

Characterization and shelf life of “roselle” leaves stored in different packages under refrigeration

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ABSTRACT: “Vinagreira” (*Hibiscus sabdariffa*) is an unconventional species with multiple possibilities of use, with food and industrialist potential. The objective of this work was to quantify some of its constituents and to evaluate the effect of the packaging on its post-harvest conservation. Branches were transported at Universidade Federal Rural do Rio de Janeiro campus and to Embrapa Agroindústria de Alimentos, where they were packed in polypropylene (perforated, micro perforated and unperforated) conical packages, except for the control and stored at 5 ± 1 °C and 75% relative moisture. Before storage were evaluated: organic acids, carotenoids, total phenol, antioxidant activity, pH, titratable acidity, soluble solids and fresh mass. The fresh mass loss, titratable acidity and soluble solids were analyzed every two days of storage. The design was completely randomized, in split plots. “Roselle” leaves may be considered sources, specially β -carotene ($28.49 \mu\text{g g}^{-1}$) and lutein ($25.70 \mu\text{g g}^{-1}$). The use of polypropylene packages in combination with refrigeration allowed for greater storage, with increase up to four days in the “vinagreira” shelf life, being the best results for unperforated packages were relatively better during storage.

Key words: cold storage; *Hibiscus sabdariffa*; non conventional vegetables; polypropylene packaging

Caracterização e vida útil de folhas de vinagreira acondicionadas em diferentes embalagens sob refrigeração

RESUMO: A vinagreira (*Hibiscus sabdariffa*) é uma espécie não convencional que apresenta múltiplas possibilidades de uso, com potencial alimentício e industrial. O objetivo do trabalho foi quantificar constituintes da planta e avaliar o efeito da embalagem na sua conservação pós-colheita. Os ramos foram transportados da Universidade Federal Rural do Rio de Janeiro para a Embrapa Agroindústria de Alimentos, onde foram acondicionadas em embalagens de polipropileno (perfurada, micro perfurada e não perfurada), além do controle sem embalagem, e armazenados a 5 ± 1 °C e 75% de umidade relativa. Antes do armazenamento foram avaliados: ácidos orgânicos, carotenoides, fenólicos totais, atividade antioxidante, pH, acidez titulável, sólidos solúveis e a massa fresca. A cada dois dias do armazenamento foram analisadas a perda de massa fresca, acidez titulável e sólidos solúveis. O delineamento utilizado foi o inteiramente casualizado, em esquema de parcelas subdivididas. As folhas da vinagreira mostraram-se fontes de carotenoides, especialmente de β -caroteno ($28,49 \mu\text{g g}^{-1}$) e luteína ($25,70 \mu\text{g g}^{-1}$). O uso de embalagens de polipropileno aliado à refrigeração permitiu maior conservação, com aumento de até quatro dias na vida útil da vinagreira, sendo os melhores resultados para os maços acondicionados nas embalagens não perfuradas.

Palavras-chave: armazenamento refrigerado; *Hibiscus sabdariffa*; hortaliças não convencionais; embalagem de polipropileno

Introduction

Consumption of vegetables has increased in recent years and may be associated with the increased concern about health, well-being and good physical shape. However, in Brazil it is limited to species that have a greater commercial appeal, such as lettuce and tomato, which may contribute to the extinction of non-conventional species. These species are characterized as *Unconventional Food Plants (UFP)*, as they are not yet known worldwide, having their distribution limited to certain regions. Kinupp & Lorenzi (2014) reported that some are still denominated weeds due to them growing between cultivated plants and because there is not knowledge about their food potential. On the other hand, some were cultivated in certain periods or regions, but fell into disuse over the years (Brazil, 2010).

Among the unconventional plants is the species *Hibiscus sabdariffa* L., which receives several popular names, being commonly found as roselle in English and as vinagreira in Portuguese. It presents advantages ranging from cultivation to consumption, such as the good adaptation to the tropical climate, being able to be cultivated for ornamental purposes or for human and animal consumption, with all parts of the plant being edible (Brazil, 2010, Kinupp & Lorenzi, 2014).

It has use potential in the food industry for the preparation of vinegar, sauces, juices, jellies, wines, teas, among others, and for the pharmaceutical industry due to the medicinal properties attributed to all parts of the plant (Da-Costa-Rocha et al., 2014).

