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Evaluating chemical composition of *Butia capitata* pulp among various populations and locations using multivariate analysis

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There are many native species from Cerrado that are used as food supply. However, their nutritional constitution is still unknown. The objective of this study was to evaluate and quantify the nutritional composition of *coquinho-azedo* fruits, obtained from different regions and populations in Northern Minas Gerais, using multivariate analysis. Ripe fruits of various *B. capitata* populations were obtained from four locations in Northern Minas Gerais. Fruit samples were analyzed for total acidity, total sugars, ascorbic acid, phenolic compounds, antioxidant activity, macro- and microelements. Results show that *Butia capitata* fruits are acidic given that values of titratable acidity ranged from 1.57 to 2.61, and Brix values ranged from 6.6° to 10.00°Bx. The total sugar content was relatively low with the lowest values observed in groups 4, 5 and 8 from Cristália (0.65, 0.75 and 0.78%, respectively). Ascorbic acid content also varied among populations and locations; the highest average (92.43) was observed in group 2 from Cristália and the highest value (821.63 mg/100 g fw) was observed in group 7 from Bonito de Minas. The highest antioxidant activity value (58.39%) was observed in group 7 from Cristália. Multivariate analysis grouped and separated populations that were genetically similar or dissimilar for ascorbic acid, antioxidant activity, total phenolic compounds and total sugars. The nutritional composition of *B. capitata* varied widely according to the sampled site and groups of plants. In general, the fruits contain high amounts of ascorbic acid, potassium and iron.

Key words: Arecaceae, ascorbic acid, antioxidant capacity, dendogram.

INTRODUCTION

Cerrado (Brazilian savannas) is the second largest biome in Brazil, and hosts a wide variety of native species (Klink and Machado, 2005), which are used for various purposes including the production of pharmaceuticals, cosmetics, food and feed (Klink and Machado, 2005; Souza et al., 2012). Native fruits of the Cerrado regions are used locally and they are consumed fresh or processed in jams, jellies, liqueurs and pastries (Almeida et al., 2011). They are very important for local economy because they help farmers and rural worker cooperatives

to generate income. Furthermore, many of these fruits are used in school meals for children.

Butia capitata Mart. Becc is a palm tree belonging to the Arecaceae family. It is native of Cerrado and found in the states of Goiás, Bahia and Minas Gerais (Lorenzi et al., 2010). This fruit is widely consumed in these regions; the fruits are constituted of a drupe oval yellowish, red or purplish epicarp and a yellow, succulent, and fibrous mesocarp (Moura et al., 2008). These are used for fresh consumption or pulp manufacturing, and are marketed regionally, or used for the production of jams, jellies, liqueurs, ice cream and popsicles (Faria et al., 2008).

Nutritional composition of *B. capitata*, similarly to many other native fruits of the Cerrado, has not been studied extensively. Further characterization and quantification of all constituents found in the pulp of this species is necessary. Faria et al. (2008) reported that the levels of ascorbic acid and potassium in pindo palm are higher than those observed in orange. Other species of the *Butia* genus showed high levels of total phenolic compounds and major carotenoids (Jacques et al., 2009).

Fruits are rich in vitamins, antioxidants, minerals and other constituents that are essential for the human body, because they participate in protein biosynthesis, cell regulation, and various processes in composite cells (Slavin and Lloyd, 2012). However, the concentration of these compounds may vary in among locations, because their production is influenced by environmental, edaphic, and genotypic factors (Asensi-Fabado and Munné-Bosch, 2011). Constituents in *B. capitata* may fluctuate significantly due to genotype, because it is a non-native domesticated species, as observed in other palm species. In *Phoenix dactylifera*, the concentration of phenolic compounds and total flavonoids varied among genotypes and locations (Biglari et al., 2008). The chemical composition of *Euterpe precatoria* juice varies due to location (Yuyama et al., 2011). Additionally, fruits of *Acrocomia aculeata* collected in warm regions had relatively higher amounts of reducing sugars, total acidity, and ascorbic acid (Sanjinez-Argandoña and Chuba, 2011).

Multivariate analysis allows an assessment of clustering individuals obtained from different locations. Cluster analysis allows the combination of individuals that are similar into separate groups (Tabachnick and Fidell, 2001). Therefore, it is a numerical methodology that proposes the classificatory structure or recognition of groups' existence. This method of analysis has been employed in various studies that aimed to characterize the bioactive compounds in fruits species, as *Mauritia flexuosa* and *Platonia insignis*. Dendogram clustering and principal component analysis allowed the formation of five distinct groups in a study of 18 fruit species (Barreto et al., 2009). Multivariate analysis was successfully used in *Averrhoa carambola* (Zainudin et al., 2014) and *Polygonum tinctorium* (Kim et al., 2012), as well.

The objective of this study was to evaluate and quantify the nutritional composition of *B. capitata* fruits collected from different populations and regions in Northern Minas Gerais using multivariate analysis.

