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Technological and food potential of *Acrocomia aculeate* vegetal beverage

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ABSTRACT. The study evaluated the physical, chemical, technological and microbiological characteristics of the vegetable drink from *A. aculeata*, in different proportions of pulp dilution: water (1:10, 1:15 and 1:20 m/m), extraction temperatures (30, 50 and 80ºC), after thermal treatment at 60ºC 20 min^{-1} and in natural conditions. Titratable acidity values were below 0.1%, indicating low levels of organic acids. The pH varied close to neutrality (pH 6-8), favoring the non-precipitation of proteins. The soluble solids contents were low, varying from 1 to 2 °Brix before the heat treatment, and from 0.3 to 1.6 after the treatment, with a low °Brix content, which can be explained by the low acidity content, giving a more pleasant taste to the palate. The extraction temperature influenced the technological parameters of color and viscosity, with extractions at 30°C showing more yellowish tones, while those performed at 50 and 80°C had more orange tones. Viscosity increased with increasing temperature, and the results were superior to those found in other studies with vegetable beverages. The microbiological analyzes were carried out in accordance with the microbiological standards recommended by the legislation, and were considered suitable for consumption, indicating that the thermal treatment was efficient to inactivate and reduce the microbiota present in the fruits. Cluster analysis was performed using the dendrogram and principal components (PCA) in order to investigate the association between the combinations of extraction temperature, dilution ratio and undergoing or not through heat treatment. The results obtained show that the extraction temperature factor (30, 50 and 80°C) within the same dilution ratio (1:10, 1:15 and 1:20), did not generate statistically significant difference. We concluded that it was possible to produce an extract of bocaiuva pulp with great technological and nutritional potential, with guaranteed food safety and free from pathogenic microorganisms.

Keywords: Native fruit; Vegetal beverage; *A. aculeate;* viscosity.

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Introduction

Cerrado is the second largest Brazilian biome, occupying about 23.3% of the entire national territory (Instituto Brasileiro de Geografia e Estatística [IBGE], 2017). Due to its diverse climate and soils, this biome stands out for its biodiversity with the richest flora among the savannas in the world, housing several native species that are traditionally used by the local population, both for "natural" consumption and for production of sweets, jellies, juices and liqueurs. However, several species are still underused by local communities, either due to scientific ignorance or lack of incentives for their commercialization (Silva et al., 2001; Borlaug, 2002; Klink; Machado, 2005; Silva et al., 2008; Farinazzi-Machado et al., 2018). The great potential of native Brazilian fruits has not yet been fully discovered, although many studies have indicated the rich sources of nutrients that are found in native fruits (Lemes et al., 2021; Lima et al., 2021; Borges et al., 2022). One of these fruits is the bocaiuva (*Acrocomiaaculeata*) a globular fruit of 3 to 5 cm in diameter with a soft epicarp, a fibrous and yellow mesocarp with a sweet and characteristic aroma (Lescano et al., 2015; Colombo et al., 2018; Andrade et al., 2020; Antoniassi et al., 2020). It belongs to the Arecaceae family (Dessimoni-Pinto et al., 2010). Its fruiting occurs throughout the year, ripening mainly between the months of September and January (Henderson, Galeano, e Bernal, 1995; Almeida et al., 1998). The edible portion of the *A.aculeata* fruit consists of pulp and almond, presenting a good yield for technological use and providing potentially nutritious elements.

The nutritional composition of this fruit draws attention for its pulp, which represents half the weight of the fruit in mass, and for the almond, which represents 20 to 40% of the weight of the fruit (Lescano et al., 2015; Antoniassi et al., 2020). The pulp stands out for its fiber concentration from 6.84 to 21.76 in g per 100 g; as well as 6.92 to 36.22 for carbohydrates; 15.28 to 28.94 lipids; 2.24 to 6.72 of protein, 300 to 348 μg g^{-1} of carotenoids, 15.71 ($mg100g^{-1}$) of ascorbic acid and 213 $mgkg^{-1}$ of total tocopherols. The almond has a high concentration of lipids 16.44 to 46.96 in g per 100 g, however the other nutrients are also significant fiber 12.49 to 35.81, protein 16.44 to 28.61; carbohydrates 1.02 to 6.06 plus minerals zinc 45.14 μgg^{-1} and manganese 18.78 μgg^{-1}(Coimbra & Jorge, 2011; Conceição et al., 2013; Lescano et al., 2015; Trentini et al., 2016; Andrade et al., 2020; Antoniassi et al., 2020).

The high concentration of *A. aculeata* lipids was studied considering its exploitation as a source of raw material for the production of biodiesel (Bergmann et al., 2013; Conceição et al., 2013; Conceição et al., 2015; Vianna et al., 2017; Colombo et al., 2018).

