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Chapter 1

# An Overview on Cagaita (*Eugenia dysenterica* DC) Macro and Micro Components and a Technological Approach

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Additional information is available at the end of the chapter

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## 1. Introduction

Many fruit species native to the Brazilian Cerrado region have great economic and ecological potential, as well as social importance to the native population (Bezerra, Silva, Ferreira, Ferri, & Santos, 2002). These fruits often supplement the diet and are a source of medicine, textile fibers, building materials and fuel. The development of new technologies may result in these fruits becoming potential sources of economic exploitation (Martinotto, Soares, Santos, & Nogueira, 2008).

The Cerrado region has an abundance of species of fruit, still underused by local communities for scientific unknown and lack of incentive for marketing (Veira, Costa, Silva, Ferreira & Sano, 2006). The sustainable use of these species can be an excellent alternative to add value to raw materials available in the Cerrado region and improve the health of the population, thereby contributing to the income of rural communities and encouraging the conservation of native species.

The cagaita tree, belongs to the Myrtaceae family of plants, consisting of 14 genera and represented by 211 species that naturally occur in the Cerrado. Myrtaceae is one of 10 plant

families found in this biome or ecosystem that together contribute to more than 51% of its richness. The cagaita is found in the Brazilian states of Goias, Minas Gerais, São Paulo, Tocantins and Bahia (Silva, Chaves, &Naves, & 2001). It occurs at highest densities in latosoil and is observed in areas with mean annual temperatures between 21.1°C and 25.5°C and at altitudes of 380 m to 1100 m (Souza, Naves, Carneiro, Leandro & Borges, 2002).

The cagaiteira, is a medium-sized tree, is 30 m tall, and has a cylindrical and twisted trunk, ranging from 20 cm to 40 cm in diameter. Its suberous bark and crevices are very unique. Its crown is long and dense, with square hairless branches, and except for the buttons, the pedicels, leaves and young branches are puberula. It is a deciduous plant and is selectively heliophytic and xerophilous (Donadio, Môro, & Servidone, 2002).

Flowering occurs in the middle of the dry season, from mid-July to early August, with the simultaneous emergence of new leaves of the cuprea (Fig.1) (Brito, Pereira, Pereira, & Ribeiro, 2003). The cagaiteira's flowers are always axillary and are either singular or clustered in arrays of three. They are hermaphrodites, and complete, are from 1.5 to 2 cm in diameter, actinomorphic, dialipetalous, dialisepalous, tetramerous, and are endowed with white petals (Lorenzi, 2000).

**Figure 1.** Cagaiteira flower and branches with flowers Source: www.plantasonya.com.br.

The cagaita tree can be used almost entirely, bringing its economic value, and the great potential for sustained exploration (Table 1).

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| Feature | Utility | References |
|---|---|---|
| Tree | Ornamental landescape | Martinottoet al., 2008 |
| Flowers | Apiculture | Lorenzi, 2002 |
| Stalk | Construction, furniture, pallets, firewood and charcoal | Chaves & Telles, 2006; Martinotto et al., 2008 |
| Shell | Tannery, antidiarrheal | Lorenzi, 2002; Chaves & Telles, 2006; Martinotto et al., 2008 |
| Leaves | Lawn trees, antidiarrhoeal, antifungal, moluscocida and treatment of diabetes and jaundice | Chaves & Telles, 2006; Martinotto et al., 2008 |

**Table 1.** Forms of exploitation and use of *Eugenia dysenterica* DC.

The cagaiteira has a great potential for use in agricultural production systems, because it has high production and relatively stable over the years, the potential of the fruit to processed products, good living with pasture, high tolerance to drought, edaphic and biotic stress, fire resistance and ease of production by seed and seedling establishment in the field among other factors (Veira, Costa, Silva, Ferreira & Sano, 2006).

According to Zucchi, Brondani and Pinheiro (2003), the cagaita fruit is a flattened and globular pale yellow berry, 2 to 3 cm in diameter, containing from 1 to 3 white seeds that are encased in a slightly acidic pulp (Fig. 2). These seeds are attached to the fruit by a dry, membranous mesocarp, although the endocarp is juicy. The seeds are globular in shape, pale yellow when ripe, with an acidic flavor and weigh between 14 to 20 g (Silva, Chaves, & Naves, 2001).

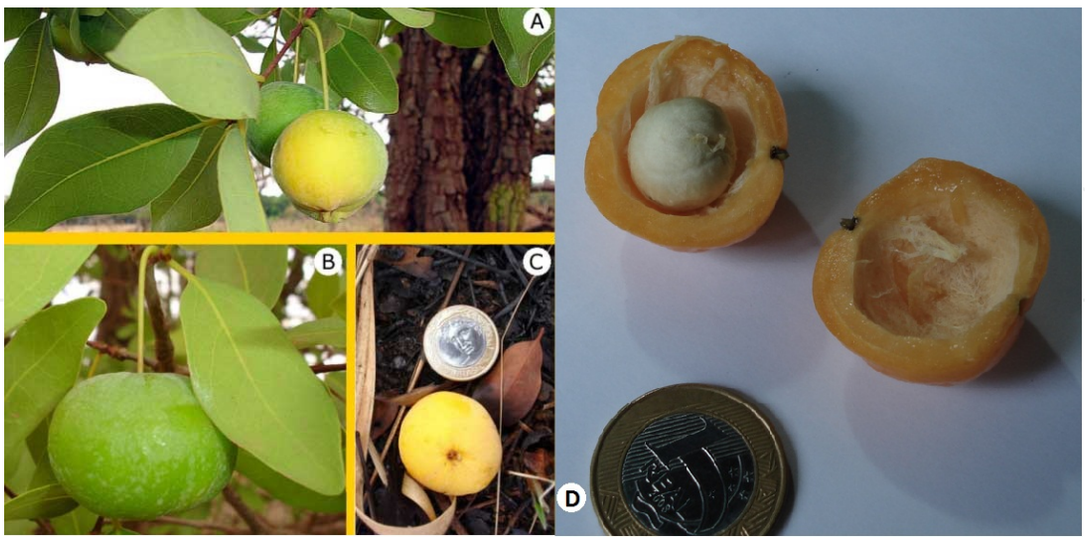


**Figure 2.** Cagaita fruit (*Eugenia dysenterica* DC): A – unripe; B – imature; C – ripefruit; D – Fruit with the seed (Source: Tatagiba, 2012; Stolfi, 2012).

