Effect of postharvest temperature on the shelf life of gabiroba fruit (*Campomanesia pubescens*)

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Abstract

The objective of this study was to determine the optimal temperature for storing gabiroba fruit (*Campomanesia pubescens)* without affecting compounds' quality. The fruits were stored at different temperatures (0 °C, 6 °C, 12 °C, and 20 °C) and the effect on the pH, total titratable acidity, soluble solids, total sugars, vitamin C, and antioxidant components such as tannins and total phenolic compounds was evaluated. It was observed an increase in the pH and total titratable acidity during storage at all the temperatures tested. Gabiroba fruits were stored for 9 and 3 days at 12 °C and 20 °C, respectively, and under both temperatures they showed a reduction in tannins and an increase in vitamin C content. As gabirobas armazenadas a 0° and 6 °C alcançaram maior tempo de armazenamento After 12 days of storage, the fruits stored at 6 °C contained higher amounts of water soluble solids, sugars, and antioxidants. In general, for long term storage, it is suggested to store gabiroba fruits at 6 °C. On the other hand, for short term storage, the temperature of 12 °C would be the better to keep high levels of vitamin C and phenolic compounds.

Keywords: gabiroba fruit; storage; temperature; vitamin C; antioxidants.

1 Introduction

Today, preservation of biodiversity in agricultural systems is a crucial objective for worldwide national agencies focused on the environmental protection and sustainability and also for the global bioeconomy. The preservation of the Savanah biome has become necessary for ensuring biodiversity and sustainable development. The study of the nutritional and commercial potential of the native species could be an economical alternative for the subsistence of the native population of different regions. Gabiroba fruit (*Campomanesia pubescens*) is one of the Cerrado's fruit with potential for human consumption that has a particular flavor and is rich in vitamin C (SILVA et al., 2009).

The sensorial and nutritional properties of Cerrado's fruits such as gabiroba, marolo, araça fruits and others have been exploited by the indigenous population based on their empirical knowledge about the benefits to humans. Scarce scientific information has been reported on the chemical, biochemical, and functional properties of those fruits (DAMIANI et al., 2011). Gabiroba is a fruit that belongs to the *Myrtaceae* family, genus *Campomanesia,* which includes up to 25 different species that grow from Mexico to Argentina, among which 15 species are native to Brazil. This plant has great ability to adapt to their environment, large number of seeds, and it is well-accepted by the market due to its sweet flavor and aroma (VIEIRA et al., 2006).

Silva et al. (2009) reported the physiological characterization of the gabiroba fruit. During fruit development, from anthesis (flower opening) to harvest, these authors detected simple sigmoidal growth pattern at the end of the ripening step, and the fruits exhibited respiratory behavior typical of climacteric fruits. Silva et al. (2009) stated that at the 43rd day after blooming or at the beginning of the development, there were major physiological changes, such as an increase in softening, respiration rate, pH, and also in the amount of soluble solids. However, there is no information about the postharvest behavior of those fruits and possible changes in their functional compounds such as vitamins and antioxidants (phenolic compounds and tannins).

Vitamin C, phenolic compounds and tannins functionally act as antioxidant compounds reducing the oxidative stress from the cellular metabolism, which can decrease the incidence of some cardiovascular diseases, certain types of cancer, arthritis, and inflammations (POLINATI; FALLER; FIALHO, 2010). Vitamin C is considered the most important water soluble antioxidant for the human body. It has the ability to remove different species of free radicals such as superoxide and hydroxyl radicals (NAIDU, 2003). Phenolic compounds have wide spectrum of medicinal properties due to their anti-inflammatory and anti-microbial activity, vasodilatation, and cardio protective effect (BALASUNDRAM; SUNDRAM; SAMMAR, 2006). Epidemiologic studies have also revealed that the frequent intake of foods rich in bioactive compounds such as vitamin C and polyphenolic compounds is associated with low incidence of degenerative diseases (HE et al., 2007). Due to healthy implications, there is a growing interest for foods (fruits and vegetables) that provide these compounds in

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sufficient amounts to prevent the incidence of some metabolic diseases (KÄHKÖNEN et al., 1999).

Silva et al. (2009) reported that the gabiroba fruit contains high content of vitamin C from anthesis to ripening, reaching values that ranged from 600 to 800mg/100g. However, fruits continue their metabolic activities after harvesting, which affected their shelf life and composition, and they depend on temperature and water availability (CHITARRA; CHITARRA, 2005). Temperature is one of the main factors that affect the physiological properties of fruits (DÍAZ-PÉREZ; MUY-RANGEL; MASCORRO, 2007). Postharvest technologies related to temperature control have been extensively applied to extend the postharvest life of fruits; consequently, they improve fruit quality. (CUADRA-CRESPO; DEL AMOR, 2010). In fact, storage temperature directly affects the physiology of fruits and consequently the cellular constituents (KEHR, 2002).