However, as highlighted by Antoniassi et al. (2020) both pulp and almond have fatty acids of nutritional value. The pulp has a higher concentration of monounsaturated fatty acids 38.9 to 67.6 (g fatty acid/total fatty acids) of which C18:1 octadec-9-enoic stands out. The polyunsaturated fatty acids vary between 8.3 to 42.1 (g fatty acid/total fatty acids) highlighting the C18:2 octadec-9,12-dienoic acid, which corresponds to 74.7 to 81.0 (g fatty acid/total fatty acids) unsaturated fatty acid. Remarkably, in almonds, the predominant fatty acids are saturated, especially C12:0 dodecanoic acid followed by C14:0 and C16:0, corresponding to 69.1 (g fatty acid/total fatty acids) (Trentini et al., 2016; Antoniassi et al., 2020).

Antoniassi et al. (2020) observed that among the genotypes, which he called macaúba doce, those that produced the highest concentration of lipids in the pulp had the lowest amount of sugars, and the opposite was also true. Essentially important sugars are present, but in varying amounts depending on the genotype. The presence of fructose 2.46 to 5.26 ($g100g^{-1}$) and glucose 2.06 to 4.37 ($g100g^{-1}$) were determined and similar concentrations of both sugars in the pulp were observed. According to Andrade et al. (2020) the concentration of carbohydrates, fibers, and phenolic compounds present in both pulp and almond contributed to the growth of beneficial bacteria, in the case of *L. casei* which was similar to that observed for fructo-oligosaccharides, proving its probiotic potential.

For all these nutritional qualities, the World Health Organization [WHO] recommends the consumption of fruits and vegetables (400 g) per day and juices are considered within this portion ([WHO], 2004;International Fruit and Vegetable Juice Association [IFU], 2018). In the systematic review carried out by Aune et al. (2017), a reduction in the risk of cardiovascular disease and cancer was evidenced by the consumption of fruits and vegetables in the amount of 500 to 800 g per day. Part of these important nutrients recommended to avoid the risks of diseases, and that are abundant in bocaiuva, are water soluble, such as vitamins and monosaccharides, but another part, such as proteins, are pH-dependent and fiber, even so desirable and carriers of some nutrients, can interfere with the production process and drink quality.

Fibers are the primary and secondary parts of cell walls and are soluble proteins, lignins and pectins and hemicellulose (Penha et al., 2021). They are responsible, among other things, for carrying aromatic compounds and biocompounds: carotenoids, vitamin C and E and phenolic compounds (Altemimi et al., 2017; Bestwick et al., 2020). However, fibers can interfere negatively in the extraction of these compounds. For the best use of nutrients and knowledge of the behavior of fruit constituents, it is imperative to test extraction processes. Beverage production follows processes that may vary with the food (Penha et al., 2021). The amount of water added, the temperature, the pH of the solution, the grinding can influence not only the sensory, aesthetic and rheological quality of the product, but also the availability of nutrients and by-products generated. For these reasons, it is a responsible attitude in the study of food to consider socioeconomic processes that minimize losses. With this attitude the present work aims to evaluate the physical, chemical, technological and microbiological characteristics of the water-soluble extract of bocaiuva pulp (*Acrocomia aculeata*, in samples "in natura" and after heat treatment at 60°C for 30 min.

Thus, studies with native fruits that present new sources of nutrients and that can be used in a sustainable way are of paramount importance both for the development of new products and for the valorization of Brazilian biomes (Silva et al., 2008; Almeida et al., 2019).

Material and method

Vegetable material

The fruits (*A. aculeata* (Jacq.) Lodd.) were selected according to the degree of maturation (intense yellow skin color), washed in running water and sanitized by immersion in chlorinated water (active chlorine 250 ppm) for 15 minutes. The disinfection process is necessary because the fruits were collected directly from the soil. Subsequently, they were dried on absorbent paper, manually peeled and pulped, and the pulp was packaged and frozen (- 20 °C) until use.

Water soluble extract

The vegetal beverage of *A. aculeata* (Figure 1) was obtained by homogenization in a food blender (Phillips, model RI 7625) at speed 2 for 2 minutes. Extraction was carried out at three different water temperatures (30, 50 and 80 °C) and proportions (1:10, 1:15 and 1:20 pulp: water (m/m)). The extracts were filtered through organza fabric packed in plastic bottles and stored under refrigeration until the analysis was carried out, which were carried out both on beverage that did not undergo heat treatment and after undergoing heat treatment.