## 2. Cagaita pulp process

The mature fruits of cagaita (*Eugenia dysenterica*) are harvested by hand. After cleaning (immersion in sodium hypochlorite 200 ppm) and selection, the fruits are depulped, packed in polyethylene bags, and freezing and stored at -18 °C (Fig. 3).

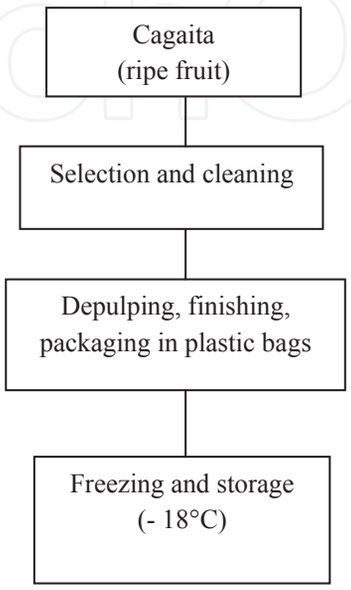


**Figure 3.** Whole cagaita pulp process (Cardoso et, 2011)

## 3. Nutritional and proximal composition

Studies have shown that the cagaita fruit's nutritional composition indicates a high water content (95.01%). It has the highest percentage of polyunsaturated fatty acids (such as linoleic (10.5%) and linolenic acids (11.86%)), surpassing corn, sunflower, peanut, soybean, olive and palm oils. Fatty acids play an important role in the human body, forming the basis of substances that are critical for developing cell membranes found in the brain, the retina and the reproductive system (Almeida, 1998).

Carvalho et al. (2010) found the moisture content of cagaita pulp to measure 94.12%, the titratable acidity at 13.78 g $m^{-1}$ and a pH of 3.05. These values are higher than other fruits of the same genera, such as the pitanga and jambo. Conversely, the ash and protein contents are lower than the jambo and pitanga (Oliveira, Figueiredo, & Queiroz, 2006). Similarly, Ribeiro (2011) evaluated the proximal composition of the cagaita pulp that was extracted with and without peels. The test results for moisture, ash, protein, lipids and carbohydrates (by difference – NIFEXT) for this pulp (with and without peels) varied from 90.08 to 88.55 g•100$g^{-1}$; 0.25 to 0.33 g•100$g^{-1}$; 1.85 to 2.03 g•100$g^{-1}$; 0.20 to 0.36 g 100$g^{-1}$ and 7.62 to 8.73 g 100$g^{-1}$, respectively. The titratable acidity, pH and soluble solids ranged from 13.78 to 14.63

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g.100ml$^{-1}$; 2.90 to 2.69 and 8.20 to 8.70°Brix, respectively, leading to the conclusion that removing the peel results in a reduction of carbohydrate content such that some remains in it after extracting the juice. Silva, Lacerda, Santos, and Martins (2008) found 20.01 TEV (Energy Total Value), 94.34 (moisture); protein 0.82; lipids 0.44; carbohydrates 3.08 and ash 0.28 g m$^{-1}$ in the cagaita pulp. The authors did not mention whether the pulp was obtained with or without peels.

In cagaita pulp extracted with the peels, Roesler et al., (2007) found 2.09 (proteins); 0.32 (lipids); 0.23 (ash); 89.71 (moisture); 20.47 (total sugars) pH of 2.8 and 26.4 (total acidity). Cardoso et al., (2011) found 0.73 g of citric acid 100g$^{-1}$, pH of 3.3 and soluble solids of 9.12°Brix in cagaita pulp from the Cerrado region of the state of Minas Gerais. Moisture content was 91.56 g 100g$^{-1}$, with similar results found by Roesler et al. (2007) in cagaita pulp from the Cerrado region within the Goias state.

Silva, Santos-Junior and Ferreira (2008) investigated the cagaita fruit at different stages of maturation; however, the results for the moisture did not differ significantly, ranging from 92.77 to 93.21 g 100g$^{-1}$.

From the results obtained by Ribeiro (2011), one can conclude that the cagaita fruit, with or without peels, is basically made up of carbohydrates and water. As expected, the moisture content in pulp extracted without peels was higher than the moisture content in pulp with peels. This was because the latter contained peels and the former was essentially pulp with a high water content. The value for cagaita pulp without peels was 90.08 g 100g-1 and the pulp with peels was 88.55 g 100g-1. However, no significant difference ($P < 0.05$) was found. Removing the peels yields a reduction in carbohydrate content, although some remains in it after extracting the juice.

Other researchers studying the cagaita fruit obtained similar results. Roesler et al., (2007) evaluated only the pulp, obtaining 89.71%. Silva, Santos-Junior & Ferreira (2008) investigated the fruit at different stages of maturation, however, the results for the moisture content did not differ significantly, ranging from 92.77 to 93.21 g 100 g$^{-1}$.

Martins (2006) found a carbohydrate content of 5.4 g 100 g$^{-1}$, which was lower than that recorded by Ribeiro (2011), at 7.62 and 8.73 g 100 g$^{-1}$. These results may be related to the geographic location of the analyzed fruits. For example, the temperature, sun exposure and maturity, among other factors, may have had an effect on the results.

Due to its low lipid content, the cagaita fruit is recommended as part of a low calorie diet. The values found by Ribeiro (2011) varied from 0.20 to 0.36 g 100 g$^{-1}$ for pulp extracted with and without peels. Those values were similar to those reported by Martins (2006) and Roesler et al., (2007), being 0.20 and 0.32 g 100 g$^{-1}$, respectively. It is worth noting that this was the only parameter that did not yield a significant difference in the 5% level of significance, showing a higher content of lipids in the peels of the fruit.