The aim of this study was to evaluate the effect of different storage temperatures (0 °C, 6 °C, 12 °C, and 20 °C) on the quality and shelf life of gabiroba fruits.

2 Materials and methods

The fruits were harvested from July to December 2010 from a native Cerrado area where *Campomanesia pubescens* was the predominant specie. The Cerrado area was located 15 km from Lavras, in Southern Minas Gerais state (Brazil). The fruits were harvested early in the morning after 48 days of anthesis, placed in plastic pouches, and taken to the Fruits and Vegetables Laboratory of the Food Science Department of Federal University of Lavras., the Gabirobas were then washed with tap water for dust removal and immersed in 1.216 μM sodium hypochlorite solution for 15 minutes. Good hygienic practices were applied during fruit handling and washing. After removing the excess of solution, 50 grams of fruits (each fruit ≈ 2 g) were placed in trays and stored in cold chambers at different temperatures (0 °C, 6 °C, 12 °C, and 20 °C) and relative humidity of 85% ± 5%, for up to 12 days. The fruits were analyzed every 3 days. Fruits that showed darkened and wrinkled skin were discarded. Discarded fruits were no longer considered for analysis.

2.1 Analysis

Five grams of fruits were homogenized with 45 ml of distilled water in a T18 Ultra Turrax (Wilmington, NC, USA) at 22,000 rpm for 1 minute at 20 °C. Next, the samples were filtered through a screen filter plate, and the filtrate was used for further analysis. The pH of the filtrate was measured directly using a pHmeter Schott Handylab (London, UK), following the AOAC official method (ASSOCIATION..., 2005).

The soluble solids (SS) were also quantified in the filtrate by refractive index using a digital refractometer ATAGO PR-100 (Tokyo, Japan) with automatic temperature adjustment, and the results were expressed in Brix degree, as described by AOAC (ASSOCIATION..., 2005).

Five milliliters of filtrate and 45 ml of distilled water were used for measuring total titratable acidity (TA) using hydroxide (NaOH) 0.1N and phenolphthalein as indicator (INSTITUTO..., 1985). The results were expressed in percentage of citric acid.

2.2 Total sugars (AST)

Total sugars were determined by the anthrone method using a Beckman 640B spectrophotometer (Colorado, US). Three grams of the fruit were homogenized with 100 ml of ethanol 80% using a Ultra Turrax T18 (Wilmington, NC, USA) at 22,000 rpm for 1 minute at 20 °C, and the homogenate was allowed to stand undisturbed for 12 hours for sugar extraction. Afterwards, the sample was filtered and washed three more times with 80% ethanol for complete sugar extraction. All the alcoholic fractions were pooled together and concentrated using a heater block timer until only 5 to 10 ml of alcohol were left. The concentrated sample was diluted to 100 ml in distilled water. An aliquot of 0.5 mL of the diluted sample was diluted again up to 10 ml in distilled water. An aliquot of 1 ml was mixed with 2 ml of anthrone and heated in a boiling water bath for 8 minutes. The sample was then cooled down in an ice bath, and absorbance was read at a 620 nm with a Beckman 640B spectrophotometer. The results were expressed as glucose grams per 100 g tissue.

2.3 Determination of antioxidant compounds

Vitamin C was determined with dinitrophenil hydrazyne following the method described by Strohecker and Henning (1967). Absorbance was read at 520 nm carried out using a Beckman 640B spectrophotometer, and the result was expressed as milligrams per 100 g pulp.

The phenolic compounds were measured in three grams of fruits to identify the compounds with reducing capacity. The compounds were quantified using the Folin-Denis colorimetric method, which is based on the reduction of phosphomolybdic-phosphotungstic acid in alkaline solution by the benzenoid poly hydroxylate compounds forming a more intense blue colour complex, molybdenum blue, with higher number of hydroxyl groups (ASSOCIATION..., 2005).

The tannins were extracted and quantified following the colorimetric method of Folin-Denis described in the Cunniff (1997); three grams of product were weighed and added to 50 ml of 80% methanol, boiled for 15 minutes in a water bath with glass rods, and held at reflux. After the elapsed time, the suspension was filtered into another flask, and the sediment was extracted again two more times. All the filtrates were pooled together and concentrated using a hot plate till approximately 5 ml; they were then diluted up to 25 ml in distilled water. An aliquot (0.1 ml) was placed in tubes and mixed with 8.4 ml of distilled water, 0.5 ml of Folin and Denis reagent, and 1.0 mL of sodium carbonate. After 30 minutes, absorbance was read at 760 nm with a Beckman 640B spectrophotometer.