MATERIALS AND METHODS

Plant material

Fruits of *B. capitata* were collected from four locations in the northern region of Minas Gerais: Abóboras, Mirabela, Bonito de Minas and Cristália. Twenty-four plants from each region were randomly sampled using a global positioning system (Garmin GPS III Plus). The population that had a median age of 25 years was native and economically exploited. Fruits were collected at maturity (yellow epicarp) and individually bagged and packed in polystyrene boxes with ice and transported to the laboratory. Fruits were washed with water and pulp was removed manually, using a stainless knife. Afterwards, it was placed in a plastic container and stored at -80°C in an ultra-freezer. Sub-samples were formed from the mixture of three plants and all analyses were performed three times. All tests were performed at the central laboratory of the Universidade Federal de Lavras (UFLA).

Physicochemical analysis

Physicochemical analysis of pH, titratable acidity (TA) and soluble solids (SS) was performed according to the analytical methods of the Association of Official Analytical Chemists (AOAC, 1992). The pH of pulps was determined by using a pH meter (Schott Handylab pH 11), and the determination of acidity was performed by titration with sodium hydroxide (NaOH) 0.1 N and phenolphthalein, as an indicator (Instituto Adolfo Lutz, 2008). Results were expressed as the percentage of citric acid. Soluble solids were identified by refractometry, using digital refractometer (ATAGO PR-100), previously calibrated with distilled water. Results were expressed in degrees Brix (°Bx). The ratio of soluble solids to titratable acidity (SS/TA) was also computed.

Mineral analysis

Samples of dry and degreased pulp were used for mineral analysis. Each pulp sample (5 g) was ground using stainless steel knives. Knife mill was cleaned after each sample to avoid cross contamination. Minerals such as phosphorus, potassium, magnesium, manganese, copper, zinc and iron were analyzed. Mineral content was determined as described by Malavolta et al. (1997), using atomic absorption spectrometer (Varian SpectrAA 110), calibrated to specific conditions of wavelength, slit and gas mixture for each element. Atomic absorption standards (Merck) were diluted with deionized water and used to construct a standard curve. Values were expressed as the average of three replicates from each sample expressed in mg/100 g of dry matter (DM).

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Total sugars

Total sugars in the mixture of pulp and candy were determined by the Antrona method (Dische, 1962) using a spectrophotometer (Beckman 640 B) at 620 nm. Results were expressed as the percentage (%) of total sugars.

Ascorbic acid

Determination of ascorbic acid in pulps was performed by the colorimetric method using 2,4-dinitrophenylhydrazine, according to Strohecker and Henning (1967). Analysis was performed with a spectrophotometer (Beckman 640 B), using a computerized system, and results expressed in mg of ascorbic acid (mg/100 g) of fresh pulp.

Total phenolic content

Two grams of pulp sample was extracted with 20 mL of 50% methyl alcohol. The mixture was homogenized and placed in the dark for 1 h at room temperature. After this period, the mixture was centrifuged at 14000 rpm for 15 min. The supernatant was collected and stored in flasks. The residue was dissolved in 20 mL of 70% acetone, homogenized and placed in the dark for 1 h at a temperature of 8°C. Then it was centrifuged at 14000 rpm for 15 min. The supernatant was transferred to a volumetric flask and volume adjusted to 50 mL with distilled water (Larrauri et al., 1997; Souza et al., 2012). Determination of total phenolic content was made as described by Kuskoski et al. (2005), using the Folin-Ciocalteu assay (aliquot of 0.5 mL from each sample is mixed with 2.5 ml of 10% Folin-Ciocalteu reagent). The reaction was neutralized with 2 mL of 4% sodium carbonate. Tubes were vortexed and placed in the dark for 2 h. Results were expressed in milligram gallic acid equivalents of 100 g of sample (mg GAE/100 g).

Antioxidant activity

Extracts were obtained following the same procedure used for the determination of total phenolic compounds. Determination of antioxidant activity was based on the extinction of 2,2-diphenyl-1-picryl hydrazyl (DPPH 60 µM) radical absorption, according to Rufino et al. (2009). For the determination of antioxidant activity, 0.1 mL aliquot of each extract was transferred in the dark to test tubes obtaining 3.9 mL of 60 µM DPPH and homogenized by shaking. Reading was performed at 515 nm with a spectrophotometer (Beckman 640 B), using a computerized system and monitored every minute by observing the reduction in absorbance until stabilization. The results were expressed as the percentage (%) of seizure induced free radical (% SFR), according to Equation 1:

$$\%SFR = \frac{(CA - SA)}{CA} \times 100 \quad (1)$$

CA = control absorbance; SA = sample absorbance.

Statistical analysis

Data of ascorbic acid, total phenolic compounds, antioxidant activity, and total sugars in pulp samples were evaluated and the genetic dissimilarity between each pair of individuals was determined using Euclidean distance. The Unweighted Pair Group Method Arithmetic Average (UPGMA) was used to group the genotypes based on their genetic similarity. Principal component analysis (PCA) was also performed for the chemical constituents. All analyses were carried out with Statistica Software 7 (Statsoft, 2007).