Vallilo, Garbelotti, Oliveira, and Lamardo (2005) evaluated other Myrtaceae fruits and found similar low values of lipids: 0.23 g 100 g$^{-1}$ in Surinam cherry (*Eugenia uniflora* L), 1.53 g 100 g$^{-1}$ in cambuci (*Campomanesia phaea* Berg), 0.80 g 100 g$^{-1}$ pears in the field (*Eugenia klotzchiana* Berg) and 0.54 g 100 g$^{-1}$ in guava (*Psidium guajava*).

The protein levels were low; although, as expected, they were higher in the fruit with their peels (2.03 g 100 $g^{-1}$) than in peeled fruits (1.85 g 100 $g^{-1}$). Some studies with the same result found similar values: 2.09 g 100 $g^{-1}$ for the whole pulp (Roesler et al., 2007) and 0.99 g 100 $g^{-1}$ in cagaita pulp (Martins, 2006).

In another study of guava, cited later in this paper, Gutiérrez, Mitchell, and Solis (2008), reviewed the fruit in relation to its protein content of 0.88%.

It can be concluded that the cagaita fruit is not high-caloric due to its low levels of protein, carbohydrates, and especially lipids.

## 4. Glucose, fructose and sucrose

Carvalho et al. (2009) and Ribeiro (2011) found a high concentration of fructose (2.54 g 100 $mL^{-1}$), followed by glucose (1.75 g 100 $mL^{-1}$) and the lowest concentration of sucrose (0.59 g 100 $mL^{-1}$) ($P$ >0.05) (Fig. 4). The high fructose content can be explained by the fact that the cagaita fruit used in their study was fully ripened.

Many different factors could have contributed to the low soluble sugar content in the cagaita pulp. One factor is mineral fertilization, where potassium is the primary mineral element causing starch accumulation in Citrus leaves (Lavon, Goldschmidt, Salomon, & Frank, 1995). On the other hand, the shortage of free sugars may trigger ethylene synthesis because defoliation, which drastically reduces sucrose transport to the fruit, increases ethylene synthesis (Ortolá, Monerri, & Guardiola, 2007) and 1-aminocyclopropane-1-carboxylic acid (ACC) accumulation (Gómez-Cadenas, Mehouachi, Tadeo, Primo-Millo, & Talón, 2000).

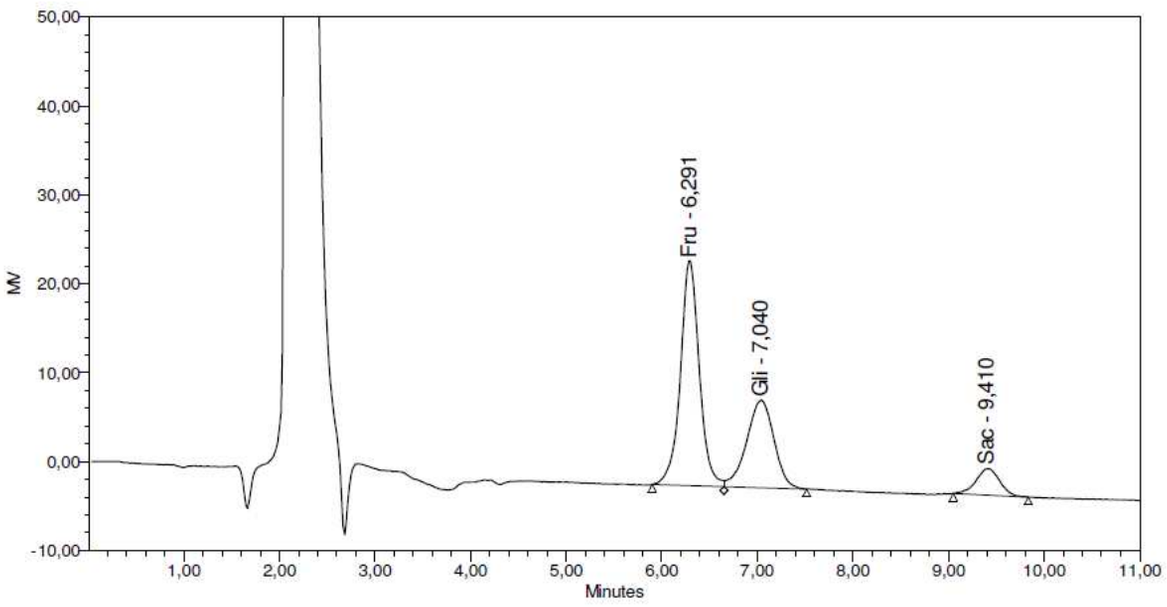


**Figure 4.** HPLC chromatogram of glucose, frutose and sucrose in whole cagaita pulp.

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The low glucose, fructose and sucrose values in the cagaita indicate that this fruit is less sweet and contains less sugar than the guava, for example. This comparison has been verified by Lee & Kader (2000). Analyzing the fruits by High Performance Liquid Chromatography (HPLC), their study found higher values in the ripe guava pulp (11.52 g.100 $ml^{-1}$ of sucrose, fructose 11.37 g.100 $ml^{-1}$ and, glucose 5.12 g.100 $ml^{-1}$.

## 5. Ascorbic acid (vitamin C)

According to Andrade, Diniz, Neves & Nóbrega (2002), the sources of ascorbic acid are classified by different levels: high sources, such as strawberry, guava and pineapple, contain 100 to 300 mg•100 $g^{-1}$; medium sources, such as orange, lemon and papaya contain an average of 50 to 100 mg•100 $g^{-1}$; and low sources, such as lime, pear and mango, contain 25 to 50 mg•100 $g^{-1}$. The vitamin C content in cagaita pulp as reported by Ribeiro (2011) was 56.66 mg 100 g-1 (Fig. 5) and by Cardoso et al. (2011), it was 34.11 mg 100 $g^{-1}$, with 30.03 mg 100 $g^{-1}$ of ascorbic acid and 4.08 mg 100 $g^{-1}$ of de-hydro ascorbic acid. Therefore, the cagaita can be classified as a medium source of ascorbic acid. The pulp of the cagaita fruit has shown considerable promise for its vitamin C content and is considered a source of that nutrient when compared to other fruit. Silva, Santos-Junior, and Ferreira (2008) found the level of vitamin C to be 27.46 mg 100 $g^{-1}$ in cagaita pulp from the Cerrado region in the state of Goias.