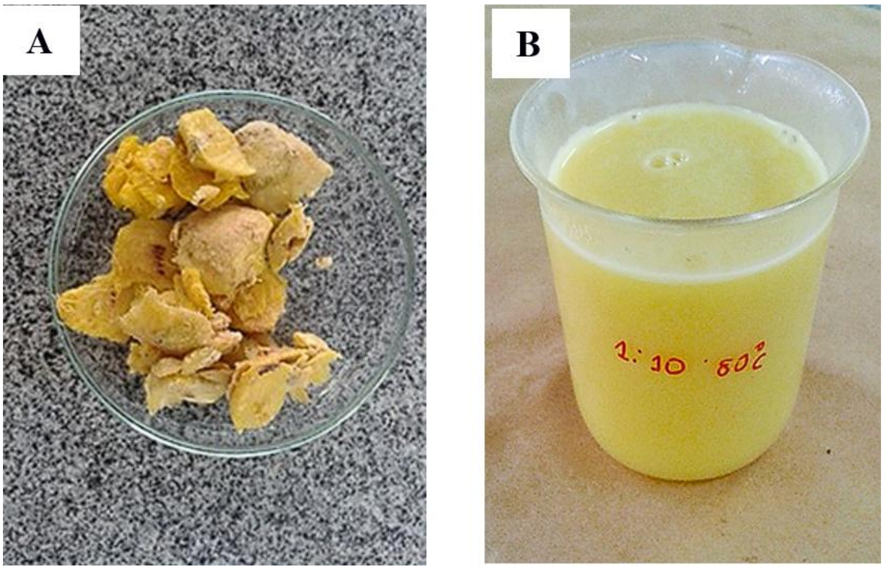

Figure 1. Bocaiuva pulp (A) and pulp extract (B).

The heat treatment was carried out slowly at 60 °C for 20 minutes, using a 1L capacity jacketed glass flask, coupled to a thermostatic bath and under agitation. Then, they were immediately cooled, placed in centrifuge tubes (Falcon) and submitted to analysis, with all parameters performed in triplicate.

Physicochemical parameters

The physical and chemical parameters were analyzed according to the method described by Instituto Adolfo Luts [IAL] (2008).

The pH was determined by a digital benchtop pHmeter (Metrohm, 827 pH lab, Herisau, Switzerland) previously calibrated with 4.0 and 7.0 buffers solutions, according to method 17/IV (IAL, 2008).

The total titratable acidity was determined by neutralization volumetry, in which the spent volume of 0.1 M NaOH in aqueous medium, added with 3 drops of phenolphthalein until the turning point was quantified (IAL, 2008), and the results expressed in citric acid equivalent.

Total soluble solids in °Brix, quantified by portable digital refractometer (Reichert Analytical Instruments, R2-mini Brix/RI-Chek, Depew, NY, USA), previously calibrated with distilled water, according to IAL (2008).

Microbiological analysis

The microbiological analyzes were carried out according to APHA (Salfinger & Tortorello, 2015), based on the microbiological standards recommended by ANVISA (Brasil, 2001) for the presence of *Salmonella* sp., most probable number (MPN) of total coliforms at 35 °C, and coliforms thermotolerant at 45°C.

Technological properties

The technological properties evaluated were: extract stability, color and rheological parameters.

The stability of the beverage was visually analyzed by means of background formation in a transparent container and by centrifuging in a (Andreas Hettich GmbH & Co.KG, MIKRO 120, Tuttlingen, Germany) centrifuge for 5 minutes at 14,000 rpm. The sedimented material (g.100 g^{-1}) was quantified by the mass of the extract sediment in relation to the total mass, before centrifugation.

The color was determined by a benchtop colorimeter (Konica, Minolta Sensing Inc., CR-400, Tokyo, Japan), and the Luminosity (L*), Chroma (C*) and Hue angle (°h) were evaluated, according to the described methodology by [IAL] (2008).

The rheological parameters of shear stress and apparent viscosity were obtained using a rotational viscometer (Brookfield, model LVDVE, Stoughton, USA) and, only for beverage prepared in the proportion of 1:10 with extraction at 30 and 80 °C. The increase in shear stress was obtained by increasing the rotation, from the continuous variation of the angular velocity of the cylinder (spindle LV1 – S61), using rotations between 0.3 and 100 rpm, corresponding to shear rates of 0.066 and 22 s^{-1}. The rheological analysis was performed in a laminar flow regime, under a torque range between 10 and 100 %, as recommended by the equipment.

Statistical analysis

Statistical analysis was performed using analysis of variance (ANOVA) and Tukey's test, at a 5% significance level ($p > 0.05$) using the Past program, version 2.17.

Two other multivariate statistical techniques were combined in conducting the analyses: principal components methods and hierarchical clustering to describe and visualize the similarity between the variables. After the selection of the main components, the hierarchical grouping was carried out based on the Euclidean distance measure and the Ward's agglomeration criterion, as we sought to generate groups (clusters) that have a high internal homogeneity.

Results and discussion

Physicochemical parameters pH and total titratable acidity

Titratable acidity is an important parameter in assessing the conservation status of a food product, and can be altered by hydrolysis, oxidation or fermentation (IAL, 2008).

Organic acids are important for respiratory metabolism in fruits and vegetables, in addition to acting as antimicrobial factors (Rivera, 2005). Thus, the determination of citric acid content becomes an important tool for evaluating the quality of a food (Brasil, 2000).