2.4 Statistical analysis

The experimental desing used was a 4×5 completely randomized (CRD) with four storage temperatures (0 °C, 6 °C, 12 °C and 20 °C) and five storage times (0, 3, 6, 9, and 12 days) with three repetitions. The results were expressed as mean

values ± standard deviation. The data were analyzed using one-way analysis of variance (ANOVA) to determine whether there was significant difference between the samples using the SISVAR statistical package (FERREIRA, 2000). The Fisher's least significant differences (LSD) test was used to differentiate means with 95% confidence.

3 Results and discussion

The fruits stored at 0 °C or 6 °C showed longer stability (12 days), whereas those stored at 12 °C and 20 °C lasted 9 and 3 days, respectively.

Different parameters were determined to assess the quality of the fruits stored at different temperatures. The storage period and temperature did not affect significantly ($P<0.05$) the titratable acidity (TA), whereas the pH was affected only by the storage period (Table 1); TA mean value was 0.24%. Similar TA values were obtained by Bolivar-Fernandez et al. (2009) when studying the ripening of saramuyo fruit (*Annona squamosa* L.) grown in Yucatan Cape (México). A slight increase in the fruits' pH was observed over the storage period (Figure 1).

This increase in pH could be related to a possible decrease in the respiratory metabolic activity, because the levels of O_2 and CO_2 change during storage. The pH increase could also be related with an increase in the vitamin C content. Machado, Coutinho and Caetano (2007) reported similar findings when studying the storage of jabuticaba fruits in plastic packages at low temperatures, and they associated that effect with the increase in the amount of vitamin C. Some other fruit pulps, such as acerola (3.28 ± 0.02) and cranberry pulp (3.18 ± 0.01) also showed lower pH values (MERCALI et al., 2011).

Table 1. Effect of storage on the pH of gabiroba fruits. Mean values of the experimental data obtained from fruits stored at 0 °C, 6 °C, 12 °C and 20 °C.

Time (days)	pH	
0	3.93	B
3	4.13	Ab
6	4.10	Ab
9	4.23	A
12	4.11	Ab
Mean	**4.10**	
SD	**0.11**	

SD: standard deviation. Values followed by different letter within a column are significantly different at $P<0.05$.

The water soluble solids and total sugars of the gabiroba fruits were affected by the temperature and time of storage (Figure 1). In general, the same trend was observed at different storage temperatures, i.e., there was a decrease in the water soluble solids at the begining of storage, followed by a sharp increase and afterwards a reduction. However, the time at which those changes occurred varied with the storage temperature. At 0 °C, the complete pattern was observed, but changes were slowed down at 6 °C, and higher temperatures accelerated the metabolic changes associated with the levels of the water soluble solids (Figure 1). At 20 °C, only a sharp increase was detected, but no further measurements could be performed due to the short sorage period. An increase in water soluble solids was observed in Gabiroba fruits stored at 6 °C (Figure 1A) after the 6th day of storage, and the same trend was observed for the amount of sugars (Figure 1B). The lowest amount of water soluble solids was observed at the end of the storage at 0 °C and 12 °C, which corresponded to 9 and 12 days, respectively. Sugars are the energy source for the respiratory process, and the decrease in the amount of sugars during storage led to a decrease in the water soluble solids.

According to Taiz and Zeiger (2002), physiologic processes such as respiration that occur during postharvest related to changes in the nutritive compounds at three levels: hydrolysis or breakage of polysaccharides into sugars, oxidation of sugars to piruvic acid (glycolitic cycle), and aerobic transformation of piruvic acid and other organic acids into CO_2 and water (Krebs cycle). This metabolic process could be responsible for the variation of sugars with storage time.

The vitamin C levels increased in the first three days in the fruits stored at 6, 12, and 20 °C and up to the nineth day in

