Fruit quality of Brazilian genotypes of feijoa at harvest and after storage

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Abstract – The objective of this work was to evaluate the physicochemical attributes and vitamin C contents of fruits of five Brazilian genotypes of feijoa (*Acca sellowiana*), at harvest and after cold storage. The Alcântara, Mattos, Helena, and Nonante cultivars, as well as accession 2316, were studied. The assessed attributes were: fresh mass loss, titratable acidity, soluble solids contents, soluble solids contents/titratable acidity ratio, pH, skin and flesh color, texture, and vitamin C contents (skin and flesh). After storage, there were reductions of 2.9% in soluble solids contents, of 32.2% in titratable acidity, and of approximately 85% in texture attributes, besides increases of 36.3% in the soluble solids contents/titratable acidity ratio and of 21.7% in the pH of fruits. The vitamin C content in the skin was higher than that in the flesh, and increased in both skin and flesh after storage. 'Alcântara' fruits have the highest contents of vitamin C in the skin and flesh. Fruits of 'Nonante' and 'Mattos' show better preservation of the texture attributes, and fruits of 'Nonante', the lowest levels of flesh browning during storage.

Index terms: *Acca sellowiana*, ascorbic acid, functional food, native fruit trees, natural antioxidant, postharvest, soluble solids content.

Qualidade dos frutos de genótipos brasileiros de goiabeira-serrana na colheita e após o armazenamento

Resumo – O objetivo deste trabalho foi avaliar os atributos físico-químicos e o conteúdo de vitamina C em frutos de cinco genótipos brasileiros de goiabeira-serrana (*Acca sellowiana*), na colheita e após o armazenamento refrigerado. Foram estudadas as cultivares Alcântara, Mattos, Helena e Nonante, e o acesso 2316. Avaliaram-se os atributos: perda de massa fresca, acidez titulável, teores de sólidos solúveis, relação sólidos solúveis/acidez titulável, pH, coloração da casca e da polpa, textura e conteúdo de vitamina C (casca e polpa). Após o armazenamento, houve redução de 2,9% nos teores de sólidos solúveis, de 32,2% na acidez titulável e de aproximadamente 85% nos atributos de textura, além de aumentos de 36,3% na relação sólidos solúveis/acidez titulável e de 21,7% no pH dos frutos. O conteúdo de vitamina C na casca foi superior ao da polpa, e aumentou na casca e na polpa após o armazenamento. Frutos de 'Alcântara' apresentam os maiores conteúdos de vitamina C na casca e na polpa. Frutos de 'Nonante' e 'Mattos' apresentam melhor preservação dos atributos de textura, e frutos de 'Nonante', menor escurecimento de polpa durante o armazenamento.

Termos para indexação: *Acca sellowiana*, ácido ascórbico, alimento funcional, frutíferas nativas, antioxidante natural, pós-colheita, sólidos solúveis.

Introduction

Native fruit species have been attracting the attention of producers and the global consumer market, and feijoa *Acca sellowiana* (O.Berg.) Burret [Syn. *Feijoa sellowiana* (O.Berg.) O.Berg.] is an important representative of this group. This species belongs to the Myrtaceae family and is native to the Southern region of Brazil and to Uruguay (Schotsmans et al., 2011).

Feijoa trees grow mainly at altitudes higher than 800 m, preferentially above 1,000 m (Moretto et al., 2014). In Southern Brazil, fruit maturation occurs between March and May (Santos et al., 2011). Physiological maturity is identified when the fruit naturally detaches from the tree, at which point it presents excellent taste

and aroma characteristics (Schotsmans et al., 2011). Because it is physically similar to common guava, in Brazil, feijoa fruit is referred to as "goiaba-serrana", "goiaba-do-mato", and "goiaba-do-campo" (Moretto et al., 2014).

Feijoa fruits have antitumor (Bontempo et al., 2007), anti-inflammatory (Rossi et al., 2007), antioxidant (Ömer et al., 2010; Pasquariello et al., 2015), hepatoprotective (El-Shenawi et al., 2008; Karami et al., 2013), and gastroprotective (Monforte et al., 2014) action. These fruits also represent an important source of vitamin C (Belous et al., 2014; Monforte et al., 2014; Pasquariello et al., 2015) and minerals (Romero-Rodriguez et al., 1994).