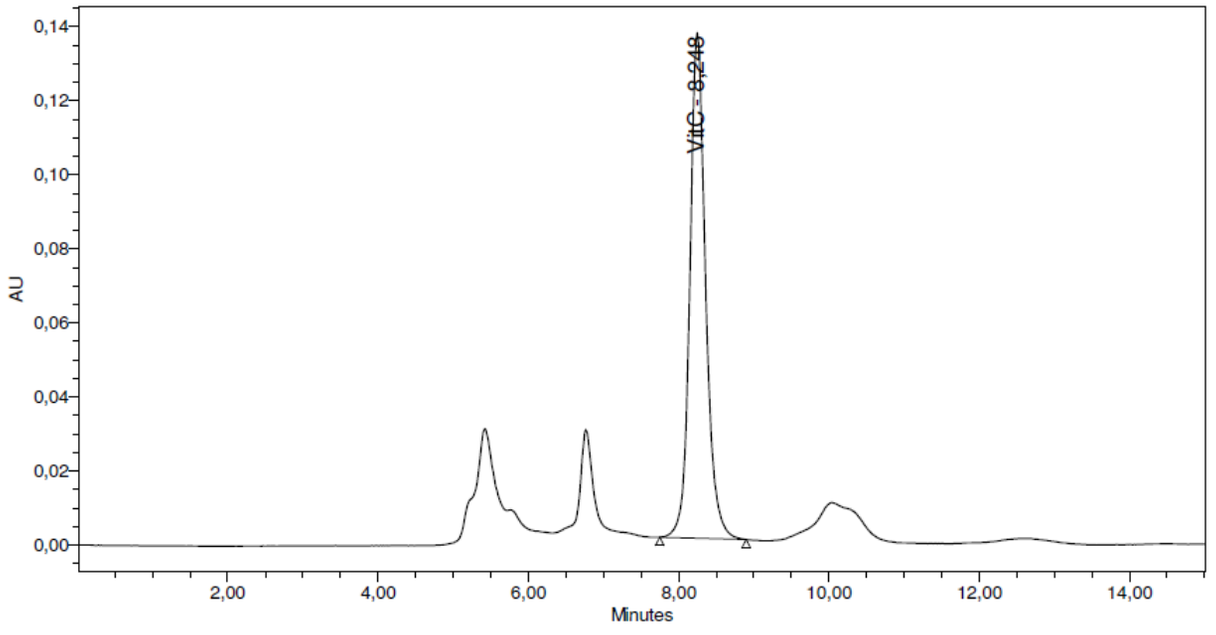


**Figure 5.** HPLC chromatogram of ascorbic acid in whole cagaita pulp.

On the other hand, the National Sanitary Surveillance Agency (ANVISA) legislation (Brazil, 1998) recommends that for a food to be considered a "source" of a certain vitamin, it should contain, at least, 15% of the Recommended Daily Intake (RDI) per 100 g of reference. To be

considered "rich" in a vitamin, it should contain at least 30% of the RDI. Therefore, the cagaita can be categorized as rich in vitamin C because it exceeds 30% of the RDI (US National Academy of Sciences, 2000).

The ascorbic acid content of 26 kinds of exotic fruits from a variety of species and families were evaluated by Valente, Albuquerque, Sanches-Silva and Costa (2011). The results ranged from 1.42 to 117 mg 100 $g^{-1}$, and those fruits that had values similar to cagaita were guava (*Psidium guajava*) with 65.8 mg 100 $g^{-1}$, kiwi (*Actinidia chinensis* Planch), cv. Hayward with 55.2 mg 100 $g^{-1}$, papaya (*Carica papaya*), cv. Taiwan with 64.2 mg 100 $g^{-1}$ and mango (*Mangifera indica* L), cv. Palmer, with 40.9 mg 100 $g^{-1}$, among others.

## 6. Polyphenols compounds

In general, phenolic compounds behaving as antioxidants are multifunctional, achieving bioactivity in several ways: fighting free radicals by donating a hydrogen atom from a hydroxyl group (OH) of their aromatic structure; chelating transition metals, such as the $Fe^{2+}$ and $Cu^{+}$; interrupting the propagation reaction of free radicals in lipid oxidation; modifying the redox potential of the medium and repairing the damage in molecules attacked by free radicals (Podsedek, 2007; Kyungmi & Ebel, 2008). These same phenolic compounds also block the action of specific enzymes that cause inflammation, modify the metabolic pathways of prostaglandins, permit platelet clumping and inhibit activation of carcinogens (Liu, 2005; Valko et al., 2007).

Historically, like tannins, phenolic compounds were classified as anti-nutrients, which have demonstrated adverse effects on human metabolism. However, identifying the specific properties of these phenolic compounds has stimulated the development of research aimed at identifying their potential health benefits (Kaur & Kapoor, 2001).

It is worth noting that a substance can be defined as polyphenolic antioxidant if it meets two conditions: (1) presence at a low concentration on the substrate to be oxidized (and this may delay or prevent oxidation), and (2) high stability of radicals formed after the reaction (Kaur & Kapoor, 2001).

Several spectrophotometric methods have been developed for the quantification of phenolic compounds in foods. The most commonly used by the scientific community is the Folin-Ciocalteau method, which involves the oxidation of phenol with a reagent and yellow phosphomolybdate heteropolyacid phosphotungsten (Folin-Ciocalteau) and colorimetric measurement of W-Mo blue complex formed in reaction in an alkaline medium (Singleton, Orthof, & Lamuel-Raventos, 1999). The results are expressed in gallic acid equivalents.

