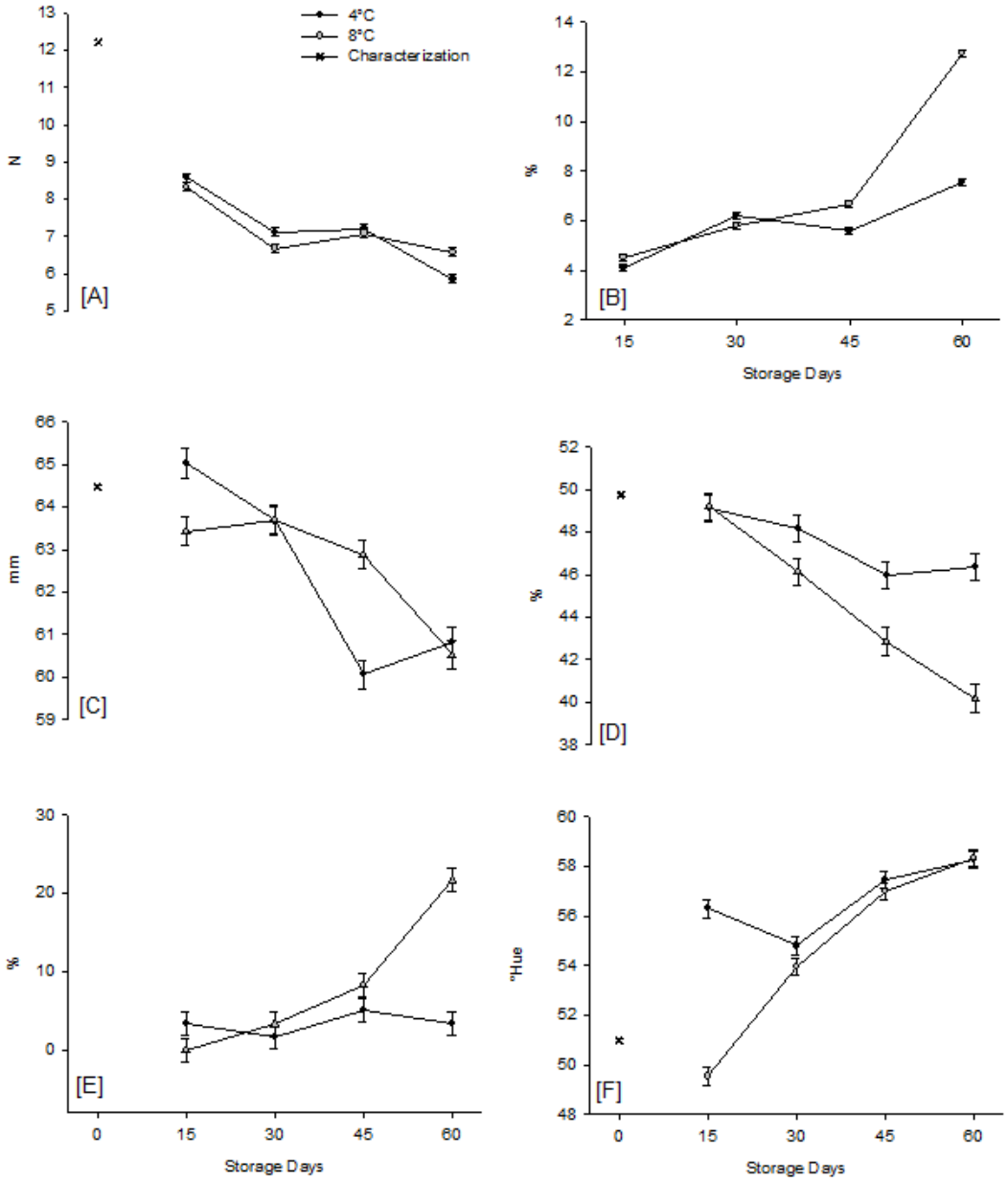

Vertical bars: DMS test (p≤0.05)

Figure 2. Mean values of firmness (A), loss of mass (B), longitudinal diameter (C), yield of juice (D), percentage of rot (E) and shade of tangerine cv. Nadorcott in different storage periods. Pelotas, 2017.

Firmness presented greater value for the fruits stored at a temperature of 4°C up to 45 days (Figure 2), inverting their behavior after this period. Fruits with low firmness present less resistance to transport, storage, and handling, and were, therefore, rejected by consumers [23]. The decrease in firmness may be related to solubilization of pectic substances. During maturation, there is a conversion of insoluble pectin to soluble pectin, which softens the fruit and decreases their resistance, as explained by Chitarra and Chitarra [7]. During cold storage, enzymes that are influenced by temperature can lead to the release of

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calcium from the cell walls, inducing protopectin solubilization, which causes a decrease in the firmness of fruits [24].