Feijoa fruits have significant economic value in several countries, including New Zealand, Colombia, and the USA (Schotsmans et al., 2011). In Brazil, notably in the state of Santa Catarina, the cultivation of feijoa is still restricted to small areas, but with prospects for expansion. The species has been studied in the state since 1986, and, in 2007 and 2008, the following four commercial cultivars were launched from there by Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri): Alcântara, Mattos, Helena, and Nonante (Santos et al., 2011).

Knowledge of the postharvest physiology of fruits is of vital importance to provide technical support to extend the storage period, conserving physicochemical, organoleptic, and nutritional characteristics. As ripening progresses, feijoa fruits undergo physicochemical changes, such as weight loss, taste deterioration (associated with a reduction in titratable acidity and soluble solids contents), and rapid darkening of the flesh, resulting in serious limitations in meeting the demands of the fresh fruit market (Rodríguez et al., 2006; Schotsmans et al., 2011). The fruits can be stored after harvest for approximately three weeks, under refrigeration at 4°C (Velho et al., 2011; Amarante et al., 2013), before the organoleptic qualities are affected and the flesh begins to darken. This storage period is relatively short and, even though, in most cases, the fruit retains an external appearance appropriate for consumption, the flesh already shows signs of darkening and losses in taste and aroma.

The objective of this work was to evaluate the physicochemical attributes and vitamin C contents of fruits of five Brazilian genotypes of feijoa, at harvest and after cold storage.

Materials and Methods

Feijoa fruits were harvested from an orchard of the active germplasm bank of Epagri, at the experimental station located in the municipality of São Joaquim (28°16'40"S, 49°56'09"W, at an altitude of 1,400 m), in the state of Santa Catarina, Brazil. Fruits of the Alcântara, Helena, Mattos, and Nonante cultivars and of accession 2316 (with the potential to be launched as a cultivar) were harvested at the commercial maturity stage, when the fruits can be easily detached from the plant. Fruits were then immediately transported to the laboratory of postharvest physiology and technology at Universidade do Estado de Santa Catarina, in the municipality of Lages, also in the state of Santa Catarina, where the analyses were carried out.

In 2012, 2013, and 2014, fruits of the five genotypes were evaluated regarding physicochemical attributes, both at harvest and after 21 days of refrigerated storage at 4±1°C and 90±5% relative humidity (RH), followed by two days under ambient conditions (23±2°C and 75±5% RH). The following fruit attributes were assessed: fresh mass loss, titratable acidity, soluble solids contents, soluble solids contents/titratable acidity ratio, pH, skin (external epidermis and internal parenchyma) and flesh color, and texture (compression and penetration forces).

Fresh mass loss (%) was evaluated by weighing the fruits at harvest (before storage) and after 21 days of refrigerated storage, followed by two days under ambient conditions (Antunes et al., 2003).

The titratable acidity values (percentage of citric acid) were obtained by titrating 10 mL of juice extracted from the fruit, diluted with 90 mL of distilled water, with 0.1 N sodium hydroxide, until pH 8.1, with the aid of the TitroLine Easy (SI Analytics, Mainz, Germany) automatic titration unit (Amarante et al., 2008). The pH of the juice was determined with the aid of the K39-2014B benchtop pH meter (Kasvi, Curitiba, PR, Brazil). The soluble solids content (%) of the fruit juice was obtained using an Abbe digital refractometer model PR-201 alpha (Atago Co., Ltd., Tokyo, Japan), with automatic temperature compensation (Amarante et al., 2008).

The color of the skin (external epidermis and internal parenchyma) and flesh of the fruits was determined with the aid of the CR 400 colorimeter (Konica Minolta Inc., Tokyo, Japan) through the quantification of lightness (L), chroma (C), and hue angle (h°) (Amarante

et al., 2008). For the color measurement of the external epidermis of the skin, two readings were taken from equidistant points along the equatorial portion of the fruit. To measure the color of the flesh, the fruits were cut in half and the reading was immediately taken from the central portion of the flesh. After the removal of the flesh with the aid of a spoon, the reading of the color of the internal parenchyma of the skin was also immediately taken.