In Brazil, its main use is as vegetable, being very traditional in the state of Maranhão in the typical dishes of the region, such as the cuxá rice. It is also commonly commercialized at fairs, with the plant branches being cut at 40-50 cm from its apex and then tied together forming bundles (Brazil, 2010; Kinupp & Lorenzi, 2014).

Herbaceous vegetables, such as hardwood, are highly perishable, due to the high metabolic activity post-harvest and the fact that they do not store significant amounts of carbohydrate, which directly reduces their storage potential, requiring the consumption of these vegetables in a few days or the usage of techniques for prolonging their conservation.

Maintaining the product at a suitable temperature, immediately after harvesting and during the storage, transportation and commercialization, is the most important factor, followed by the relative humidity control. Hardwood vegetables exposed to the highest temperature and low relative humidity, have both their respiration and transpiration increased, having as an immediate consequence the wilting due to the loss of turgidity and, subsequently, an accelerated reduction of the quality characteristics.

In addition to controlling temperature and humidity, another technique fairly used in the post-harvest of vegetables is the modified atmosphere. According to Chitarra & Chitarra (2005), the modification of the atmosphere is achieved with the use of plastic films that allow changes in the gas exchanges of the product. Inside the package, a reduction of O₂ and elevation of CO₂ concentrations occur. These gases

concentration varies with the time, temperature, film type and respiratory rate of the vegetable, being able to provide benefits such as reduction of respiration, transpiration, biosynthesis and the action of ethylene and growth of microorganisms, especially when associated with refrigeration, prolonging the useful life of the product.

Thereby, the present work aimed to quantify some of the roselle leaves (*Hibiscus sabdariffa* L.) constituents and to evaluate the effect of the packaging on its post-harvest conservation.

Materials and Methods

The roselle (*Hibiscus sabdariffa*) was cultivated between the months of May and September in a Planosol in the Horticulture sector from the Federal Rural University of Rio de Janeiro - UFRRJ, in Seropédica - RJ, whose geographic coordinates are 22°44'38" S, 43°42'28" W, at an altitude of 26 m and with the region climate being the Aw type, from the Köppen classification, with rainy summers and high temperatures, and between April and September the climate is milder and dry (Fiorini et al, 2016).

The seeds were sown in polystyrene trays with the Standard Organic Carolina substrate. After 30 days, the seedlings were transplanted to the final beds, at a spacing of 1.0 x 0.5 m, the fertilization was done directly in the pits, using tanned compound, consisting of leftovers from the university restaurant, poultry and cattle manure. During the cultivation, two cover fertilizations were performed with tanned cattle manure and poultry litter, and the irrigation was carried out by conventional spraying.

After 120 days of transplanting, the plant branches were harvested between 6:00 a.m. and 7:00 a.m., being removed at ± 40 cm from their apex and transported in plastic bags of polypropylene by vehicle with refrigeration around 17 °C to the Embrapa Agroindústria de Alimentos, located at approximately 40 km away, in the city of Rio de Janeiro.

The branches were immediately washed in the wash tank by whirling with running water and left on benches in a refrigerated room in order to remove the excess water. For composing the roselle bundles, the branches with good looking leaves were selected, that is, without symptoms of pest deterioration or handling.

The bundles with approximately 150 g were distributed in the treatments consisting of transparent conical polypropylene containers, with a welded bottom of segmented form, in the dimensions 41 x 11 x 29 cm and thickness of 0.038 microns. It was used perforated (P), micro perforated (MP), non-perforated (NP) packagings and the control (C), in which no packaging was used. In sequence, the roselle bundles were stored in a refrigeration chamber at a temperature of 5 ± 1 °C and 75% relative humidity, where they remained until the apparent quality reduction.

Before storage, that is, still without the effect of treatments, the organic acids, carotenoids, total phenolics and antioxidant activity of the roselle leaves were evaluated.