RESULTS AND DISCUSSION

The highest pH value was found in group 5 of Mirabela. Groups 3, 4, 6 and 8 had the lowest pH values compared to the other groups or locations (Table 1). Additionally, Brix values were the highest in group 2 of Mirabela (11.6° Bx). In Bonito de Minas, the largest Brix values were observed in groups 1, 4 and 8. The lowest Brix value was found in group 5 of Bonito de Minas (Table 1). In general, the highest acidity values were observed in the population of Cristália, especially in groups 1, 2 and 6. The highest ratio of soluble solids to titratable acidity was found in groups 1, 3 and 5 of Bonito de Minas, while the lowest values were obtained in group 3 of Abóboras (2.62) and Cristália (2.77) (Table 1).

Acidity values found in this study are similar to those reported by Silva et al. (2006). They observed that the pulp of *Butia eriospatha* had an average acidity of 2.20 and 1.91% in Paraná and Santa Catarina, respectively. Average Brix values for *B. capitata* ranged from 6.4 to 7.7°Bx in Santa Catarina and Paraná, and were similar to those found by Silva et al. (2006). In Groups 5 and 8 of Cristália and Bonito de Minas, Brix values were higher than those previously reported (Table 1). The pH of *B. capitata* was higher compared to *B. eriospatha*. The latter had values that ranged from 2.93 in fruits collected from Paraná to 3.06 in those from Santa Catarina (Silva et al., 2006). Results obtained from the analysis of *Acrocomia aculeata*, a palm tree in Cerrado biome, showed that pH and acidity values varied between locations. *A. aculeata* is less acidic compared to *B. capitata*; fruits collected from Presidente Epitácio and Dourados had acidity values of 69 and 0.73% and pH values of 5.7 and 6.9, respectively (Sanjinez-Argandoña and Chuba, 2011). In addition, in *Euterpe oleracea* and *Euterpe edulis,* acidity values were lower compared to *B. capitata*; acidity values were 0.19% in both species, and pH values were 4.84 in *E. oleracea* and 5.0 in *Euterpe edulis*. Brix values of *B. capitata* were higher than those of *E. edulis* and *E. oleracea* (3.03 Bx and 2.7°Bx, respectively) (Ribeiro et al., 2011).

In fruits, organic acids influence the taste, odor, color, stability, and maintenance of quality, because they are intermediate products of the respiratory metabolism. Therefore, acidity is important for determining ripeness and conservation status of the product (Oliveira et al., 1999). A comparative analysis with other palm fruits showed that *B. capitata* had a higher percentage of acidity in juice, which is the fruit's produce most used in the Northern Minas Gerais. The value of pH influences

Table 1. Values of pH, Brix, titratable acidity and soluble solids to titratable acid ratio of *Butia capitata* pulp collected from different populations and locations in Northern Minas Gerais.

Location	Groups of plants							
	G1	G2	G3	G4	G5	G6	G7	G8
pH								
Abóboras	3.39±0.00	3.36±0.10	3.34±0.00	3.41±0.00	3.46±0.00	3.42±0.00	3.36±0.00	3.52±0.00
Mirabela	3.49±0.00	3.49±0.1	3.10±0.00	3.15±0.00	4.00±0.00	3.15±0.00	3.33±0.10	3.14±0.00
Bonito de Minas	3.67±0.00	3.54±0.00	3.53±0.10	3.48±0.00	3.53±0.00	3.41±0.00	3.37±0.00	3.38±0.00
Cristália	3.31±0.00	3.36±0.00	3.36±0.00	3.38±5.40	3.26±0.00	3.22±0.00	3.41±0.00	3.58±0.00
°BRIX								
Abóboras	9.0±0.00	7.0±0.00	6.6±0.50	7.6±0.50	8.0±0.00	8.0±0.00	7.0±0.00	7.0±0.00
Mirabela	7.6±0.50	7.0±1.0	11.6±1.50	7.0±3.0	7.6±0.50	8.6±0.50	9.6±0.50	9.6±0.50
Bonito de Minas	9.6±1.50	8.0±0.00	6.6±0.50	9.0±2.00	6.0±1.00	8.6±0.50	8.0±0.00	10.0±1.0
Cristália	8.6±0.50	8.6±0.50	8.6±0.50	7.6±5.0	10.0±2.0	8.6±1.50	8.6±0.50	6.6±0.50
Titratable acidity (%)								
Abóboras	2.54±0.10	1.96±0.40	2.48±0.00	2.21±0.10	2.02±0.10	2.35±0.30	2.22±0.10	1.96±0.00
Mirabela	2.02±0.10	1.96±0.00	1.96±0.50	2.28±0.20	2.15±0.20	1.83±0.10	1.76±0.20	2.09±0.00
Bonito de Minas	1.70±0.30	1.76±0.20	1.50±0.2	1.76±0.2	1.57±0.0	1.70±0.1	1.96±0.0	1.70±0.0
Cristália	2.61±0.00	2.61±0.00	2.02±0.10	2.15±6.50	2.28±0.10	3.20±0.10	2.54±0.10	2.35±0.30
STT/ATT - ratio								
Abóboras	3.53±0.01	3.67±0.20	2.62±0.10	3.10±0.10	3.95±0.10	3.43±0.40	3.16±0.20	3.57±0.00
Mirabela	3.70±0.10	3.57±0.50	6.31±2.50	3.15±1.60	3.48±0.10	4.65±0.10	5.45±0.90	4.64±0.20
Bonito de Minas	6.58±1.0	6.29±0.70	7.40±1.0	6.29±0.70	7.02±0.00	6.50±0.50	5.61±0.00	6.48±0.00
Cristália	3.25±0.20	3.25±0.20	4.19±0.20	3.47±1.30	4.35±0.80	2.65±0.40	3.33±0.10	2.77±0.10