Texture was analyzed with the aid of the TA.XT plus electronic texture analyzer (Stable Micro Systems Ltd., Surrey, United Kingdom), according to the methodology described by Amarante et al. (2008). For the quantification of the fruit penetration force, a 2-mm diameter probe (model PS2) was inserted into the equatorial portion of the fruits, and two readings were taken from opposite sides. The probe was introduced to a depth of 8 mm, with pre-test, test, and post-test velocities of 10, 1, and 10 mm s^{-1}, respectively. The force required for fruit compression (until achieving a 3-mm deformation of the fruit surface) was determined using a plunger (model P/75) with a diameter of 75 mm, with pre-test, test, and post-test velocities of 10, 0.5, and 30 mm s^{-1}, respectively.

In 2013 and 2014, fruits of the five evaluated genotypes were analyzed with regard to the vitamin C contents (mg ascorbic acid per 100 g fresh weight) in the skin (external epidermis and internal parenchyma) and flesh tissues. Vitamin C was assessed at harvest and after 21 days of refrigerated storage (4±1ºC and 90±5% RH), followed by two days under ambient conditions (23±2ºC and 75±5% RH) by the spectrophotometric method using 2,4-dinitrophenylhydrazine (Strohecker & Henning, 1967). In 2014, the vitamin C contents were determined for the skin and flesh of fruits of the cultivar Alcântara, after 21 days of refrigerated storage (4±1ºC and 90±5% RH), followed by exposure to ambient conditions (0, 6, 12, 24, 36, 48, and 72 hours at 23±2ºC and 75±5% RH).

The experiment was carried out in a completely randomized design, with eight replicates of five fruits each. Since the data for all variables were consistent along the seasons (three seasons for the physicochemical attributes and two for vitamin C contents), only the average data for all seasons were subjected to the analysis of variance, and the means of the treatments were compared by Tukey's test, at 5% probability, using the SAS software (SAS Institute Inc., Cary, NC, USA). For the data on the vitamin C contents in the skin and flesh of the fruits of the cultivar Alcântara, after refrigerated storage followed by exposure to ambient conditions, polynomial models were tested (linear and quadratic), relating the vitamin C content to the number of hours at ambient temperature (0 to 72 hours).

Results and Discussion

The average fresh mass of the fruits at harvest varied from 94.6 g for 'Nonante' to 120.5 g for 'Mattos' (Table 1). The fresh mass loss of the fruits during the 21 days of refrigerated storage, followed by two days under ambient conditions, did not differ between genotypes, with an average of 3.6%. Of the total fresh mass loss, 28.4% occurred during the two days of fruit exposure to ambient conditions after removal from the refrigerated environment. The fresh mass loss observed in the post-refrigeration period, compared with that during total fruit storage time (23 days), shows the importance of refrigerated storage for this fruit. The lower temperature and the higher relative humidity conditions in refrigerated storage reduce the vapor pressure deficit and, consequently, decrease fruit transpiration, which contributes to the low fresh

Table 1. Fresh weight of fruits of different genotypes of feijoa (*Acca sellowiana*) at harvest and after 21 days of cold storage (CS, 4±1ºC and 90±5% RH), followed by two days at ambient temperature (AT, 23±2ºC and 75±5% RH), as well as total fresh weight loss[1].

Genotype	Fresh weight (grams per fruit)			Total fresh weight loss (%)[2]
	At harvest	After 21 days of CS	After two days at AT	
Alcântara	109.9a	107.0a	104.9a	4.5[ns]
Helena	118.9a	115.5a	114.7a	3.5
Mattos	120.5a	118.4a	117.6a	2.4
Nonante	94.6b	91.5b	90.7b	4.1
Accession 2316	118.5a	115.6a	114.1a	3.7
Mean	112.5	109.6	108.4	3.6
CV (%)	16.9	18.3	18.1	39.9

[1]Means followed by equal letters, in the columns, do not differ by Tukey's test, at 5% probability. [2]Total fresh weight loss between harvest and cold storage for 21 days, followed by two additional days at ambient temperature. [ns]Nonsignificant. RH, relative humidity. CV, coefficient of variation. Values are the mean of three years (2012, 2013, and 2014).

mass loss of the samples (Mélo et al., 2000; Antunes et al., 2003). In feijoa fruits harvested in New Zealand, Rupavatharam et al. (2015) reported an average fresh mass loss of 1.2% after six weeks of refrigerated storage at 4°C and 90% RH.