Organic acid analysis was carried out according to the methodology described by the manual manufacturer of the Bio-Rad Aminex[®] HPX-87H (300 mm x 7.8 mm) column, with isocratic elution, having the 0.008 N sulfuric acid in the mobile phase at a discharge of 0.60 mL min⁻¹, pressure of 751 psi and temperature of 35 °C. It was injected 20 µl of sample, the detection was at 210 nm, and the run time was 25 minutes. The standards used in the calibration were the oxalic, citric and malic commercial acids. All the chromatographic system used was from the Waters[®] brand, model 2487 chromatograph.

In order to determinate the carotenoids, phenolics and antioxidant activity, the roselle leaves were removed from the bundle and triturated in a food microprocessor (Eletrolux[®]).

The extraction for total carotenoids and the profile was carried out according to Rodriguez-Amaya (2001) methodology, with saponification of the extracts to remove lipids and chlorophylls which may interfere in the chromatographic separation. The total carotenoids were determined by reading in an UV-Visible spectrophotometer (SPECORD 205) at 450 nm, and afterwards the carotenoid profile was determined by the HPLC technique according to the methodology of Pacheco (2009), with the results expressed in µg g⁻¹. A Waters[®] model 996 chromatograph, column C30 (S-3 carotenoids, 4.6 mm x 250 mm, YCMTM) was used at a flow rate of 0.8 mL min⁻¹. It was injected 15 µl of the sample, elution mode by gradient using methanol as the mobile phase: *tert*-butyl ether (80:20 v/v) and run time of 28 min.

The total phenolic content was determined by the Folin-Ciocalteu spectrophotometric method proposed by Singleton & Rossi (1965) and modified by Georgé et al. (2005), in which the sample was pre-extracted with a 70:30 acetone/water solution and an aliquot of this extract used for the reaction in Folin-Ciocalteu at 10% and 7.5% sodium carbonate. For the quantification, it was then carried out the absorbance reading at 760 nm in a spectrophotometer (SPECORD 205), based on the calibration curve of the gallic acid (0 to 80 mg L⁻¹) and the results expressed in mg of gallic acid g⁻¹ of roselle leaves sample.

The antioxidant activity was determined by two methods:

1) TEAC (Trolox Equivalent Antioxidant Capacity) in which the methodologies of Re et al. (1999) and Rufino et al. (2007) were used. The extraction was carried out with 50% methanol and 70% acetone and for the reaction the ABTS^{•+} radical, obtained from the solution of ABTS and potassium persulfate in ultra purified water (Milli-Q) left at rest for at least 16 hours and subsequently diluted in 95% ethanol. The quantification was carried out from the readings in UV-Visible spectrophotometer (SPECORD 205) at 734 nm, using standard trolox curve in 95% ethanol, whose concentrations were 50, 100, 500, 1000 and 1500 µmol and the results then expressed in µmol Trolox g⁻¹ sample.

2) ORAC (Oxygen Radical Antioxidant Capacity) determined according to Zulueta et al. (2009) and the extracts obtained from the TEAC methodology, but diluted in a 75 mM Phosphate Buffer Solution and pH 7.4, at the ratio of 1:40. The reading was carried out on Fluorimeter with a TECAM Infinite[®] 200 PRO

microplate, with a 78 nM Fluorescein solution, obtained from fluorescein sodium salt dissolved in phosphate buffer and the solution of AAPH 2,2'-Azobis (2-methylpropionamide) dihydrochloride also dissolved in buffer. A standard trolox curve diluted in phosphate buffer at concentrations of 10 to 120 µM was used, with the fluorescence data regarding the time treated by the Prism 5 program and the antioxidant activity then calculated and expressed in µmol Trolox g⁻¹ of sample.

In addition to that, prior to starting the storage and every two days after it (2, 4, 6 and 8) the post-harvest conservation of the leaves from each treatment was evaluated, through the loss of fresh mass, titratable acidity (TA) and soluble solids (SS).

The accumulated fresh mass loss was obtained by the difference between the weight of each bundle of roselle in a semianalytic scale on the day of harvest and every two days of the storage, until day 4 for the control and day 8 for the other treatments, being then expressed in percentage.

For the other analyzes, which were destructive, every two days the processing of each treatment and the control, which consisted of the removal of the leaves from the bundle and trituration in a food microprocessor (Eletrolux[®]), was carried out. The obtained materials, duly identified, were stored in a freezing chamber at -18 °C until analyzes were carried out.