Mean value ± standard deviation of fruit pulp weight; n = 3; *AB, Abóboras; MI, Mirabela; BM, Bonito de Minas; CR, Cristália.

several factors such as enzyme activity, maintenance of pulp flavor and aroma, food spoilage, and growth of microorganisms in ripe fruit (Oliveira et al., 1999). The ratio of soluble solids to titratable acidity is used as an index of total sugars in fruits, indicating the degree of maturity. Soluble solids consist of water-soluble compounds, as sugars, acids, ascorbic acid, and some pectin (Oliveira et al., 1999).

The percentage of total sugars varied due to location and plant population. The highest values were found in groups 2 and 3 (3.35 and 3.22%, respectively) of Mirabela (Table 2). In Bonito de Minas, the highest value was observed in group 1. The lowest percentages of total sugars were observed in groups 3, 4, 5 and 8 of Cristália (Table 2). The values of total sugars in the pulp of *B. capitata* were up to 7 times lower than those found in *A. aculeate*, collected in Presidente Epitácio (11.58%) and Dourados (14.53%) (Sanjinez-Argandoña and Chuba, 2011). In fruits, as banana, the total sugars ranged from 19.3 to 24.4% depending on the genotype (Cerqueira et al., 2004). In genotype of *Spondia smombin,* values ranged from 6.28 to 11.58% (Pinto et al., 2003). Overall, the pulp had a relatively low amount of sugar compared to other *B. capitata* palm trees or other species.

The content of ascorbic acid was higher in group 2 of Cristália (Table 2). In Abóboras, the highest means were found in Groups 5 and 7, while in Mirabela these were observed in group 7. Groups 6 and 7 had low amounts of carbohydrate, which were 32.40 and 38.03 mg/100 g fw, respectively. According to Ramful et al. (2011), fruits can be classified into three categories with respect to the amount of ascorbic acid: low (<30 mg/100 g), medium (30-50 mg/100 g) and high (> 50 mg/100 g). In this study, there were plants in group 1 of Cristália with values higher than 50 mg/100 g, although population from Mirabela showed valued considered medium.

Ascorbic acid in *B. capitata* ranged from 38 to 73 mg/100 g fw in previous studies (Faria et al., 2008). In *B. eriospatha*, levels of this nutrient varied due to location and the values found in samples were 70.44 mg/100 g (Paraná) and 17.61 mg/100 g fw (Santa Catarina) (Silva et al., 2006).

In *A. aculeate*, ascorbic acid had an average of 11.46 mg/100 g fw in fruits obtained from Presidente Epitácio and 34.67 mg/100 g in those collected from Dourados (Sanjinez-Argandoña and Chuba, 2011). Data of ascorbic acid values from other palms or fruits as *Citrus sinensis* (62.50 mg/100 g) and *Citrus reticulate* (32.47 mg/100 g), demonstrated that *B. Capitata* is an excellent source of vitamin C.

Table 2. Total sugars, ascorbic acid, total phenolics and antioxidant activity of *B. capitata* pulps from different groups of plants and populations in Northern Minas Gerais.

Locations*	Groups of plants							
	Total sugars (%)							
	G1	G2	G3	G4	G5	G6	G7	G8
AB	2.30±0.10	2.03±0.20	0.93±0.20	1.46±0.10	1.92±0.10	0.61±0.10	1.14±0.00	1.60±0.10
MI	2.11±0.20	3.22±0.00	3.35±0.00	2.22±0.00	1.29±0.00	1.94±0.00	1.69±0.00	2.68±0.10
BM	2.84±0.20	1.86±0.20	1.48±0.10	1.60±0.20	1.68±0.20	1.78±0.10	1.56±0.10	1.72±0.60
CR	1.29±0.40	1.52±0.20	0.88±0.30	0.66±0.10	0.79±0.00	1.04±0.20	1.06±0.30	0.76±0.00
Ascorbic acid (mg/100 g)								
AB	61.80±1.2	66.68±2.1	74.77±10.4	76.12±6.8	87.93±3.0	64.95±8.0	83.24±0.9	67.04±11.8
MI	62.75±7.2	82.85±13.1	55.43±0.00	59.42±9.6	54.53±5.0	38.04±4.8	32.40±2.0	57.95±1.3
BM	71.91±5.3	62.48±9.2	62.62±13.1	63.97±2.3	52.23±3.3	70.36±5.1	64.11±4.5	62.76±7.2
CR	30.53±27.7	92.43±0.5	83.06±17.5	86.85±5.6	82.41±9.9	59.19±7.1	85.08±0.6	85.14±8.9
Total phenolic content (mg/100 g)								
AB	716.89±250.3	545.12±3.0	607.71±42.7	528.15±155.1	528.33±43.2	583.02±28.9	520.52±112.3	413.76±16.5
MI	578.51±36.8	534.24±6.2	615.20±154.1	776.13±0.7	717.45±115.5	767.16±3.2	821.66±70.9	642.86±9.1
BM	368.14±0.8	337.26±62.9	649.46±74.4	573.02±223.2	729.21±20.5	392.18±62.8	536.84±50.4	536.84±50.4
CR	571.11±8.80	401.43±21.9	360.42±18.2	735.91±36.9	369.44±26.8	531.69±42.1	420.69±15.2	649.23±2.50
Antioxidant activity (%)								
AB	35.99±11.9	40.15±12.2	35.68±4.3	33.46±2.5	40.73±3.0	27.77±0.30	28.74±0.20	33.78±0.50
MI	39.33±6.2	28.92±0.2	21.31±2.9	17.20±16.1	44.80±5.0	44.80±5.0	38.21±2.60	27.49±1.90
BM	26.21±0.10	24.96±0.5	19.57±3.30	23.08±0.20	38.95±4.7	39.86±8.0	23.73±2.2	18.64±5.50
CR	37.69±1.40	32.46±4.10	47.71±6.40	30.97±27.50	35.18±6.00	31.14±2.50	58.39±0.30	43.73±13.40