Loss of mass increased with the longest storage period for the fruits stored at both temperatures (Figure 2 B), but increased significantly from 45 up to 60 days in fruits stored at 8℃, reaching approximately 12.5%. According to Agostini and co-workers [25], it must be considered that the loss of fresh mass in fruits, when superior 10%, impairs or hinders their commercialization *in natura*. These losses are associated mainly with the dehydration of fruits. This is one of the main causes of deterioration, resulting in quantitative and qualitative losses [9]. This behavior was already expected considering that part of the water contained in the fruits is lost to the transpiration process, which reflects, throughout the storage, in wilting, loss of mass and loss of consistency [22].

The longitudinal diameter of the fruits of cv. Nadorcott decreased throughout the refrigerated storage, ranging from 5 to 3 mm at temperatures of 4℃ and 8℃, respectively (Figure 2 C). This behavior was expected since the diameter is related to firmness and loss of mass of the fruits. According to the marketing standards established by the Programa Brasileiro de Modernização da Horticultura (Brazilian Program for Horticulture Modernization) adopted by CEAGESP [19], the tangerine cv. Nadorcott is inserted in Group C, with less than 70mm in diameter.

Yield of juice for this variety decreased approximately 10% when stored at 8℃ and around 3% when stored at 4℃ up to 60 days of storage (Figure 2 D). This behavior may be related to loss of mass which occurred during storage and also to the percentage of rotting found during this period, considering that when the fruits were subjected to 8℃ storage, the percentage of rotten fruit was higher, reaching 20% of losses due to rotting (Figure 2).

Commercially this value becomes impracticable, raising the costs of production and affecting the quality of the final product. Felício and co-workers [26] did not find rotting in fruits cv. Murcott stored up to 8 weeks at 1℃ and 4℃. They attributed the good results to three main factors: the good phytosanitary control of the orchard, low storage temperature that may have contributed to the suppression of pathogens, and the immersion of the fruits in sanitizing solution. By observing the studied period, we can highlight the importance of low storage temperature. It was observed that up to 60 days at 4℃ the results showed approximately 3% of contaminated fruit, thus showing that low temperatures are effective in the control of pathogens.

The largest variation in rind hue occurred in the first 15 days of storage (Figure 2 F) in fruits submitted to temperatures of 4℃ showing higher values of Hue angle, and showing the same behavior up to 30 days, but with less difference in Hue between the temperatures. After this period there were no significant differences for the Hue angle between the two temperatures. According to Borguini [27], the Hue angle corresponds to the variation of colors ranging from blue (270º) to red (0º), passing through yellow (90º) and green (180º). In this work, the data obtained varied 54.14 in the characterization of the fruits up to approximately 58 at the end of the experiment. This result shows that the tangerines kept the orange-colored hue close to the beginning to the study.

Despite the difference between treatments, the reduction in the coloration intensity is not so serious. It is a small variation observed until the end of the study and it is insufficient to interfere with the commercial acceptance of the fruits. Brunini and co-workers [16], in experiments with Hamlin oranges, noticed that temperature and storage time showed little interference in this parameter. However, Felício and colleagues [26] observed a different behavior in their study of Murcott tangor. They found that the decrease in the Hue angle was more evidenced when the fruits were stored at 4℃ instead of 1℃. It is worth remembering that each species, variety, or cultivar responds differently. Therefore, when it comes to the cv. Nadorcott, the small variation of color in cold storage is intrinsic to the cultivar.

Citrus generally show in their constitution several compounds with antioxidant action, such as ascorbic acid, carotenoids, and total phenolic compounds. In Figure 3, the averages for antioxidant capacity, total phenolic compounds, total carotenoids, and vitamin C content of the Nadorcott mandarins are presented.