Using a 794 Basic Titrino automatic titrator from Metrohm[®], it were obtained the pH by potentiometry according to ISO 1842:1991 (ISO, 1991) and the TA by titration with sodium hydroxide (NaOH) at 0.1 N, until pH 8.1 and the results expressed in g of malic acid 100 g⁻¹ of sample according to ISO 750:1998 (ISSO, 1998).

The SS content was determined by direct reading of the triturated and filtered samples in the Atago PAL-1 digital refractometer and the results expressed in °Brix according to ISO 2173: 1978 (ISSO, 1978).

The experimental design was completely randomized, with five replicates, in a sub-divided plot scheme, with the treatments consisting of perforated (P), micro perforated (MP), and non-perforated (NP) packagings and the control (C) in which no packaging was used, and the storage time (0, 2, 4, 6, 8) in the subplots. The data were interpreted by ANOVA in subdivided plots and the effect of the treatments along the storage days by the regression analysis, all analyzes were performed in the SPSS program, version 20.0.

Results and Discussion

Two organic acids were identified from the three standards used in calibration: the malic acid and the oxalic acid. The mean value of malic acid was of 7.32 mg g⁻¹ at retention time of 16.1 minutes and 1.75 mg g⁻¹ of oxalic acid, at the retention time of 8.3 minutes (Figure 1).

For the citric acid, no equivalent peak was found, despite it being described as one of the constituent organic acids of the plant (Da-Costa-Rocha et al., 2014), other authors did not identify its presence as well, such as Jabeur et al. (2017)

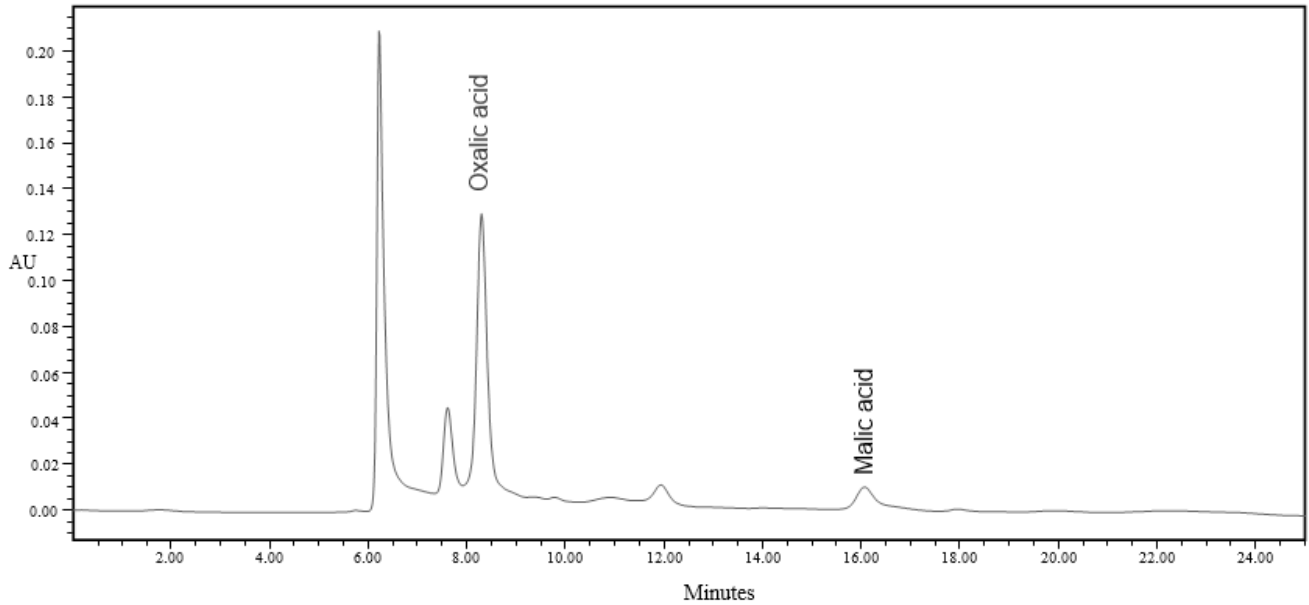


Figure 1. Chromatogram of the organic acids present in the roselle leaves before the storage, obtained by High Performance Liquid Chromatography (HPLC).

which by ultrafast liquid chromatography found the oxalic, malic, chiquimic and fumaric acids in the dried roselle calyxes, with malic being predominant. Jung et al. (2013), by high performance liquid chromatography, found only the malic acid in the roselle dry calyxes samples.