The average soluble solids content for the feijoa genotypes at harvest was 10.12%. Fruits of the Mattos cultivar had the highest soluble solids contents at harvest and after refrigerated storage, followed by two days under ambient conditions. The Nonante and Helena cultivars, as well as accession 2316, had intermediate soluble solids contents, whereas the Alcântara cultivar had the lowest (Table 2).

After refrigerated storage, the soluble solids contents only reduced for accession 2316 an increased in Mattos cultivar, in comparison to the assessment at harvest. For the other genotypes, soluble solids contents did not change during cold storage. Similar results were obtained by Velho et al. (2011) for feijoa fruits harvested in São Joaquim, in the state of Santa Catarina – there was no reduction in the soluble solids contents after four weeks of refrigerated storage (4ºC and 90% RH). However, feijoa fruits harvested in the same location showed a reduction in soluble solids contents after three weeks of refrigerated storage at 4ºC and 90% RH (Amarante et al., 2013).

At harvest, 'Alcântara' had the lowest titratable acidity values, and no differences were found between the other genotypes. After the storage period, the Mattos and Nonante cultivars showed the highest titratable acidity values. Titratable acidity decreased during refrigerated storage, except in 'Mattos'. The average titratable acidity of the five genotypes decreased from 1.21% at harvest to 0.82% after storage, indicating a reduction of 32.2%. This decrease in titratable acidity shows that organic acids represent an important substrate for respiration in feijoa fruits at postharvest (Amarante et al., 2013).

The pH of the fruits of the feijoa genotypes differed only at harvest, varying from 2.45 to 3.68. These values are close to those reported by Romero-Rodriguez et al. (1994) for feijoa. After the storage period, the average pH value for the five feijoa genotypes was 3.68, showing an increase of 21.7% in comparison with the corresponding value at harvest. This pH increase was mainly due to the reduction in titratable acidity observed in the fruits at the end of the storage period.

Considering the average values for the five genotypes, the soluble solids contents/titratable acidity ratio increased by 36.3% after 21 days of refrigerated storage, followed by two more days under ambient conditions (Table 2). This increase in the soluble solids content/titratable acidity ratio after storage is explained by the reduction in titratable acidity (Amarante et al., 2013). The soluble solids contents/ titratable acidity ratio was higher for the Alcântara cultivar and accession 2316 at harvest, and for the Helena and Alcântara cultivars after storage. It should

Table 2. Soluble solids contents (SSC), titratable acidity (TA), SSC/TA ratio, and pH of fruits of different genotypes of feijoa (*Acca sellowiana*) at harvest and after 21 days of cold storage (4±1ºC and 90±5% RH), followed by two days at ambient temperature (23±2ºC and 75±5% RH)[(1)].

Genotype	SSC (%)		TA (%)		SSC/TA ratio		pH	
	At harvest	After cold storage	At harvest	After cold storage	At harvest	After cold storage	At harvest	After cold storage
Alcântara	8.93cA	8.60cA	0.81bA	0.55cB	11.14aB	15.92abA	3.68aB	4.02aB
Helena	9.87bA	9.48bA	1.19aA	0.49cB	8.30bB	19.71aA	2.45cB	3.77aA
Mattos	11.16aB	11.89aA	1.46aA	1.24aA	8.22bA	12.56bcA	2.67cB	3.49aA
Nonante	10.37bA	9.95bA	1.47aA	1.11abB	7.64bA	9.16cA	2.46cB	3.54aA
Accession 2316	10.31bA	9.25bcB	1.12aA	0.73bcB	9.20abB	12.93bcA	3.18bB	3.60aA
Mean	10.12A	9.83B	1.21A	0.82B	8.95B	14.05A	2.88B	3.68A
Coefficient of variation (%)	8.2	12.9	29.8	51.1	22.6	35.1	18.3	11.9

[(1)]Means followed by equal letters, lowercase in the columns comparing genotypes and uppercase in the lines comparing harvest and cold storage evaluations for the same attribute, do not differ by Tukey's test, at 5% probability. Values are the mean of three years (2012, 2013, and 2014). RH, relative humidity.

be noted that, for 'Helena', the soluble solids contents/titratable acidity ratio increased from 8.30 at harvest to 19.71 after storage. This indicates that this genotype has a more rapid loss of postharvest sensorial quality than the other ones studied.