Mean value ± standard deviation of fruit pulp weight; n = 3; *AB, Abóboras; MI, Mirabela; BM, Bonito de Minas; CR, Cristália.

The highest value of phenolic compounds was observed in group 7 of Mirabela (Table 2). In Cristália, the highest average was obtained in groups 4 and 8, followed by group 1. The lowest phenolic compounds were obtained in group 3 of Cristália and the same group of Bonito de Minas (Table 2). According to Vasco et al. (2008) fruits can be classified into three different categories based on their concentration of phenols: Low (<100 mg GAE 100 g), medium (100-500 GAE mg100 g) and high (>500 GAE mg100 g). In general, the values found in some groups of Cristália were considered high, while the values in the groups of Bonito de Minas would be characterized as medium.

The total amount of phenolic compounds in the pulp of *B. capitata* was higher than this in many palm species and other plants. Biglari et al. (2008) reported amounts that ranged from 2.89 to 6.64 mg/100 g in different genotypes of *Phoenix dactylifera*; Jacques et al. (2009) reported an average of 328.6 mg/100 g in *B. odorata* and Faria et al. (2008) reported amounts that ranged from 163 to 250 mg/100 g fw in *B. capitata*. However, Shahdadi et al. (2015) observed a variation in amounts of phenols in four fruit ripening stages of *Phoenix dactylifera*, with values ranging from 2.89 to 4.82 mg/100 g fw in mature fruits. These compounds are essential to plant growth, reproduction and defense against

Table 3. Dry matter basis phosphorus, potassium, and magnesium of *B. capitata* pulp obtained from different groups of plants and populations in northern Minas Gerais.

Locations	Groups of plants							
	G1	G2	G3	G4	G5	G6	G7	G8
Phosphorus (mg/100 g)								
Abóboras	0.19±0.00	0.19±0.01	0.19±0.01	0.19±0.00	0.18±0.01	0.19±0.00	0.19±0.00	0.19±0.00
Mirabela	0.14±0.01	0.15±0.00	0.14±0.00	0.15±0.00	0.15±0.00	0.16±0.00	0.16±0.01	0.16±0.01
Bonito de Minas	0.15±0.00	0.17±0.00	0.18±0.00	0.18±0.01	0.17±0.00	0.18±0.00	0.18±0.00	0.18±0.00
Cristália	0.14±0.00	0.13±0.00	0.16±0.00	0.13±0.00	0.14±0.00	0.17±0.00	0.16±0.00	0.14±0.00
Potassium (mg/100 g)								
Abóboras	1.22±0.04	1.18±0.01	1.25±0.03	1.50±0.02	1.99±0.00	1.44±0.01	1.07±0.02	1.09±0.01
Mirabela	1.21±0.01	1.32±0.05	1.30±0.1	1.33±0.00	1.35±0.00	1.50±0.02	1.16±0.00	1.34±0.00
Bonito de Minas	1.34±0.00	1.42±0.00	1.20±0.01	1.23±0.00	1.48±0.00	1.34±0.03	1.53±0.00	1.22±0.00
Cristália	1.40±0.05	1.58±0.01	1.15±0.00	1.52±0.00	1.39±0.01	1.53±0.04	1.67±0.00	1.19±0.01
Magnesium (mg/100 g)								
Abóboras	0.09±0.00	0.07±0.00	0.08±0.01	0.08±0.01	0.06±0.01	0.07±0.00	0.07±0.00	0.07±0.01
Mirabela	0.04±0.00	0.04±0.00	0.06±0.00	0.05±0.01	0.08±0.00	0.05±0.02	0.05±0.00	0.05±0.00
Bonito de Minas	0.06±0.00	0.05±0.00	0.07±0.00	0.05±0.00	0.07±0.00	0.06±0.00	0.06±0.00	0.05±0.00
Cristália	0.08±0.00	0.07±0.00	0.09±0.00	0.08±0.00	0.07±0.00	0.10±0.02	0.10±0.02	0.08±0.00

Mean value ± standard deviation of fruit pulp weight; n = 3. *AB, Abóboras; MI, Mirabela; BM, Bonito de Minas; CR, Cristália.

pathogens. Phenols have high antioxidant activity due to their ability to sequester free radicals and donate electrons and hydrogens (Balasundram et al., 2006). The results demonstrated that *B. capitata* presents higher antioxidant activity than other palm trees, given the high values found in this study (>500 GAE mg100 g).