Malic acid is known by being predominant in other vegetables such as lettuce, celery and broccoli, and the oxalic acid by being predominant in spinach (Chitarra & Chitarra, 2005). Oxalic acid in large amounts is considered an "antinutritional factor" because it may interfere in digestibility, absorption or utilization of nutrients and may also cause health damage due to the formation of calcium oxalate in the urine, increasing the risk of kidney stones formation (Benevides et al., 2011).

Regarding the total carotenoids present in the leaves, the mean was $67.82 \mu\text{g g}^{-1}$ of fresh leaf, value higher than those found by Nachtigall et al. (2007) for some conventional and

unconventional species, such as cabbage, watercress, spinach, chard, mustard, *serralha* (sowthistle), *almeirão* (chicory), *azedinha* (sorrel), *ora-pro-nóbis* (blade-apple cactus) and *taioaba* (arrowleaf elephant ear). According to Rodriguez-Amaya et al. (2008), are considered foods rich in carotenoids those with total contents higher than $20 \mu\text{g g}^{-1}$. Therefore, roselle leaves may be considered a good source of this compound, however, the spectrophotometric method may overestimate the results, and thus the use of another method such as the chromatography proves important.

While evaluating the constituent carotenoids from the roselle leaves by high performance liquid chromatography (HPLC) it was possible to identify the presence of β -carotene, lutein, 13-*cis* β -carotene and 9-*cis* β -carotene (Figure 2).

The β -carotene was shown as the major carotenoid presenting a mean value of $28.49 \mu\text{g g}^{-1}$ and a retention time of 16.45 minutes, followed by lutein which presented a mean

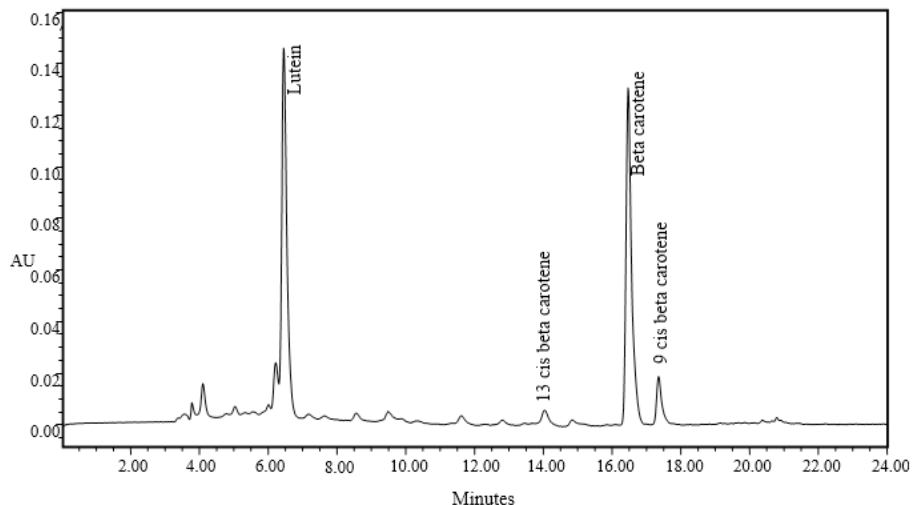


Figure 2. Chromatogram of the carotenoids present in the roselle leaves before the storage, obtained by High Performance Liquid Chromatography (HPLC).

value of $25.70 \mu\text{g g}^{-1}$ in the time of 6.45 minutes. According to Rodriguez-Amaya et al. (2008), lutein, β -carotene, violaxanthin and neoxanthin are the main carotenoids in green vegetables and have high antioxidant activity, and β -carotene is the most important metabolite as a source of vitamin A.