The titratable acidity values in terms of % of citric acid presented in Table 1 showed equivalent values lower than 0.1%, indicating low levels of organic acids. Slightly higher values were observed only for beverages obtained in a 1:10 ratio at 30°C, which decreased as they were diluted and extracted at higher temperatures.

Table 1. pH data and titratable acidity of natural bocaiuva beverage and after heat treatment.

Sample	pH		Titratable Acidity (% citric acid)	
	Nat*	Hts**	Nat*	Hts**
B1030	6.39±0.08cdA	6.67±0.04Cb	0.0927±0.004Aa	0.0339±0.007aB
B1050	7.24±0.01aA	7.21±0.02abA	0.0384±0.004bA	0.0136±0.000bcB
B1080	7.29±0.02aA	7.31±0.01aA	0.0169±0.003cA	0.0136±0.000bcA
B1530	6.35±0.05cA	6.39±0.05eA	0.0678±0.000dA	0.0226±0.004bcB
B1550	7.14±0.02aeA	6.93±0.04dB	0.0362±0.004beA	0.0124±0.002cB
B1580	7.30±0.05aA	7.19±0.10abA	0.0158±0.004cA	0.0068±0.000cB
B2030	6.53±0.11dA	6.54±0.09cA	0.0407±0.000bA	0.0113±0.004cB
B2050	7.25±0.03aA	7.10±0.04bB	0.0294±0.002eA	0.0079±0.002cB
B2080	7.07±0.06eA	7.06±0.01dA	0.0136±0.000cA	0.0068±0.000cB

Mean values (n=3) plus or minus standard deviation followed by different lowercase letters in the same column and different uppercase letters in the same row (for each parameter) show a statistical difference at 5% significance ($p > 0.05$) according to the Tukey test. * Nat = natural. **Hts = heat treated sample.

Also relatively low values of titratable acidity (0.69 and 0.73%) in pure *A. aculeata* pulp were found by the authors Sanjinez-Argandoña and Chuba (2011). However, these values were higher than those found in this study, due to the pulp sample used by these authors being *in natura* and not extracted in water.

Studies developed by Pereira et al. (2002) in açaí pulp (tropical palm tree native to the Amazon) obtained 0.31% acidity, and Carvalho et al. (2003) reported acidity of 1.24% in pulp of bacuri (*Platonia insignis* Mart.). Thus, it is possible to observe that the pulp of bocaiuva has a lower acidity content than the previously mentioned fruits, giving it qualities suitable for consumption *in natura*.

The measurement of pH is important in the analysis of the maturation content of fruit-based foods, because the higher the state of maturation, the lower the pH and acidity of the fruits will be (Cecchi, 2003; Damodaran et al., 2010). pH values close to neutrality (6 to 8) are considered favorable because the acidification of the medium reduces the load and hydration of proteins, which can cause their precipitation (Food Ingredients Brasil [FIB], 2016).

The pH values for the analyzed samples (Table 1) generally varied between 6.35 and 7.31 for all extracts, and these values were considered neutral. Therefore, based on the data presented, it is possible to infer that both the dilution and the change in extraction temperature did not generate great changes in the pH values for the bocaiuva extracts.

Studies developed by Munhoz et al. (2007) and Sanjinez-Argandoña and Chuba (2011), in which they analyzed the pure bocaiuva pulp (natural), obtained pH values that varied between 5.7 and 6.29, being considered more acidic than the extracts obtained. in that job. Probably due to the fact that the analyzed sample was not dissolved in water.

Soluble solids

Soluble solids (SS) are made up of all solids dissolved in water, starting with sugar, salts, proteins, acids, among others. The SS content is commonly adopted as a sugar quantification parameter, with the reading of the measured value corresponding to its total sum, and the °Brix corresponding to the measurement unit used (Moraes, 2007).

The values found in the extracts were low, ranging from 1 to 2 °Brix before heat treatment and 0.3 to 1.6 after treatment. This low content can be explained by the lower total titratable acidity content, 0 to 0.1 %, indicating low levels of citric and organic acids that may have influenced the low content of soluble solids. The soluble solids contents of this work are correlated with the pH values that they presented, a pH ranging from 6.0 to 7.0, it can be said that the fruits evaluated in this study are slightly acidic. Similar pH results were found by Lescano et al. (2015) in *A. aculeata* pulp. Thus, *A. aculeata* pulp can be considered as a fruit with low acidity and soluble solids and neutral pH as presented in Table 1 and 2, through the results of acidity and °Brix, which favors the sensory characteristics of this fruit, making its flavor more pleasant to the palate (Brasil, 2005;Sanjinez-Argandoña & Chuba, 2011).

Table 2. Content of soluble solids (°Brix) and sedimentation in beverage of natural bocaiuva and after heat treatment.