Some results of the polyphenols content in ethanolic (18.38 g GAE $kg^{-1}$) and aqueous (16.23 g GAE $kg^{-1}$) extracts of cagaita pulp were reported by Roesler et al. (2007). The content of the total phenolics in cagaita pulp was evaluated by Ribeiro et al. (2011) who found 10.51 mg GA g-1 in pulp with peels and, in the pulp without peels, found 9.01 mg gallic acid g-1.

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Therefore, no significant difference was found at a 5% level between them. Thus, the cagaita fruit was found to have high total phenolic compounds.

## 7. Antioxidant capacity

Determining the antioxidant activity of foods, in addition to recognizing its antioxidant potential before being consumed, is important to assess the defense against oxidation and degradation reactions that can lead to the degradation of its quality and nutritional value (Lima, 2008). Currently, there are no approved or standard methods for the determination of antioxidant activity. However, several *in vitro* methods have been and are being tested to evaluate the total antioxidant activity of substances and foods, especially in complex matrices such as wine, fruits and other vegetables. These methods are necessary because of the difficulty in comparing and measuring each compound separately and also because of the potential interactions between different antioxidants in the system. (Cao & Prior, 1999; Kulkarni, Aradhya, & Divakar, 2004; Scherer & Godoy, 2009).

The methods most often cited in the literature include the antioxidant power in the reduction of iron (FRAP), DPPH (radical 2,2-diphenyl-1-picrihidrazil) Activity of Oxygen Radical Absorption (ORAC), ABTS [acid 2,2 - Azin-bis (3-ethylbenzothiazoline) – 6 - sulfonic acid Spectrometry and Electron Spin Resonance (ESR) (Kulkarni, Aradhya and Divakar, 2004; Lima, 2008).

While evaluating the efficiency of using methanol and ethanol as solvents to determine the antioxidant activity in cagaita pulp (Ribeiro et al., 2011) found that the amount of ethanol ranged between 6.6% and 96.82% and that of methanol ranged between 11.20% and 92.60%, in different concentrations. It was also shown that the cagaita pulp reached its maximum value at a concentration of 500 $\mu g\ ml^{-1}$, in both cases.

Roesler et al. (2007) found the antioxidant activity ($IC_{50}$) in cagaita pulp extracted with peels to measure 387.47 mg $ml^{-1}$ in the ethanolic extract and 879.33 mg $ml^{-1}$ in the aqueous extract.

## 8. Carotenoids

Gomes et al. (2011) measured the total carotenoid content in the whole cagaita pulp and also in the freeze-dried pulp and found 0.87 and 9.29 mg 100 $g^{-1}$, respectively (Table 2 and Fig. 6). Lutein was the most abundant carotenoid in the whole and freeze-dried pulps (0.21 and 2.22 mg 100 $g^{-1}$, respectively), followed by zeaxanthin (0.19 and 2.05 mg 100 $g^{-1}$, respectively) and β-carotene (0.11 and 1.33 mg 100 $g^{-1}$, respectively).

According to these results, cagaita may be a source of lutein and zeaxanthin (which are natural antioxidants), particularly in freeze-dried pulp. By microencapsulating the freeze-dried pulp, it can become a beneficial food additive because cagaita pulp is widely consumed in the Brazilian Cerrado.

| Samples | Total Carotenoids | β-carotene | 9-cis-β-carotene | 13-cis-β-carotene | β-criptoxantin | α-carotene | Lutein | Zeaxanthin |
|---|---|---|---|---|---|---|---|---|
| Whole Pulp | 8.22 ± 0.06 | 0.97 ± 0.08 | Nd | Nd | 0.35 ± 0.01 | Nd | 1.81 ± 0.12 | 1.99 ± 0.05 |
| Saponified Whole Pulp | 5.83 ± 0.52 | 1.70 ± 0.18 | 0.20 ± 0.01 | 0.09 ± 0.01 | 1.49 ± 0.11 | 0.18 ± 0.16 | 0.85 ± 0.01 | 0.79 ± 0.02 |

Source: Gomes, 2012

**Table 2.** Carotenoids (μg/g) and isomers of saponified and not saponified cagaita pulp

Lutein can be found in a variety of vegetables and is especially plentiful in cabbage (15 mg 100 $g^{-1}$), parsley (10.82 mg 100 $g^{-1}$), spinach (9.20 mg 100 $g^{-1}$) and pumpkin (2.40 mg 100 $g^{-1}$). However, it is found in lower concentrations in fruits such as peach and orange (0.02 and 0.35 mg 100 $g^{-1}$, respectively).

Gomes (2012) identified $\alpha$-carotene, β-carotene isomers and 9:13-cis β-carotene, β-cryptoxanthin, lutein and zeaxanthin in the pulp produced in cagaita Damianópolis, Goias, Brazil (Fig. 6).

The β-carotene and β-cryptoxanthin the most abundant carotenoids, lutein and zeaxanthin and the carotenoids intermediate, and the $\alpha$-carotene carotenoid the minority (Table 2).

There were significant differences in levels of total carotenoids according to the saponification step. The hydrolysis step was necessary to facilitate the identification of different carotenoids. The average concentration of total carotenoids found in the extracted pulp without the saponification step was 8.22 mg / g. There was a 29% decrease in total carotenoid content of the pulp subjected to saponification step (5.83 μ / g ± 0.18). This drop was expected and may occur as a function of temperature application of tests, and also by the exposure time of the pigment to the alkali (Mercadante, 1999; Penteado, 2003).