Analyzing the composition of some unconventional vegetables, Viana et al. (2015) found significant values of β -carotene for *azedinha* (sorrel) ($7.91 \mu\text{g g}^{-1}$), *bertalha* (Indian spinach) ($7.36 \mu\text{g g}^{-1}$) and *peixinho* (lamb's ear) ($7.84 \mu\text{g g}^{-1}$) by high performance liquid chromatography, it is observed that the values found were significantly lower than those found for the roselle.

Nachtigall et al. (2007) in their work, highlighted as a source of lutein all vegetables which presented levels higher than $10 \mu\text{g g}^{-1}$ of product, thus including the roselle leaves.

Carotenoids and phenolic compounds have antioxidant activity and the continued ingestion of foods rich in these compounds is associated with the prevention of degenerative diseases (Silva et al., 2010).

The mean content of total phenolic compounds by extraction with 70:30 acetone was $1.55 \text{ mg gallic acid g}^{-1}$ of fresh leaves. Zhen et al. (2016), evaluating dry leaves from *Hibiscus sabdariffa* observed a content between 18.98 to $29.9 \text{ mg gallic acid g}^{-1}$ for the different varieties by the Folin-Ciocalteu method and extraction with 70% methanol in 0.1% acetic acid solution.

According to Gobbo-Neto & Lopes (2007), differences in the content of secondary metabolites, such as phenolic compounds, occur due to several factors ranging from crop cultivation conditions such as the water availability, temperature, seasonality, nutrients, solar radiation, atmospheric pollution and pathogen attack, as well as factors linked to the harvest, such as the time when it was carried out, the occurrence of mechanical damage, the development degree of the plant and the vegetal organ harvested. Factors after the harvesting such as transport and storage conditions will also interfere.

As for the values found for the antioxidant activity in the roselle leaves, it was observed that these differed in accordance to the method used, since by the ORAC the mean content was $63.51 \mu\text{mol Trolox g}^{-1}$ of fresh leaves and by the TEAC method was $10.93 \mu\text{mol Trolox g}^{-1}$ of fresh leaves.

The authors Seong et al. (2016) also observed a significant difference between the methods, in which by the ORAC the mean content was of $8.16 \mu\text{mol Trolox g}^{-1}$ for the dry leaves of the cabbage, whereas by the TEAC the mean was $2.67 \mu\text{mol Trolox g}^{-1}$. According to Zulueta et al. (2009), this can be explained by the short reaction time of the TEAC method, leading to underestimation of the results.

Thereby, the roselle showed much better results than the cabbage (Seong et al., 2010) mainly on the account of being *in natura* leaves, while the results for the cabbage were expressed in relation to dry leaves. As Da-Costa-Rocha et al. (2014) noted in their review, roselle is reported by many authors as a species rich in antioxidant compounds, being able to eliminate free radicals and reactive oxygen species (ROS), as well as to protect from lipid oxidation.

Regarding the post-harvest conservation evaluations of the roselle bundles (loss of accumulated fresh mass, titratable acidity and soluble solids), it was observed that there was interaction between the treatments and the storage time, as expressed by the regression curves for each treatment. The mathematical models were chosen by the coefficient of determination (R^2) and by the expected variation over time for each studied characteristic.

The loss of fresh mass increased with the storage period, being higher for the control, which was stored without the use of plastic packaging, in which at every 1 day of storage there was an increase of approximately 6.6% of the fresh mass loss. For those packaged in the plastic packaging there was no statistical difference until the fourth day of storage, with the increase of fresh mass loss at every 1 day from 2.3 to 2.6%, however, at the sixth and eighth days the loss was significantly higher for the bundles packaged in the perforated packagings, of 6.53 and 5.53 respectively, while those in the unperforated and micro perforated packagings had an increase in the fresh mass loss between 2.67 and 3.55 (Figure 3).

On the second and fourth day, the percentage of fresh mass loss for the control was greater by two to three times than those packed in the packages, and on the fourth day the control bundles were very wilted and with the visual quality of the leaves reduced, which limited its useful life, determining then the final period of analysis. This fact was only observed on the eighth day of storage for those packaged in the packagings.

The reduction in fresh mass loss with the use of packaging was also achieved by Teixeira et al. (2016) for the basil bundles, resulting in increased useful life, from one to four days, when compared to the ones stored without packaging.