Regarding the textural analysis, considering the average values for all genotypes, the fruit compression and penetration forces reduced in 43.2 and 29.1%, respectively, after storage (Table 3). This shows that the fruit texture deteriorates substantially as the fruit ripens (Rupavatharam et al., 2015). The Nonante cultivar had higher values for fruit penetration force at harvest and after storage than the other genotypes. At harvest, the Mattos cultivar showed the greatest fruit compression force, and no differences were found between the other genotypes. After storage, although the Mattos cultivar had the highest loss of firmness (49.5%), it still showed, together with the Helena cultivar, the highest values for fruit compression force (Table 3). The texture data indicate that the Nonante and Mattos cultivars showed greater capacity to resist deformation, remaining in better conditions after refrigerated storage, followed by exposure to ambient temperature.

Table 3. Forces for penetration and compression of fruits of different genotypes of feijoa (*Acca sellowiana*) at harvest and after 21 days of cold storage (4±1ºC and 90±5% RH), followed by two days at ambient temperature (23±2ºC and 75±5% RH)[(1)].

Genotype	Force for penetration (N)[(2)]		Force for compression (N)	
	At harvest	After storage	At harvest	After storage
Alcântara	7.71bA	4.93bB	55.65bA*	30.01cB
Helena	6.29cA	4.35bB	56.58bA	36.68abB
Mattos	6.20cA	4.98bB	78.56aA	39.56aB
Nonante	11.01aA	7.47aB	52.07bA	34.44bB
Accession 2316	5.52cA	4.30bB	50.42bA	25.95cB
Mean	7.35A	5.21B	58.22A	33.33B
CV (%)	30.6	26.2	20.9	17.3

[(1)]Means followed by equal letters, lowercase in the columns comparing genotypes and uppercase in the lines comparing harvest and cold storage evaluations for the same attribute, do not differ by Tukey's test, at 5% probability. Values are the mean of three years (2012, 2013, and 2014). [(2)]N, Newton. RH, relative humidity. CV, coefficient of variation.

In relation to the external epidermis color, reductions in the L and C values were found after storage (Table 4). The results showed that there was a loss in the green color intensity, as well as in the shine of the external epidermis as fruit ripened. A reduction in the L values after storage was observed for the Alcântara, Helena, and Mattos cultivars. There was also a reduction in the C values (loss of color definition) in the Helena cultivar, and in hº (loss of green color intensity) in the Mattos cultivar after storage. However, it should be highlighted that all changes in the color of the external epidermis of feijoa fruits are practically imperceptible to the naked eye. Therefore, evaluating fruit quality based on color changes is not recommended when carried out by a subjective visual assessment, only when a colorimeter is used.

Storage favored the darkening of the internal parenchyma of the skin and flesh (lowest L value). The L value reduced in the internal parenchyma of the skin of the Alcântara and Nonante cultivars, and in the flesh of the Mattos cultivar and accession 2316. The flesh darkening of feijoa fruits after refrigerated storage (4°C) for 21 days, followed by ambient temperature (23°C) for two days, has also been previously reported by Amarante et al. (2013). Internal darkening, particularly in the flesh, adversely affects the quality of fruit destined for consumption. The results indicate that the Mattos cultivar and accession 2316 were more sensitive to flesh darkening at postharvest. The fruits of the Nonante cultivar did not show changes in any of the flesh color attributes during storage, indicating their better postharvest potential due to lower flesh darkening.