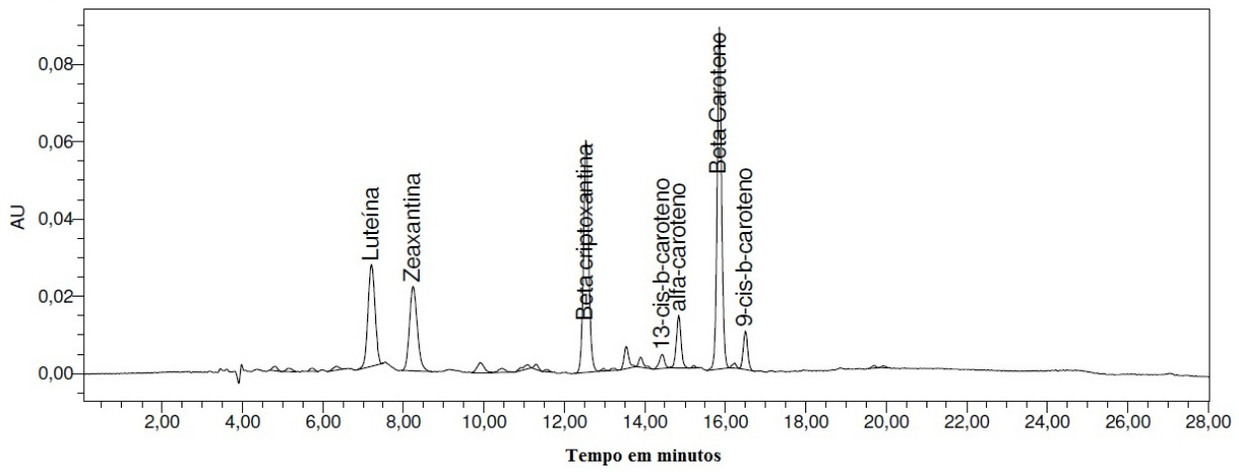


**Figure 6.** HPLC chromatogram of saponified cagaita pulp. Source: Gomes, 2012

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Cardoso et al. (2011) found a lower total carotenoid content (0.77 mg100 $g^{-1}$) in the cagaita pulp from the Cerrado in the state of Minas Gerais. The major carotenoids were the $\alpha$--carotene (0.31 mg 100 $g^{-1}$) and β-carotene (0.39 mg 100 $g^{-1}$) provitamin A carotenoids. They still found a small quantity of lycopene (0.06 mg100 $g^{-1}$), however lutein and zeaxanthin were not found.

## 9. Minerals

According to Carvalho et al. (2009), the most abundant mineral found in the cagaita pulp was potassium (75.83 mg 100 $g^{-1}$), followed by sodium (6.80 mg 100 $g^{-1}$), phosphorus (6.68 mg 100 $g^{-1}$) and magnesium (5.92 mg 100 $g^{-1}$). The levels of zinc were lower (0.23 mg 100 $g^{-1}$), as were the levels of iron (0.06 mg 100 $g^{-1}$) and calcium (0.65 mg 100 $g^{-1}$) (Table 1). Higher values of calcium (0.8 mg 100 $g^{-1}$) and, similarly, iron (0.04 mg 100 $g^{-1}$) were found by Silva, Santos-Junior Junior, and Ferreira (2008) in the cagaita pulp, but zinc was not found at higher levels. Leterme, Buldgen, Estrada, and Londoño (2006), in analyzing the fruits of araçáboi (belonging to the same family and genus as the cagaita), found similar values: 78 mg 100 $g^{-1}$ (potassium), 7 mg 100 $g^{-1}$ (phosphorus), 2 mg 100 $g^{-1}$ (sodium) and 9 mg 100 $g^{-1}$ (magnesium), respectively.

| Mineral | mg/100g | Mineral | mg/100g |
|---|---|---|---|
| **Potassium** | 75.83 (± 0.43) | **Aluminum** | 0.23 (± 0.06) |
| **Phosphorus** | 6.68 (± 0.14) | **Zinc** | 0.23 (± 001) |
| **Sodium** | 6.80 (± 0.13) | **Manganese** | 0.13 (± 0.01) |
| **Magnesium** | 5.92 (± 0.08) | **Iron** | 0.06 (± 0.01) |
| **Calcium** | 0.65 (± 0.08) | **Copper** | 0.01 (± 0.01) |

Mean Value (± Standard deviation (n = 3)). Source: Carvalho et al., 2009

**Table 3.** Minerals in the unpeeled cagaita pulp (*Eugenia dysenterica* DC).

Comparing the cagaita (*Eugenia dysenterica* DC) to the results of the study by Dembitsky et al. (2011), in which different fruits were analyzed, confirms that the acerola (*Malpighia punicifolia* Linn) contains lower amounts of potassium (41 mg/100 g), zinc (0.09 mg/100 g) and manganese (0.7 mg 100 $g^{-1}$) and much higher amounts of calcium (4 mg 100 $g^{-1}$), iron (37 mg 100 $g^{-1}$) and magnesium (22 mg 100 $g^{-1}$).

While analyzing the fruits of guava-boi (*Eugenia stipit*ata Mark Vaughn) that belong to the same family and genus as the cagaita, Leterme, Buldgen, Estrada, and Londoño (2006) found similar amounts: 78 mg 100 $g^{-1}$ of potassium, phosphorus 7mg 100 $g^{-1}$, mg 100 $g^{-1}$, 2 mg 100 $g^{-1}$ and 9 mg 100 $g^{-1}$ of sodium and magnesium. These variations could be due to climatic conditions, soil type and the addition of fertilizers, for example.

## 10. Volatile compounds

Volatile compounds are responsible for the aroma and flavor of foods. The same fruit, even if native to Brazil, can vary greatly from region to region, with different varieties having a dissimilar volatile composition (Alves & Franco, 2003). The methods used for the extraction of volatile substances are time-consuming, requiring large amounts of sample (Sánchez-Palomo, Díaz-Maroto, & Pérez-Coello, 2005). Solid-phase Microextraction (SPME) is a fast, low-cost technique that allows the extraction of volatile substances that can then be analyzed by gas chromatography coupled to mass spectrophotometry (GC/MS). This technique replaces traditional extraction methods, avoiding the formation of artifacts without the need for solvents, thereby minimizing artifact formation (Pawliszyn, 1997; Riu-Aumatell, Castellari, & López-Tamames, 2004).