Reis et al. (2014) observed a much higher loss of water for lettuces stored in fully opened plastic packagings when compared to the partially closed ones, considering that for lettuces packed in fully enclosed packagings the loss was practically null for ten days of storage.

However, it was observed in the present work that the loss of fresh mass was quite high when compared to the results

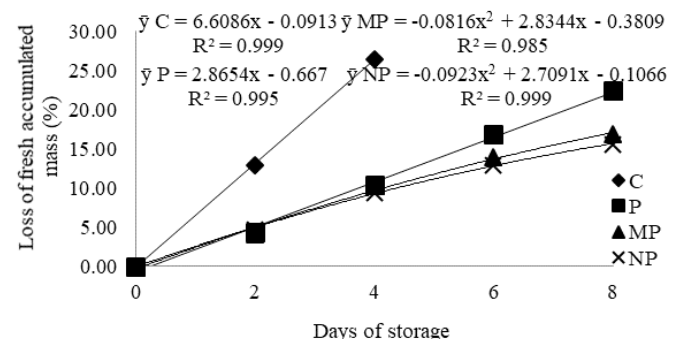


Figure 3. Loss of accumulated fresh mass (%) of the roselle leaves packed in polypropylene packages, in which: C- control; P- perforated packaging; MP- micro perforated packaging and NP- non-perforated packaging, during the storage time at 5°C .

found by Reis et al. (2014) for lettuce. This fact is mainly due to storage conditions, because although the lettuces were also stored at 5 °C the RH of the chamber was of 90%, while for the roselle the RH was of approximately 75%, due to the impossibility of regulation in the chamber. The used packaging may also have favored the mass loss by the roselle, due to the opening in the upper end.

For the titratable acidity there was also a linear increase over time in the leaves of the control, in which every 1 day of storage increased 0.07 g 100 g⁻¹ of malic acid, while for the leaves of the bundles packaged in the perforated and non-perforated packagings there was a reduction until the sixth day with increase in the sequence, being this increase of 0.14 and 0.12 g 100 g⁻¹ malic acid per day. The leaves packed in the micro perforated packagings showed a slight reduction only on the sixth day, with a subsequent increase of 0.2 g 100 g⁻¹ malic acid day⁻¹, a value significantly higher than the other treatments (Figure 4).

Similar behavior during roselle storage was observed by Gioppo et al. (2012) for the purple cabbage stored at 5 °C in different packagings, reducing TA until the fourth day of storage with subsequent increase, considering that the acidity was higher for the cabbage packed in the polypropylene perforated packaging, where loss of fresh mass was also higher when compared to the material packaged in the other packagings evaluated. In the present work a higher TA was observed for the leaves that composed the control bundles, which had higher water loss, as observed by the analysis of fresh mass loss, which may promote the concentration of chemical compounds in the vegetable after the harvest, such as the organic acids.

The reduction in the titratable acid content during storage is common, since the organic acids are used as substrate for the respiratory process, but in some rarer cases it may occur an increase with maturation (Chitarra & Chitarra, 2005).

Before storage the mean titratable acidity in the roselle leaves was of 2.474 g malic acid 100 g⁻¹ of fresh mass and the mean pH of 3.01, indicative of acid samples. The authors Jung et al. (2013) also observed low pH and high acidity for the calyxes of the roselle cultivated in Germany, with the pH

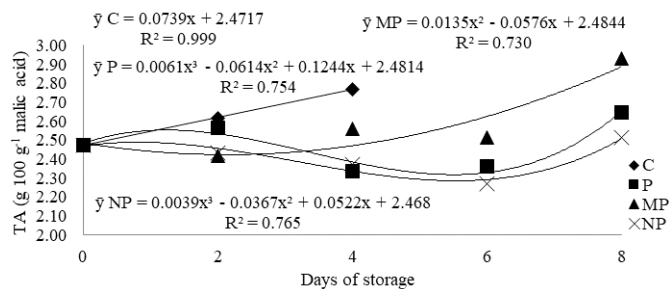


Figure 4. TA content (g malic acid 100 g⁻¹ of fresh mass) from the roselle leaves packed in polypropylene packagings, in which: C- control; P- perforated packaging; MP- micro perforated packaging and NP- non-perforated packaging, during the storage time at 5 °C.

being 2.42 and 2.49 and the titratable acidity of 2.62 and 2.23 g malic acid 100 mL⁻¹ for the aqueous and ethanolic extracts, respectively.