For all genotypes, the vitamin C content in the skin was about 28% higher than that in the flesh, both at harvest and after storage (Table 5). Higher vitamin C contents in the skin have also been reported by Belous et al. (2014) for feijoa produced in Russia. These authors found average values of 47.2 mg 100 g^{-1} fresh weight in the skin and 37.1 mg 100 g^{-1} fresh weight in the flesh. The fruits of 'Alcântara' had the highest vitamin C contents at harvest (101.0 and 92.5 mg 100 g^{-1} fresh weight in the skin and flesh, respectively) and after storage (121.5 and 96.8 mg 100 g^{-1} fresh weight in the skin and flesh, respectively). At harvest, the vitamin C contents in the skin and flesh of 'Alcântara' fruits were 37.1 and 58.1% higher, respectively, when

compared with 'Helena', which had the lowest vitamin C contents.

The vitamin C contents for the flesh of the five genotypes studied are higher than those reported by other authors for feijoa fruits produced in: Russia, of 37.1 mg 100 g^{-1} fresh weight (Belous et al., 2014); in Italy, varying from 25.43 to 39.87 mg 100 g^{-1} fresh weight, depending on the genotype (Pasquariello et al., 2015); in Spain, of 26.9 mg 100 g^{-1} fresh weight (Romero-Rodriguez et al., 1994); and in Colombia, of 26.4 mg 100 g^{-1} fresh weight (Valente et al., 2011).

The vitamin C contents in the flesh of the fruits of the evaluated feijoa genotypes are higher than those found for mango (*Mangifera indica* L.) (17.5 mg 100 g^{-1} fresh weight) and tangerine (*Citrus reticulata* Blanco) (21.5–32.5 mg 100 g^{-1} fresh weight), but similar or slightly lower than those for other types of fruits, such as orange (*Citrus sinensis* Pers.) (64.6–84.0 mg 100 g^{-1} fresh weight), guava (*Psidium guajava* L.) (85.9 mg 100 g^{-1} fresh weight), and papaya (*Carica papaya* L.) (80.2 mg 100 g^{-1} fresh weight) (Couto & Canniatti-Brazaca, 2010; Oliveira et al., 2011). This shows that feijoa fruit

Table 4. Color of the skin (external epidermis and internal parenchyma) and flesh tissues of fruits of different genotypes of feijoa (*Acca sellowiana*) at harvest and after 21 days of cold storage (4±1ºC and 90±5% RH), followed by two days at ambient temperature (23±2ºC and 75±5% RH)[(1)].

Genotype	At harvest			After storage		
	External epidermis	Internal parenchyma	Flesh	External epidermis	Internal parenchyma	Flesh
			Lightness (L)			
Alcântara	45.6aA	65.0aA	46.1bA	43.8abB	59.5aB	44.3bcA
Helena	45.0aA	61.8abA	54.8aA	43.4abB	60.0aA	53.3aA
Mattos	44.7aA	60.5bcA	50.5abA	42.6bB	56.8abA	42.3cB
Nonante	46.8aA	61.6bcA	50.1abA	45.0aA	54.8bB	48.4abA
Accession 2316	44.9aA	58.5cA	52.0aA	44.2abA	56.6abA	49.0abB
Mean	45.4A	61.5A	50.7A	43.8B	57.5B	50.7B
CV (%)	2.9	4.3	7.9	3.0	5.1	9.7
			Chroma (C)			
Alcântara	21.5abA	20.8bB	9.3cB	21.1aA	22.5A	11.3cA
Helena	20.6bA	22.7abA	12.5bA	19.3aB	22.7A	13.6abA
Mattos	20.5bA	22.7abA	12.4bA	19.6aA	30.9A	12.9bA
Nonante	23.6aA	23.5aA	13.2bA	21.2aA	22.6A	14.2abA
Accession 2316	21.3abA	20.9bB	15.5aA	20.8aA	22.6A	14.7aA
Mean	21.5A	22.1B	12.6B	20.4B	24.3A	13.3A
CV (%)	8.6	6.9	17.2	6.3	27.6	10.4
			Hue angle (hº)			
Alcântara	124.5aA	87.7bA	88.7bA	123.9aA	85.2abB	84.4bB
Helena	124.2aA	93.6aA	93.1aA	124.5aA	90.3aA	98.1aB
Mattos	125.6aA	88.6bA	91.5abA	123.4abB	86.6abA	85.6bB
Nonante	120.6bA	87.5bA	91.0abA	121.5bA	83.4bB	89.9aA
Accession 2316	123.9aA	88.4bA	88.7bA	123.1abA	87.6abA	86.6abA
Mean	123.8A	89.2A	90.6A	123.3A	86.6B	87.1B
CV (%)	1.6	3.1	2.9	1.2	4.6	3.6