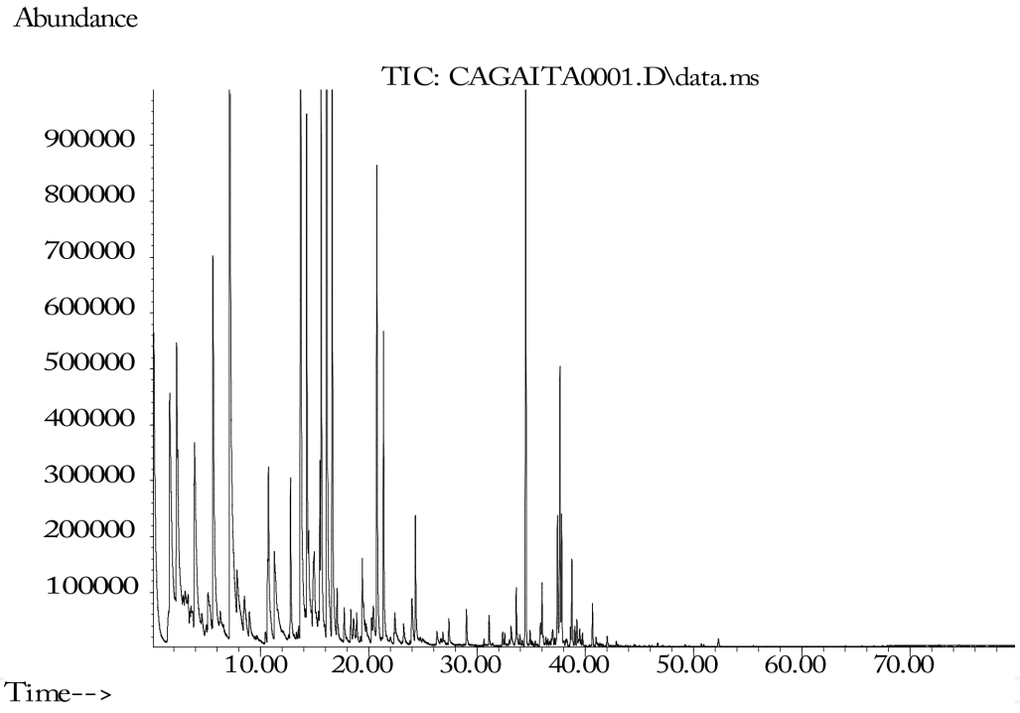


**Figure 7.** Chromatogram of the cagaita pulp volatile compounds. Source: Cardoso et al, (2011).

Fifty six volatile compounds were found in cagaita pulp extracted by solid phase micro-extraction and were analyzed by GC/MS. Among them, 19 could not be identified by Carvalho et al. (2009). Ethyl hexanoate was the most abundant compound in the cagaita pulp (51.4%), followed by the ethyl butanoate (14.7%), which also imparts the fruity aroma of the fruit juices and pulp. The results revealed that a greater concentration of esters, mainly methyl, ethyl hexanoate (6.5%) and butanoate, are responsible for the fruity aroma. Alcohols and terpenes were present at low concentrations, with ethanol being the most abundant (3.0%). These volatile compounds were also found in pineapple, apple and papaya, among other fruits (Van Den Dool, & Kratz, 1963; Adams, 1972). Alves and Franco (2003) also identified some major com-

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pounds in murici, finding esters and alcohols. Ethanol (28.1%), ethyl hexanoate (25.1%) and methyl hexanoate (5.2%) were the major components. However, they reported that the high ethanol levels could be due to fermentation following maturation. Because no other authors reported these compounds, it is not possible to compare the reported results. A typical total ion chromatogram obtained from the cagaita pulp analysis is presented in Figure 7.

It is noteworthy that this is the first time that volatile compounds have been found in cagaita fruit from the Cerrado region in Goias.

## 11. Membrane processes applied to cagaita pulp

The consumption of fruit juice in Brazil and in the industrialized world has increased significantly in recent decades. Using fruit juice or pulp that has been clarified by the membrane processes of microfiltration is already a reality in the international market. The cagaita pulp can be introduced as a new product used in the formulation of carbonated beverages, energy and isotonic drinks. The demand for products with less nutritional and sensory changes led to the development of non-thermal preservation techniques such as the process of membrane separation. The membrane separation process is based on the selective permeability of one or more components through a membrane. The determination of the hydraulic permeability is an important tool in evaluating the permeate flux and the integrity of the membrane. Cardoso et al., (2011) evaluated the cagaita pulp clarified by microfiltration with a tubular polyethersulfone membrane (0.3 μm) at 2 Bar (Fig. 8). A mean flux after 2 hours process was 20 L./$m^2$ h. and the clarified juice yield was 43%. The results for the flux of the juice permeate were acceptable and the permeate was clear and translucent.

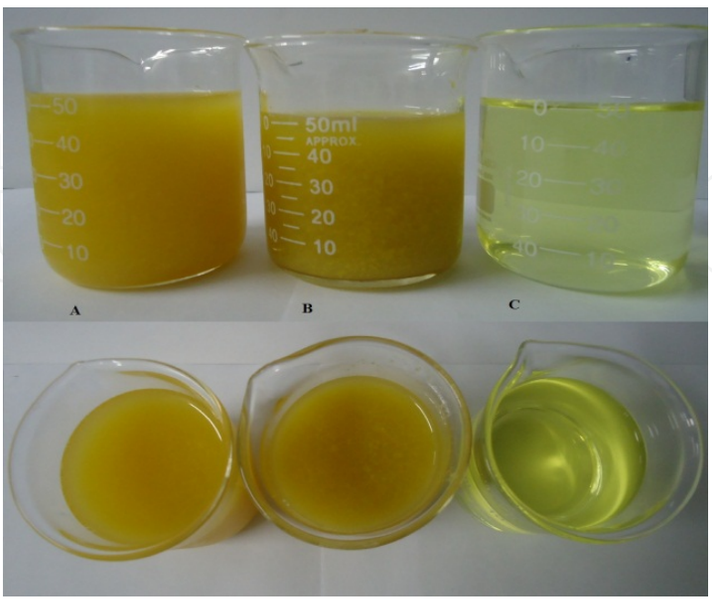


**Figure 8.** Cagaita pulps (*Eugenia dysenterica* DC): A – Whole, B – Concentrated e C – Clarified. (Cardoso et al., 2011).