Sample	Soluble Solids (°Brix)		Sedimentation (%)	
	Nat*	Hts**	Nat*	Hts*
B1030	1.40±0.17aA	1.33±0.12acA	6.1±0.6cbA	9.5±2.6aA
B1050	1.47±0.06aA	1.40±0.10aB	7.4±0.4bA	9.6±1.1aB
B1080	1.43±0.06aA	1.63±0.12bA	10.3±0.7aA	8.8±1.2abA
B1530	1.53±0.17acA	0.70±0.10cB	8.1±0.6bA	8.4±0.5abA
B1550	1.63±0.12bcA	0.87±0.15aB	4.0±0.8dA	6.5±0.9abB
B1580	1.73±0.25bA	1.20±0.20bB	8.4±0.8abA	9.4±0.8abA
B2030	1.77±0.12bA	0.57±0.15acB	6.9±0.8bcA	6.6±1.1abA
B2050	1.57±0.15acA	0.37±0.06cB	8.5±1.0abA	6.1±0.3bB
B2080	1.27±0.21aA	1.03±0.06abA	6.0±0.7cdA	7.0±0.7abA

Mean values (n=3) plus or minus standard deviation followed by different lowercase letters in the same column and different uppercase letters in the same row (for each parameter) show a statistical difference at 5% significance ($p > 0.05$) according to the Tukey test. * Nat = natural. **Hts = heat treated sample.

Technological properties color

The color parameter is specified numerically in a spherical three-dimensional space, defining axes. The Luminosity - L*, varies from black (0) to white (100). The Chroma parameter (C*) indicates the saturation, with higher values of C* indicating greater color intensity and values close to zero indicating a opaquer color. The Hue angle (°h) indicates the shade of the color, for example, 0° represents red and 90° represents yellow (Konica Minolta, 2017).

The extracts prepared in the proportion of 1:10 with extraction at 80°C (Table 3), showed the highest results within the parameters luminosity and saturation (chroma), both in the samples that underwent heat treatment, as well as in those that remained natural, demonstrating that the higher pulp concentration contributed to higher values of the parameters mentioned above.

As for the values of the hue angle or hue, the beverage showed values between 80 and 90 °h, being characterized with a yellow-orange hue. It is also observed that the extraction temperature exerted an influence on the tone of the extract, since the extractions at 30°C presented tones closer to yellow, while the extractions obtained at 50 and 80°C presented tones closer to yellow and orange, respectively.

Table 3. Color parameters of natural bocaiuva pulp beverage and after heat treatment.

Sample	Brightness		Chroma – Saturation		Hue - Hue	
	Nat*	Hts**	Nat*	Hts**	Nat*	Hts**
B1030	58.82±0.08bA	54.15±0.05cB	40.41±0.04Ba	37.37±0.04bB	83.84±0.02fA	84.15±0.05fB
B1050	57.00±0.08dA	54.01±0.07dB	39.94±0.15cA	37.42±0.48bB	81.73±0.11hA	82.83±0.05gB
B1080	60.46±0.07aA	56.84±0.04aB	43.82±0.12aA	40.88±0.03aB	81.05±0.02iA	81.83±0.02hB
B1530	57.50±0.10cA	50.95±0.05eB	35.84±0.06dA	31.45±0.03cB	86.23±0.01bA	87.93±0.03bB
B1550	52.96±0.12eA	49.67±0.03fB	32.46±0.04eA	30.56±0.04eB	84.58±0.02eA	85.67±0.03eB
B1580	52.41±0.10fA	49.64±0.03fB	35.27±0.09fA	32.56±0.02dB	82.81±0.01gA	82.14±0.04hB
B2030	52.80±0.06eA	54.74±0.03bB	30.43±0.04gA	31.66±0.02cB	88.17±0.02aA	88.73±0.02aB
B2050	52.23±0.11fA	46.80±0.04hB	31.61±0.04hA	27.54±0.03gB	85.47±0.03cA	86.40±0.56cB
B2080	48.38±0.05gA	48.01±0.06gB	28.84±0.04iA	28.17±0.06fB	84.94±0.03dA	85.05±0.02dB

Mean values (n=3) plus or minus standard deviation followed by different lowercase letters in the same column and different uppercase letters in the same row (for each parameter) show a statistical difference at 5% significance (p > 0.05) according to the Tukey's test. * Nat = natural. **Hts = heat treated sample.

Physical stability of the beverage

Sedimentation is a parameter that is related to the physical stability of the product, and the higher the sedimented mass value, the lower the stability of the beverage to keep its components in suspension, and thus, more susceptible to formation of bottom body and agglomerates, making the drink less appealing to the consumer. Therefore, it is possible to observe through Figure 2, that among the three proportions with extraction at 30°C, the 1:10 formulation was the one that remained the most stable after resting, without visible phase separation.