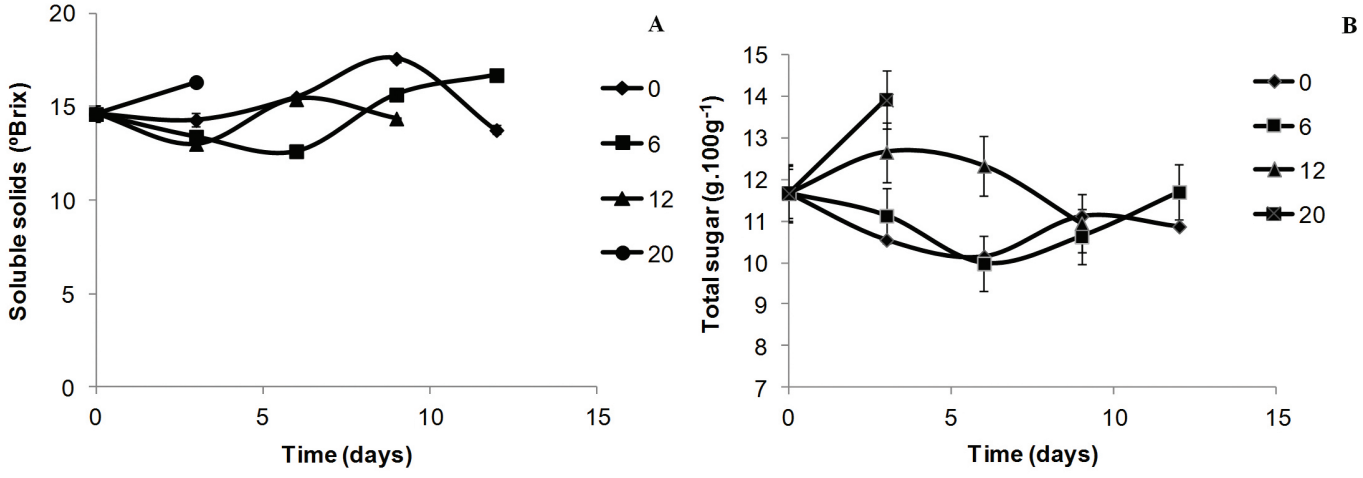

Figure 1. Effect of storage temperature on the amount of water soluble solids (Figure 1A) and sugars (Figure 1B) of gabiroba fruits. Legends corresponded to different storage temperatures.

those stored at 0 °C (Figure 2). The lowest temperatures (0 and 6 °C) reduced the vitamin C synthesis rate, suggesting an effect of the cold temperatures on the metabolism control. Although the vitamin C levels tend to decrease during the storage of the most fruits, vitamin C synthesis was observed in some species such as guava (BASHIR; ABU-GOUKH, 2003). Guabiroba and guava belong to the same family (Myrtaceae) and exhibit similar behaviour. The maximum amount of vitamin C, 700 and 900 mg $100g^{-1}$, was found in the fruits stored at 20 and 12 °C. Although no analysis of moisture and weight loss has been conducted in stored fruits, it is likely that the values found for vitamin C were not affected by loss of water since 5% moisture loss greatly affects the fruit quality and appearance, which was not observed in gabirobas during storage. At lower storage temperatures, the levels of vitamin C were always lower than those observed at 20 e 12 °C. The significant increase in the amount of vitamin C during the storage of gabiroba fruits is of great importance since this vitamin has antioxidant activity. The vitamin C values obtained during storage in the present study were lower than those reported for gabiroba fruits at the end of its development (1,000 mg.$100g^{-1}$ in the pulp fruits with 43 day development), but similar to that found in mature fruits (800 mg.100 g $pulp^{-1}$) (SILVA et al., 2009). Smirnoff and Wheeler (2000) highlighted the importance of vitamin C for the human metabolism due to its ability to participate in the processes of cellular oxidation releasing hydrogen and capturing oxidative free radicals, and consequently, decreasing the incidence of diseases such as cancer. In vegetables, the vitamin C participates in a variety of metabolic processes such as photosynthesis, photo protection, growth and expansion of the cellular wall and others. The recommended dietary allowance (RDA) for vitamin C of for adults is 60 mg day^{-1}; therefore, the consumption of 10-20 g of gabiroba fruit is enough to meet the daily recommendations (BRAZIL, 1998).

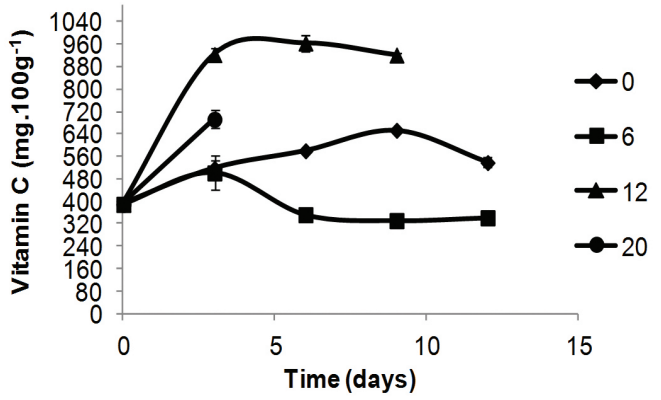

Figure 2. Amount of vitamin C in gabiroba fruits during storage under different temperatures.