## 12. Microbiological quality

Microbiological studies of cagaita pulp revealed no growth of microorganisms. Coliforms at 45°C, were indicative of its tolerance to sample $10^2$ CFU (colony forming units) as was the absence of salmonella in 25 g of the sample (Carvalho et al., 2009). Therefore, the analyzed pulps were found fit for human consumption because they were in accordance with standards established by ANVISA (Brasil, 1998).

| Samples | Total Coliforms (UFC/mL) | Thermotolerant Coliforms (UFC/mL) | Yeast and Mold (UFC/mL) | *Salmonella* sp. (Absence 25 g or mL) |
|---|---|---|---|---|
| WCP | < 10 | < 10 | < 10 | Absence |
| RCP | < 10 | < 10 | < 10 | Absence |
| CCP | < 10 | < 10 | < 10 | Absence |

WCP: Whole Cagaita Pulp; RCP: Retentate Cagaita Pulp; CCP: Clarified Cagaita Pulp

**Table 4.** Microbiological analysis of whole, retentate and clarified cagaita pulp.

## 13. Particle size of the cagaita pulp

Particle size analysis is an important tool to observe the enzymatic hydrolysis and the particle size reduction in order to optimize the membrane pore size before clarification processes.

Particle size analysis can be an useful tool to observe particle size reduction during enzymatic hydrolysis optimization to reduce juice viscosity. Few studies are found in the literature reporting the use of particle size analysis to observe viscosity decrease in fruit juices.

Laser diffraction analysis was used to evaluate the effects of cloud particle characteristics such as shape, volume fraction, and soluble pectin on the viscosity of cloudy apple juice. Cloudy apple juice results in a suspension of irregular-shaped particles ranging from 0.25 to 0.5 μm in size. Data indicate that the effect of nonspherical particles on cloudy apple juice viscosity can be neglected and soluble pectin can significantly increase the viscosity (Genovese & Lozano, 2000).

The distribution of the average particle diameter, i.e., its frequency as measure by Carvalho et al. (2009 and 2011), was 12.11%, and the average particle diameter within cagaita pulp was 68.17 μm (Fig. 9). The presence of nanoparticles of less than 1 micrometers was still observed, but in low frequency (0.1%).

After enzymatic hydrolysis of lemon juice at different incubation times, Carvalho et al., (2006) evaluated the particle size reduction in prior membrane microfiltration processes in order to obtain better permeate fluxes. The whole lemon juice showed a wide distribution of

particle size ranging from 5 to 900 μm, and the greatest particle size reduction after hydrolysis ranged from 5 to 200 m. There were few particles above this size.

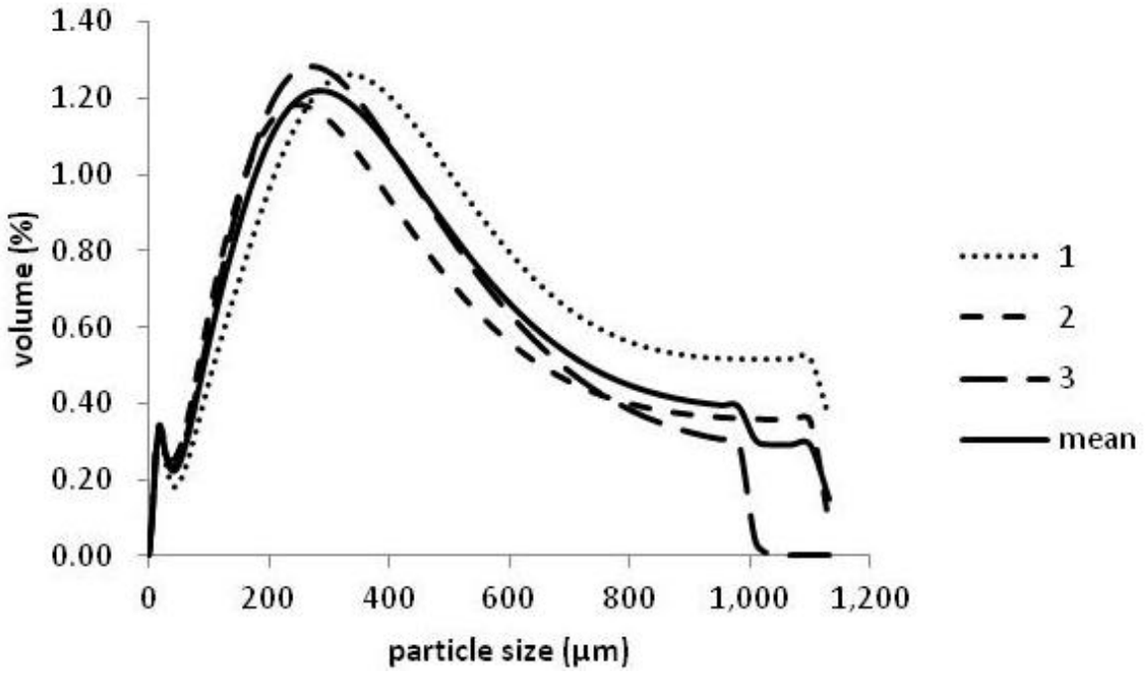


**Figure 9.** Particle size and frequency of cagaita pulp (*Eugenia dysenterica* DC).

## 14. Conclusions and future trends

Based on the results reported by several authors cited in this paper regarding the physical and chemical characteristics of the antioxidant action of the cagaita fruit, one can conclude that there is potential for therapeutic and medicinal applications. Additionally, a variety of new products with beneficial properties, such as jams, juices and energy beverages, can be made from the fruit of the cagaita. Using an established technology such as membrane processing, to acquire clarified juice, and then adding nutrients, offers the potential for another profitable business venture. Because the population of the Brazilian Cerrado region consumes the fruit both, whole or processed by hand, the industrial manufacture of cagaita fruit products is a viable business opportunity, especially considering that most of the production fails to be fully utilized at this time.

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