[(1)]Means followed by equal letters, lowercase in the columns comparing genotypes and uppercase in the lines comparing harvest and cold storage evaluations for the same fruit tissue, do not differ by Tukey's test, at 5% probability. Values are the mean of three years (2012, 2013, and 2014). RH, relative humidity. CV, coefficient of variation.

is a rich source of vitamin C. The recommended daily intake (RDI) of vitamin C, established by the Food and Nutrition Board of Institute of Medicine of National Academy of Sciences (United States, 2000), are 75 and 90 mg per day for women and men above 19 years of age, respectively. In Brazil, the RDI for adults is 45 mg per day (Anvisa, 2005); therefore, the daily intake of 100 g feijoa (skin or flesh) would meet the RDI.

The vitamin C contents increased after refrigerated storage, from 77.3 to 99.6 mg 100 g^{-1} fresh weight in the skin (22.4% increase) and from 55.2 to 72.7 mg 100 g^{-1} fresh weight in the flesh (24.1% increase) (Table 5). In most fruits and vegetables, a substantial loss in vitamin C is common during storage due to the enzymatic oxidation of ascorbic acid, particularly through the action of ascorbate oxidase (Lee & Kader, 2000). However, for some crops, studies show an increase in the vitamin C content at postharvest. Antunes et al. (2003) found an increase in the vitamin C content in blackberry (*Rubus* spp.) stored until six days at 20°C. The same behavior was verified by Mélo et al. (2000) for pitanga (*Eugenia uniflora* L.) stored under refrigeration at 8°C. In both cases, the increase in vitamin C contents was attributed to the water loss of fruits during storage. However, in the present study, the fresh mass loss does not entirely explain the increase in vitamin C in feijoa fruits (Table 1).

An increase in vitamin C contents was also observed in 'Alcântara' fruits subjected to low storage temperature (4±1°C), followed by exposure to ambient conditions (23±2°C) (Figure 1). At harvest, the vitamin C contents of the flesh and skin of the fruits of this cultivar were 93.6 and 102.6 mg 100 g^{-1} fresh weight, respectively. Compared with these values, the vitamin C contents slightly increased in the flesh and skin at time zero at ambient temperature, after removal from refrigerated storage (21 days). It should be pointed out that the vitamin C contents, both in the skin and flesh, had a substantial increase, followed by a decrease, when kept at ambient temperature after removal from refrigerated storage. The vitamin C contents reached maximum values of 97.08 mg 100 g^{-1} fresh weight in the flesh after 33 hours and of 122.04 mg 100 g^{-1}

Table 5. Vitamin C contents of the skin and flesh tissues of fruits of different genotypes of feijoa (*Acca sellowiana*) at harvest and after 21 days of cold storage (4±1°C and 90±5% RH), followed by two days at ambient temperature (23±2°C and 75±5% RH)[(1)].

Genotype	Skin		Flesh	
	At harvest	After storage	At harvest	After storage
	Vitamin C (mg ascorbic acid per 100 g fresh weight)			
Alcântara	101.0aB	121.5aA	92.5aB	96.8aA
Helena	63.5dB	90.0cA	38.7eB	49.5eA
Mattos	82.0bB	97.0bA	56.3bB	80.8bA
Nonante	64.0dB	90.7cA	41.1dB	58.1dA
Accession 2316	75.8cB	98.8bA	47.1cB	78.4cA
Mean	77.3B	99.6A	55.2B	72.7A
CV (%)	18.2	11.7	36.0	23.6

[(1)]Means followed by equal letters, lowercase in the columns comparing genotypes and uppercase in the lines comparing harvest and cold storage evaluations for the same fruit tissue, do not differ by Tukey's test, at 5% probability. Values are the mean of two years (2013 and 2014). RH, relative humidity. CV, coefficient of variation.