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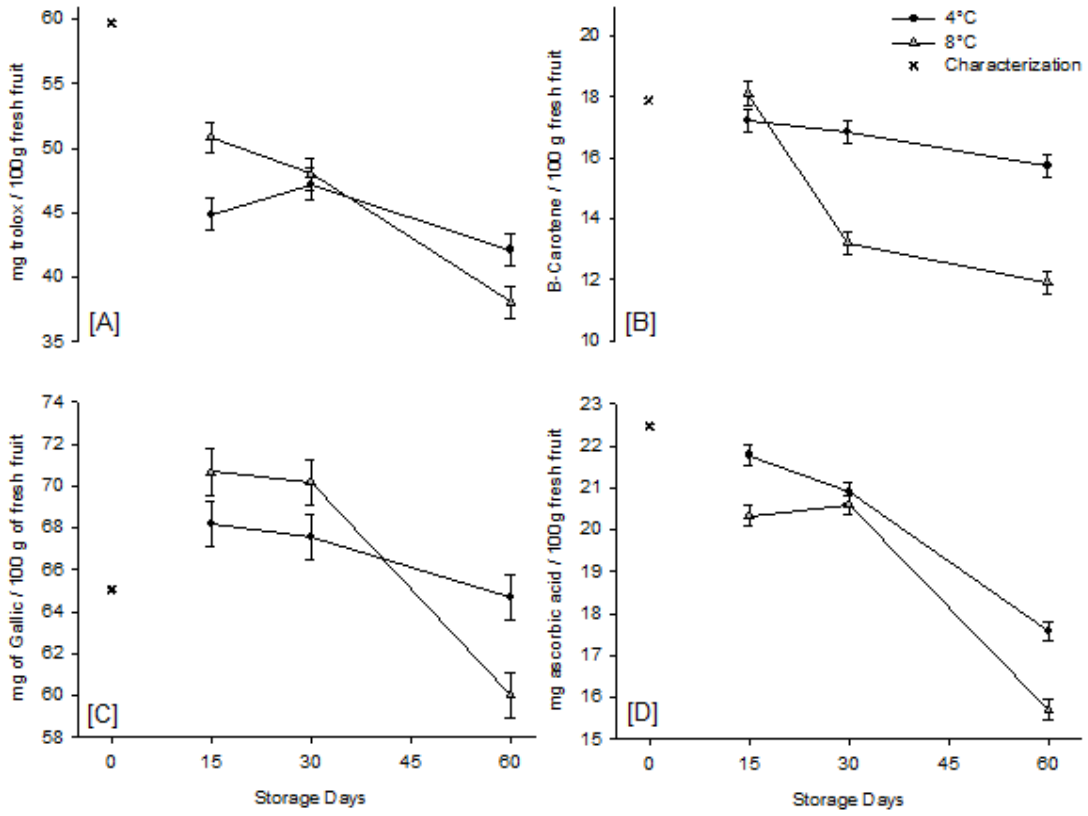
The antioxidant capacity, on the whole, showed a higher decrease in the first 15 days of storage (Figure 3). It showed a significant difference between temperatures, with the fruits kept at 8°C presenting higher decrease of antioxidant capacity when compared the fruits kept at 4°C at 60 days of storage. This performance can be related to the difference in chemical composition, such as phenolics, ascorbic acid, and carotenoids [28]. However, antioxidant compounds of natural origin may be lost during the storage period, which affects the antioxidant capacity of the food [29].



Vertical bars: DMS test (p≤0.05).

Figure 3. Average contents of antioxidant activity (A), total carotenoids (B), total phenolic compounds (C) and vitamin C (D) content of tangerines cv. Nadorcott in different storage periods. Pelotas, 2017.

Total carotenoid content for cultivar is higher than the contents found its progenitor, the Murcott, as demonstrated by some authors (30, 20]. All cv. Nadorcott fruits stored at a temperature of 4°C presented, from the 15th day of storage, more carotenoid content over time studied (Figure 3 B). This result differs when compared to the fruits stored at a temperature of 8°C. These fruits, after the 15th day of storage, presented a sudden decrease in the carotenoids level. This fact could be related to the increased metabolic activity in the tangerines stored at 8° C, which caused acceleration in the degradation of these compounds, due to their susceptibility to oxidation [20].

The phenolic compounds are widely found in plants and belong to a very diversified group of phytochemicals derived from phenylalanine and tyrosine. Those are compounds that originate from the secondary metabolism and are essential to the growth and reproduction of plants [31].

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When it comes to "Nadorcott" mandarins, on the whole, the phenolic compound contents decreased during the period of storage (Figure 3 C), showing a higher value in fruits stored at a temperature of 8℃ until the 30 days of storage, and at 60 days the situation was reversed. A sharp decrease in the level of phenolic compounds was observed at the end of the study period. This episode can be attributed to the type of compound that is predominant in the sample, and it may be related to enzymatic activity, blocking the initialization of oxidation; or, unrelated to enzymatic activity, interacting with free radicals and being consumed by this reaction [31].

Concerning the vitamin C content, only significant effect isolated from time and temperature occurred. On the whole, a decrease in the vitamin C content, from the harvest up to the end of the storage period, was observed (Figure 3). The presence of vitamin C in fruits is an important aspect that influences the consumption of fresh fruits [32]. Vitamin C is known by its antioxidant and functional potential and it occurs naturally in fruits in the form of L-ascorbic acid, which, in tangerines, is present on an average of 20 to 50 mg to every 100 mL of juice [33].

The Nadorcott mandarins that showed concentration around 20.50 mg of L-ascorbic acid in the beginning of the experiment, got to the end of the 60 days with less than 16 and 18 mg of vitamin C when stored at 4ºC and 8ºC, respectively. This shows that the most effective temperature is 4℃ when it comes to the maintenance of ascorbic acid in all periods of storage. The reduction in the vitamin C content is usually observed after harvest because it is a natural antioxidant involved in antioxidant reactions that are processed during the senescence of the fruit, due to its metabolic processes, manly respiration [26, 16]. Agostini and co-workers [25] attributed the reduction of the vitamin C content in cold storage to the the highest storage temperature, which may lead to early senescence, consuming the ascorbic acid on oxidative reactions.

4. CONCLUSION

Nadorcott mandarin cultivar maintains postharvest quality characteristics when stored up to 45 days at 4℃, with relative humidity between 90-95%, and commercialized for 2 days at a temperature of 20℃.

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