Ascorbic acid and phenolic compounds in plants are mainly influenced by environmental conditions, as light and temperature, genetic variation, soil type, and stress on maturation stage (Lee and Kader, 2000). For example, in tomato, the values of ascorbic acid, total phenols, and antioxidant capacity relate positively to increased light and temperature (Raffo et al., 2006). However, genetic factors seemed to influence these parameters in tomato as reported by Caliman et al. (2010). More specifically, ascorbic acid values were higher for variety 'Santa Clara' (17.71 mg/100 g), compared to'BGH-320' and 'Carmen', which had an average of 13.00 mg/100 g, under the same cultivation conditions. The highest average of antioxidant activity was obtained in group 7 of Cristália (58.39%). The lowest antioxidant activity was observed in group 4 (17. 20%) of Mirabela (Table 2). Antioxidant activity of *B. capitata* was similar to values obtained in other palm species, as in *E. edulis* (41.73%) (Lima et al., 2012) and higher than *Citrus reticulate* (29.30%) and *Citrus sinensis* × *Citrus reticulata* (12.78%) (Couto and Canniatti-Brazaca, 2010).

Averages of phosphorus concentration, in samples obtained from Abóboras, were higher compared to other regions; however, the amount of this mineral was similar between the groups, except of 5 of them (Table 3). The lowest values of phosphorus were observed in groups 2 and 4 of Cristália and group 1 of Mirabela (Table 3). Potassium concentration was the highest in some samples obtained from Abóboras (1.99%) and seven groups of Cristália (1.67%). The lowest amounts of potassium were obtained in group 7 of Abóboras and the same group of Mirabela. Magnesium values were the highest in group 1, followed by groups 3 and 4 of Abóboras. The values of magnesium in group 6 and 7 of Cristália were higher, compared to the same groups from other locations (Table 3).

The highest averages of copper were obtained in groups 4, 5 and 6 of Abóboras followed by Group 2 of Cristália. The lowest values were observed in groups 5 and 6 of Bonito de Minas (Table 4). Manganese values in group 4 of Abóboras and Group 5 and 6 of Cristália were higher than the minor amounts found in groups 1 and 2 of Mirabela. Zinc was abundant in all groups. The highest averages of zinc were obtained in group 5, 6 and 7 of Cristália (Table 4). Iron was found in great amounts in *B. capitata*. The highest averages were observed in group 5 of Bonito de Minas, Group 4 of Abóboras and group 6 of Mirabela, while the lowest averages were obtained in group 2 of Mirabela and group 8 of Bonito de Minas (Table 4).

B. capitata has higher potassium and iron amounts than their fruits. Banana is rich in potassium and its content ranges from 297 to 341 mg/100 g fw (Ramos et al., 2009). Generally, the pulp of palm trees is a good source of potassium; reported values ranged from 77.19 and 125.08 mg/100 g in *Euterpe precatoria* (Yuyama et al., 2011), and were in average 766 mg $100g^{-1}$ in *A. aculeate* (Ramos et al., 2008). Iron is present in relatively

Table 4. Dry matter basis copper, manganese, zinc, and iron of *B. capitata* pulp obtained from different groups of plants and populations in Northern Minas Gerais.