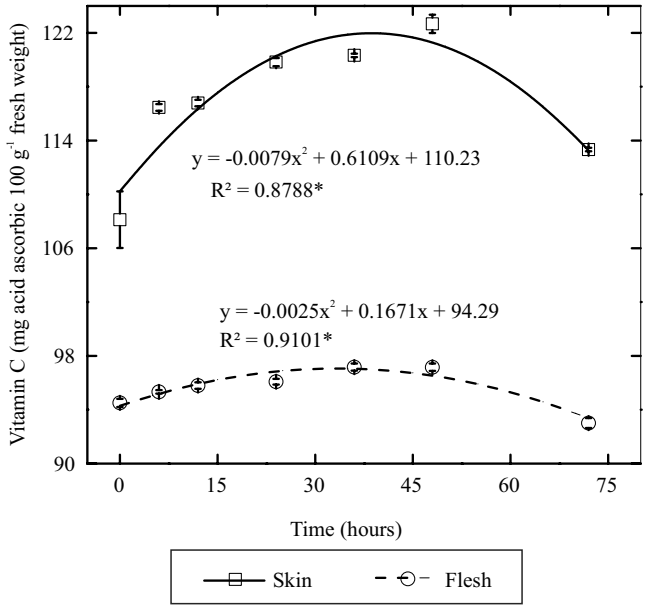

Figure 1. Vitamin C contents of the skin and flesh tissues of fruits of the 'Alcântara' genotype of feijoa (*Acca sellowiana*) after 21 days of cold storage (4±1ºC and 90±5% RH), followed by different times (in hours) at ambient temperature (23±2ºC and 75±5% RH). Vertical bars represent the standard deviation of the mean. *Adjusted quadratic models are significant at 5% probability. At harvest, in 2014, the vitamin C contents of the flesh and skin tissues were 93.6 and 102.6 mg ascorbic acid per 100 g^{-1} fresh weight, respectively.

fresh weight in the skin after 39 hours under ambient conditions.

In plants, vitamin C production occurs via the rapid conversion of L-galactono-1,4-lactone (GAL) into L-ascorbic acid by the enzyme GAL dehydrogenase (Locato et al., 2013). The enzymatic activity of GAL dehydrogenase increases under low-temperature storage (Smirnoff & Wheeler, 2000). This could explain, in the case of feijoa, the increase in vitamin C observed during refrigerated storage, particularly when followed by exposure to ambient temperatures, as a defense mechanism to protect the fruit tissues from chilling injury. It is also important to note that vitamin C is more stable in an acid medium (Lee & Kader, 2000). Therefore, the maintenance of the vitamin C content in feijoa could have been favored by the low pH values of the fruits (Table 2).

The feijoa fruits showed a short postharvest life due to the occurrence of physicochemical changes, which led to flesh darkening and losses in quality-related attributes, such as texture, taste, and aroma (Tables 2, 3, and 4). However, the feijoa genotypes differed regarding the postharvest preservation of quality attributes. For all genotypes, the vitamin C content in the skin was higher (~28%) than that in the flesh, and increased in both tissues after refrigerated storage, i.e., by 22.4% in the skin and 24.1% in the flesh (Table 5). Since the skin is a portion of the feijoa fruit which is not traditionally consumed, further studies are required to determine the presence of other minerals and functional compounds in it, as well as to develop technologies to facilitate its use in food products.

Conclusions

1. Feijoa (*Acca sellowiana*) fruits exhibit flesh darkening and a rapid reduction in titratable acidity and loss in texture during cold storage at 4±1°C for 21 days, followed by exposure to ambient temperature of 23±2°C for two days.

2. Fruits of the Nonante and Mattos cultivars show better preservation of texture, and fruits of Nonante exhibit less flesh darkening during storage, with higher postharvest potential.

3. The vitamin C content in the skin is higher than that in the flesh of feijoa fruits, and, during cold storage, vitamin C contents increase in both tissues.

4. The highest vitamin C contents are found in the skin and flesh tissues of the fruits of the Alcântara cultivar.

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