Other functional compounds such as tannins and phenolic compounds were also quantified during storage (Figure 3). Different trend was observed for tannins and phenolic compounds during storage at different temperatures. Tannins (Figure 3A), were in general, lower than the those obtained in the fresh fruits (0 day), with the exception of fruits stored at 0 °C for 3 days. The reduction in the tannins could be due to their polymerization or hydrolysis, which is responsible for improving the taste of fruits during ripening (FISCHER; BENNET, 1991).

A progressive increase in the amount of phenolic compounds was observed during storage up to a maximum value that dependent on the storage temperature. During storage at 6 °C, the increase was only noticeable after 6 days of storage. This increase may be due, in part, to the water loss during storage. During longer term storage, such as that at 0 °C and 6 °C, a slight decrease was observed at the end of the storage period. The values obtained in the present studied are in accordance with those reported for other fruits such as jabuticaba (450 mg.100 g of $pulp^{-1}$) (LIMA et al., 2008).

Oliveira et al. (2011) reported similar values of phenolic compounds in guava, but lower values were obtained in papaya and mango fruits from Brazil. Phenolic compounds and tannins have important antioxidant activity. However, their levels affect the taste fruit taste due to their astringency. Kuskoski et al. (2006) characterized the amount of phenolic compounds and

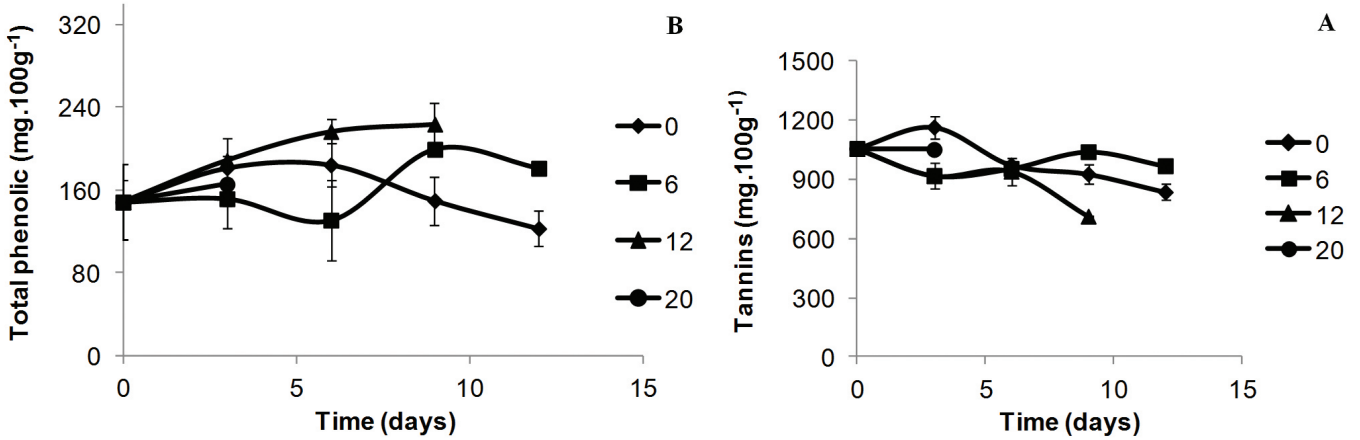

Figure 3. Effect of storage temperature on the amount of tannins (Figure 3A) and total phenolic compounds (Figure 3B) of gabiroba fruits.

anthocianins of wild fruits and their frozen pulp. These authors found different values of phenolics compounds depending on the fruits, 544.9 mg.100 g^{-1} for mango pulp, 580.1 mg.100 g^{-1} for acerola, 21.7 mg.100 g^{-1} for passion fruit, and 117.1 mg.100 g^{-1} for grapes. Phenolic compounds and tannins are found in the vascular tissues of vegetables, acting as protective agents against insect attacks (FELTON et al., 1989; RICE-EVANS; MILLER; PAGANGA, 1997).

4 Conclusion

In addition to its importance as a preservative method to extend the shelf life of fruits, storage temperature significantly affects the level of functional compounds in the gabiroba fruits. The fruits stored at 0 °C or 6 °C exhibited more stability, but considering the levels of functional compounds such as vitamin C, phenolic compounds, and tannins, 6 °C is the recommended temperature for storage. Therefore, it would be advisable to store gabiroba fruits at 6 °C when longer term storage is required, but for short term storage, 12 °C is the best temperature because at this temperature, high levels of vitamin C and phenolic compounds are obtained.

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