In relation to the soluble solids content from the roselle leaves, a similar behavior to the titratable acidity was observed during the storage time, in which by regression there was a linear increase for the control, which was of approximately 0.25 °Brix each day. Before storage, the leaves of the roselle showed 6.4 °Brix and at the fourth day 7.4 °Brix, and their useful life was limited to four days. For the packs packaged in the perforated and non-perforated packages there was a slight reduction on the fourth and sixth day, with an increase in the sequence of 0.4 °Brix each day, while those of the micro perforated packagings maintained the value until the sixth day and after increasing 0.75 °Brix every day, being this significantly higher from the sixth to the eighth day of storage (Figure 5).

After harvesting, it is common to occur a reduction in the content of soluble solids, since they are also used as organic substrate for the respiratory process of the vegetable. An increase in the SS content during storage was also observed by Nunes et al. (2013) for the arugula bundles, which according to the authors may have occurred due to the different plants that constituted the bundle, associated to its ripening and also by the reduction of the water content that causes the concentration of these compounds.

Reis et al. (2014), when storing lettuce in fully opened, partially open and fully closed LDPE packagings observed that the SS contents were significantly higher in the fully opened packagings in comparison to the others, thus relating the higher concentration of soluble solids to the greater loss of water by the vegetables in the opened packagings. In a similar way to these authors, it was observed in the present work that the SS content was higher for the control, in which there was greater loss of accumulated fresh mass, confirming then that the reduction of water in the leaves provides compounds concentration, such as the SS. Considering that

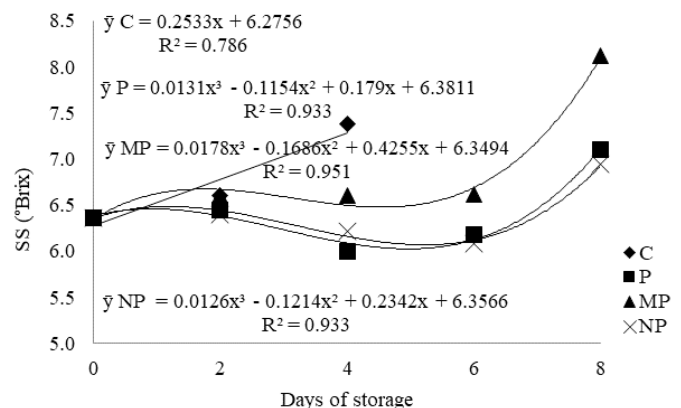


Figure 5. SS content (°Brix) of roselle leaves packed in polypropylene packagings, in which: C- control; P-perforated packaging; MP- micro perforated packaging and NP- non-perforated packaging, during the storage time at 5 °C.

the measurement of soluble solids represents all substances that are dissolved in the vacuolar sap, like sugars, vitamins, phenolics, pectins, organic acids and such (Chitarra & Chitarra, 2005).

A much lower result was found by Jung et al. (2013) for the calyxes of the roselle cultivated in Germany, with contents of 1.80 °Brix for the aqueous extract and 1.71 °Brix for the ethanolic extract. As reported by the authors, it is difficult to compare the results with those from other studies, as these substances depend on the variety and conditions of cultivation, as well as post-harvest factors such as the extraction.

Regarding the increase of soluble solids and titratable acidity observed from the sixth to the eighth day, for the bundles packaged in polypropylene packagings, a quotation by Chitarra & Chitarra (2005) is ratified, that is a natural consequence of the senescence process of the vegetable, because there is solubilization of the cell wall, giving rise to substances mixable in water, such as galacturonic acid.

Conclusions

The roselle leaves are source of carotenoids, especially β -carotene and lutein, which have antioxidant properties and are able to bring benefits to the health of the consumer.

Like other hardwood vegetables, roselle has high perishability, so the refrigerated storage combined with the use of polypropylene plastic packaging allow a greater quality preservation and can increase its useful life up to four days. The unperforated packages were shown as more efficient in the preservation of the soluble solids and titratable acidity during the storage time, demonstrating the potential for other packages being evaluated in later researches.

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