Locations*	Groups of plants							
	G1	G2	G3	G4	G5	G6	G7	G8
Copper (mg/100 g)								
AB	0.50±0.01	0.44±0.01	0.32±0.01	0.41±0.00	0.67±0.01	0.54±0.01	0.39±0.05	0.45±0.01
MI	0.41±0.01	0.41±0.02	0.46±0.02	0.40±0.00	0.41±0.03	0.36±0.02	0.40±0.03	0.48±0.00
BM	0.31±0.00	0.34±0.01	0.34±0.00	0.36±0.04	0.29±0.00	0.28±0.01	0.39±0.02	0.35±0.00
CR	0.59±0.03	0.62±0.03	0.55±0.00	0.66±0.01	0.50±0.00	0.64±0.02	0.52±0.00	0.51±0.00
Manganese (mg/100 g)								
AB	0.63±0.00	0.45±0.00	0.83±0.02	2.41±0.01	0.54±0.01	1.09±0.01	0.60±0.06	0.51±0.02
MI	0.38±0.01	0.36±0.03	0.96±0.01	0.89±0.01	1.41±0.03	1.32±0.01	0.90±0.46	0.65±0.00
BM	1.71±0.00	0.90±0.00	1.17±0.02	1.13±0.01	3.12±0.02	1.07±0.00	1.23±0.02	0.87±0.00
CR	1.03±0.00	1.03±0.00	1.58±0.01	1.82±0.02	1.28±0.01	2.20±0.06	1.44±0.01	1.10±0.52
Zinc (mg/100 g)								
AB	0.98±0.01	0.92±0.00	0.86±0.00	0.87±0.01	0.97±0.02	0.97±0.03	0.94±0.01	0.99±0.03
MI	0.80±0.23	0.77±0.01	0.81±0.01	0.91±0.01	1.05±0.02	0.81±0.05	0.78±0.01	0.90±0.00
BM	0.83±0.00	0.80±0.01	0.78±0.00	0.72±0.01	0.95±0.00	0.63±0.00	0.87±0.00	0.76±0.05
CR	0.95±0.01	1.00±0.01	1.17±0.00	1.23±0.00	1.23±0.02	1.28±0.00	1.34±0.00	0.94±0.00
Iron (mg/100 g)								
AB	5.04±0.01	4.06±0.01	3.52±0.01	58.53±0.01	7.92±0.01	3.10±0.00	3.74±0.01	3.52±0.01
MI	3.20±0.00	2.60±0.06	6.25±0.00	17.54±0.00	26.71±0.01	45.72±0.00	3.72±0.01	7.02±0.01
BM	9.79±0.01	3.04±0.01	4.26±0.00	6.41±0.00	83.94±0.02	3.82±0.00	4.45±0.00	2.63±0.00
CR	5.73±0.02	4.35±0.00	3.48±0.00	3.28±0.00	3.92±0.01	26.02±0.00	3.37±0.00	17.40±0.12

Mean value ± standard deviation of fruit pulp weight; n = 3; *AB, Abóboras; MI, Mirabela; BM, Bonito de Minas; CR, Cristália.

larger amounts than their microelements in *E. edulis* (46.6 mg/100 g) (Ribeiro et al. 2011) and *A. aculeate* (7.71mg/100 g) (Ramos et al., 2008). Zinc amount was relatively higher in *E. precatoria*, ranging from 163.43 to 318.32 mg/100 g, compared to other plant species (Yuyama et al., 2011).

Palm fruit is a popular food in the northern region of Minas and is offered to children at schools and daycare centers. *B. capitata* pulp has high nutritional value since it is rich in ascorbic acid, phenolic compounds, antioxidants and fiber. Results obtained in this study may be used for an initial nutritional characterization and the development of product labels. They may also assist to future breeding, conservation, and educational programs.

UPGMA allowed the identification of five major groups (Figure 1). Group A included groups of plants from all evaluated populations, most of them obtained from Mirabela. It is noteworthy that group A included plants highly similar in ascorbic acid, sugars, total phenols and antioxidant activity. Group B had three sub-groups, including samples of population from Cristália and Abóboras. Group C included the highest plants from all populations. Group D and E included groups of populations with low similarity in ascorbic acid, sugars, total phenols and antioxidant activity.

In principal components analysis (PCA), the first axis represented 42.15% of total variation and the second axis represented 29.90% of total variation. In Figure 2, the distance of Cristália groups 7 and 3 from other groups was highlighted. Most individuals were similar in the middle of the dendogram. UPGMA and PCA were also effective for separating and grouping 18 different fruit species for ascorbic acid, total phenols, carotenoids, and flavonoids. Barreto et al. (2009) supported that this analysis could differentiate related species and those with low similarity for the production of bioactive compounds. In *A. carambola*, PCA allowed the grouping of pulps collected at harvest time and analyzed for various bioactive compounds (Zainudin et al., 2014). The separation of plants into different groups can help breeders to select distinct *B. capitata* genotypes, and can guide producers for the best harvest time of fruit. Fruits are manually harvested by native populations and sold at local markets or the extracted pulps are supplied by cooperatives to school lunch programs.