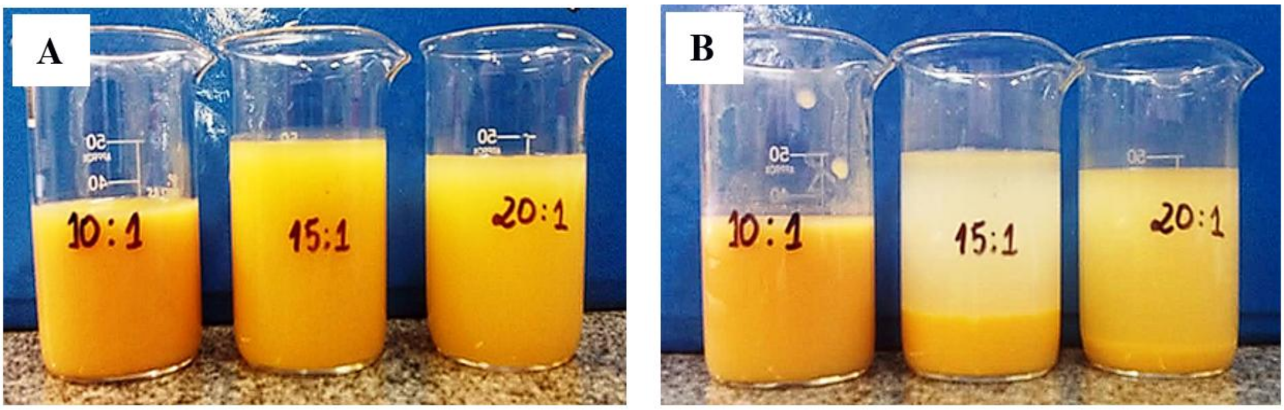

Figure 2. Stability of beverage in proportions 1:10, 1:15 and 1:20 (mm^{-1}) with extraction at 30°C, homogenized (A) and after rest (B).

Figure 3 presents the sedimentation values for the different concentrations and extraction temperatures, after the centrifugation process. It is shown that the highest percentage of sediments was observed in the 1:10 beverage obtained at 80°C, in the natural beverage. Probably due to the fact that it is the sample with the highest concentration among all those evaluated.

The sample that was more stable after centrifugation was the one prepared in the proportion 1:15 obtained at 50°C, with lower sediment values both naturally and after heat treatment. The other extracts showed no statistical difference at 5% of significance.

Thus, the evaluation of the physical stability of the extract is of paramount relevance, as studies show that beverages without the addition of stabilizers lose their homogeneity after the storage period, and they must be packaged in non-transparent packaging, with indication for agitation before consumption (Lopes & Wurlitzer, 2015).

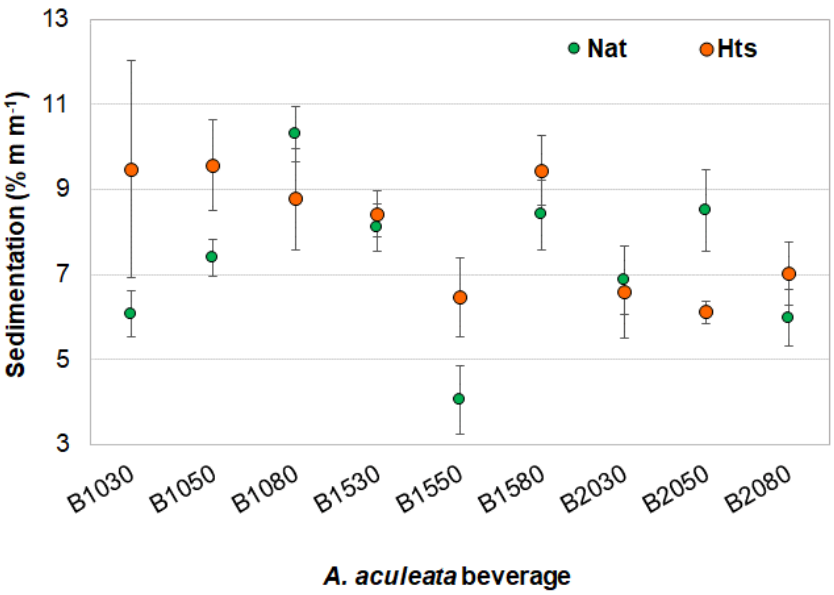

Figure 3. Sedimentation by centrifugation of *A. aculeata* beverages in proportions 1:10, 1:15 and 1:20 (mm^{-1}), in samples without (natural) and after heat treatment (60°C / 20 min).

Rheological behavior: shear stress and viscosity

The shear stress and apparent viscosity values were obtained from beverages prepared in the proportion of 1:10 with extraction at 30 and 80°C, from the flow curves related to the apparent viscosity (mPa.s) as a function of the strain rate (s^{-1}).

The extracts obtained in the 1:10 dilution without thermal treatment at 60°C20min^{-1}, obtained higher values of shear stress. Those obtained at 30°C, the shear stress range varied from 0.62 to 6.21 Pa, while those at 80°C, varied from 0.57to 4.13 Pa (Figure 4).