Conclusion

The results demonstrated that *B. capitata* pulp is rich in

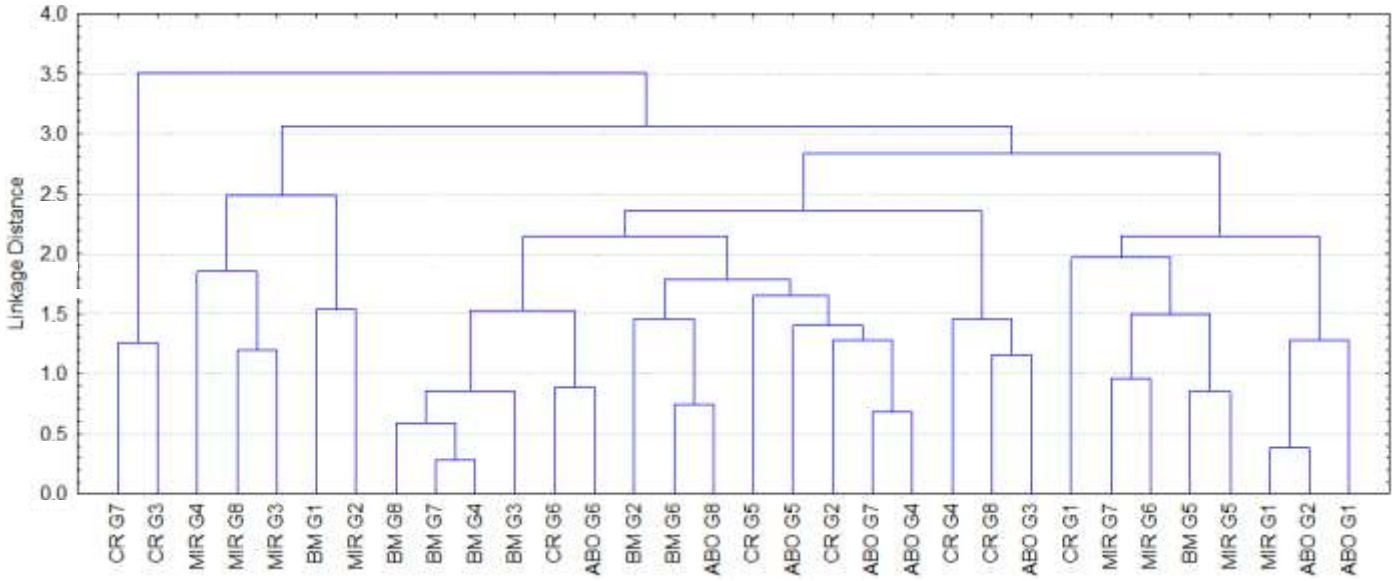


Figure 1. UPGMA dendrogram showing genetic similarity between *B. capitata* populations collected from Bonito de Minas (B), Mirabela (M), Abóboras (A), Cristália (C) in Northern Minas Gerais.

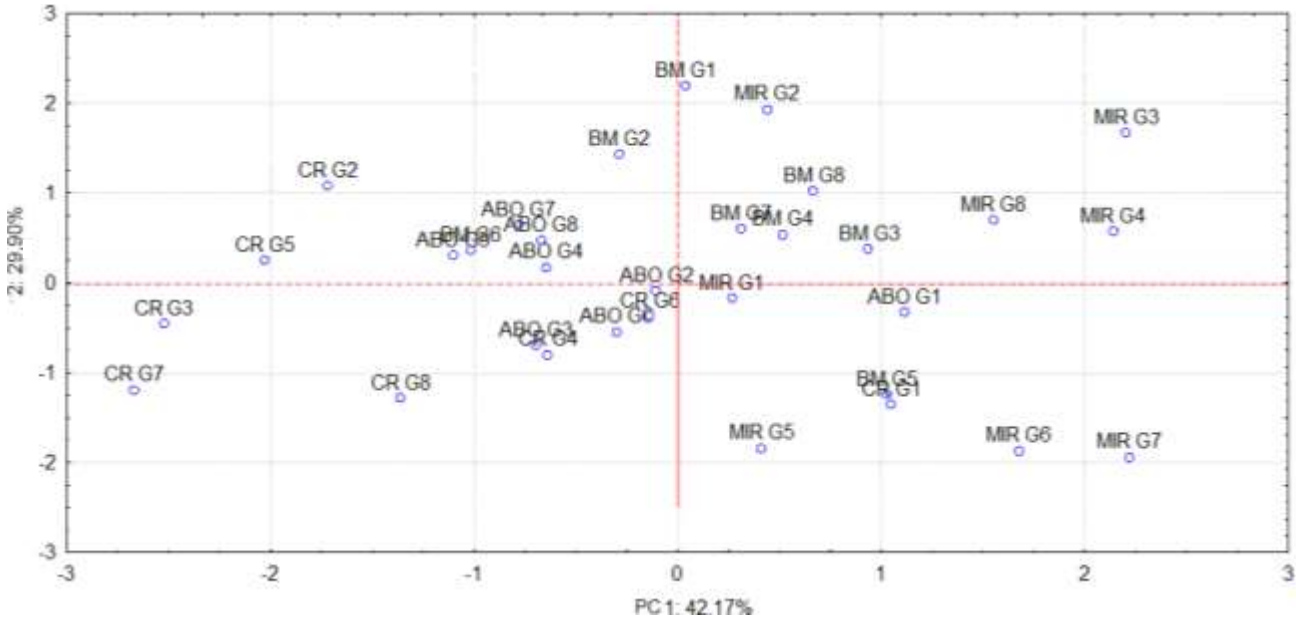


Figure 2. Principal components analysis (PCA) of ascorbic acid, phenolic compounds, total sugars, and antioxidant activity among different populations and groups of *B. capitata* collected from Bonito de Minas, Mirabela, Abóboras and Cristália in Northern Minas Gerais.

ascorbic acid (with average values higher than 65 mg/100 g fw) and minerals, especially potassium and iron. It contains large amounts of phenolic compounds and has a good antioxidant capacity. This composition varies due to soil composition, climatic conditions, and genotype. Multivariate analysis grouped and separated populations that were genetically similar or dissimilar for ascorbic acid, antioxidant activity, total phenolic compounds and total sugars.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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