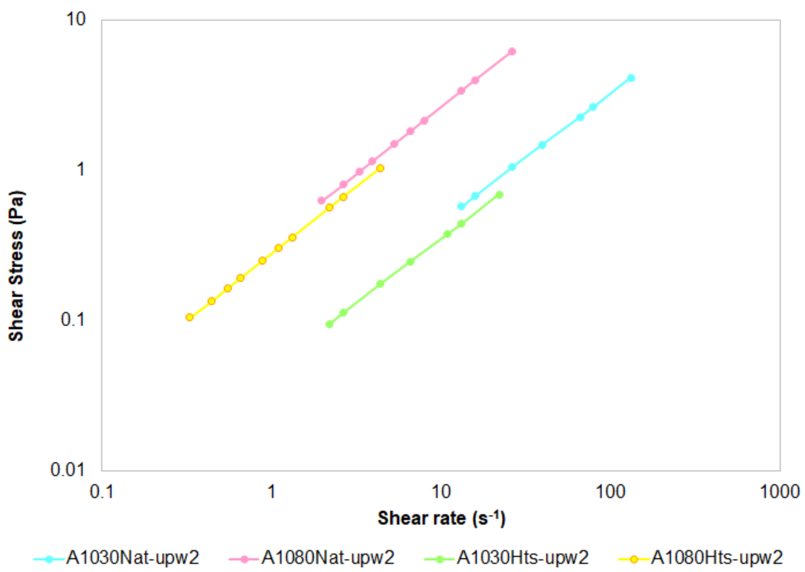

Figure 4. Behavior of the shear stress of beverages obtained in the proportion 1:10 at 30 and 80°C, with and without heat treatment of 60°C20 min^{-1}.

Regarding the viscosity parameter (Figure 5), it is possible to observe that the same beverages (1:10 dilution at 30 and 80°C, without heat treatment at 60°C20min^{-1}) that presented the highest values of shear stress, presented concomitantly, the highest viscosities. In this way, it is possible to observe that a greater tension to promote a deformation rate implies greater resistance to the fluid flow, causing greater viscosity.

Bocaiuva pulp is naturally considered to have high viscosity, and from the results obtained, it is possible to infer that the extraction temperature interfered in this characteristic, providing an increase in the viscosity of the beverage.

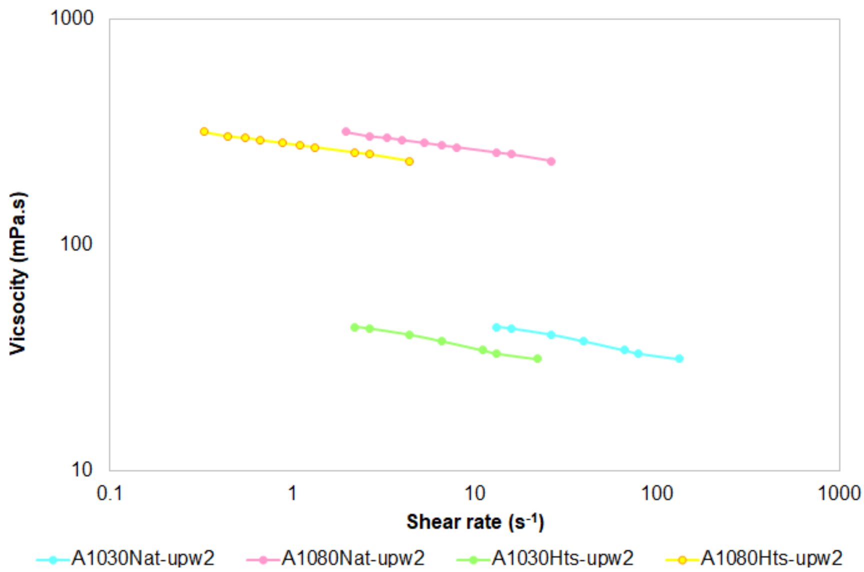

Figure 5. Behavior of shear stress and viscosity as a function of strain rate of beverages obtained in the proportion 1:10 at 30 and 80°C, with and without heat treatment of 60°C20 min^{-1}.

Studies in the literature identified the viscosity of vegetable beverages with an average value of 3.2 mPa.s for rice beverages (Russell & Delahunty, 2004), values ranging from 11 to 43 mPa.s in soybean beverages with different sucrose percentages (Barbosa, 2007) and between 13.50 and 26.60 mPa.s in commercial soy beverages (Terhaag, 2011). Jaekel el al. (2010) showed an average value of 27.67 mPa.s for a beverage made with different proportions of rice and soy. These data reveal that bocaiuva has great potential for the incorporation of water-soluble beverages due to its high viscosity, which was superior to the data reported in the literature, and can act as a natural thickener, as already evidenced by Reis and Schmiele (2019).

Multivariate statistics

Figure 6 presents cluster analysis for all formulations of beverages, taking into account the factors extraction temperature and dilution proportions.

There is a separation into three groups within the dendrogram, where there is intragroup homogeneity and intergroup heterogeneity, in relation to the variables studied.

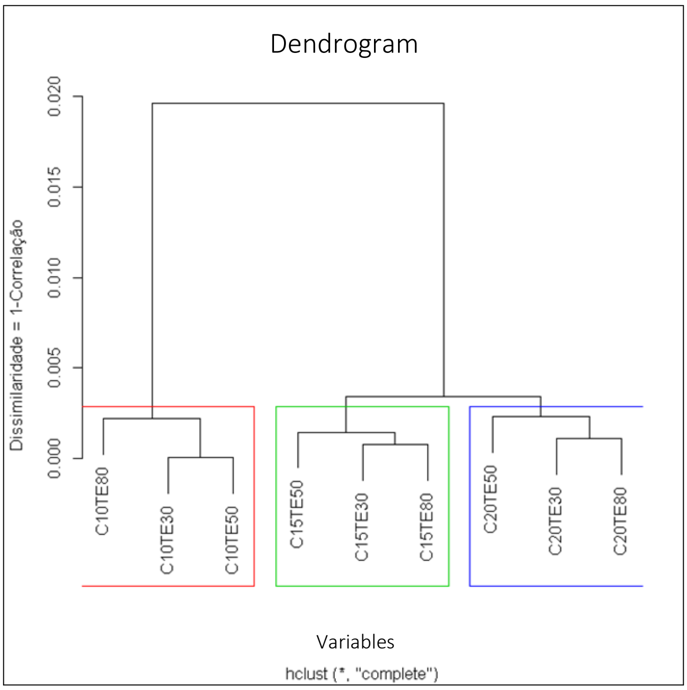

Figure 6. Dendogram formed by hierarchical grouping of the formulations of beverages obtained at different dilution ratios (1:10, 1:15 and 1:20), and extraction temperatures (30, 50 and 80ºC).

The three groups were separated according to the pulp: water dilution ratio (1:10, 1:15 and 1:20), where it is possible to notice that within the same group, the temperature factor did not generate a statistically significant difference.

Principal component analysis (PCA) was used to investigate the association between the combinations of extraction temperature, dilution ratio and passing or not passing through heat treatment prior to performing the analyzes (Figure 7).

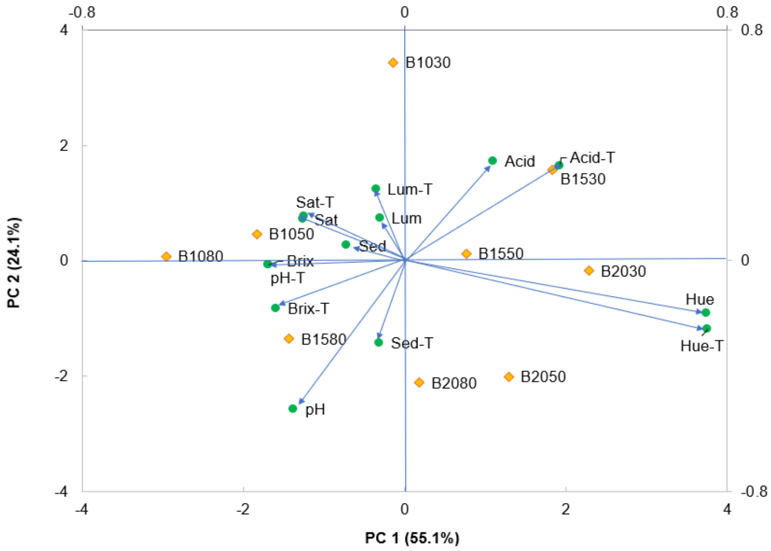

Figure 7. Principal component analysis (PCA) of beverages obtained at different dilution ratios (1:10, 1:15 and 1:20), extraction temperatures (30, 50 and 80°C) and heat treatment of 60°C20 min^{-1}.

The first two main components explain 79.2% of the data variance (PC1 = 55.1% and PC2 = 24.1%), with Figure 7 divided into four regions or quadrants.

It is observed that all the beverages obtained by dilution 1:20 are in the lower right quadrant indicating that the extraction temperature in these dilutions did not generate a correlation with the analytical parameters studied, with the exception of the hue or color tone which showed high correlation.

The beverages obtained by dilution 1:15 showed high correlation with the parameter titratable acidity (upper right quadrant) and pH (lower left quadrant). Those obtained by dilution 1:10, are close to each other (upper left quadrant), as well as strongly correlated with the other analytical parameters studied.

Thus, the results obtained in the principal component analysis (PCA) and dendrogram hierarchical grouping, shown in Figures 6 and 7, demonstrate that the extraction temperature factor (30, 50 and 80°C) within the same dilution ratio (1:10, 1:15 and 1:20), shows a strong statistical correlation.

Microbiological profile

Considering that beverage was obtained only from the pulp of bocaiuva, the microbiological standards of RDC nº 12 of 2001 (Brasil, 2001) were established for pasteurized and refrigerated juices, which must be absent from Salmonella sp. in 25 mL of product and, maximum limit of 10 most likely number (MPN) of thermotolerant coliforms at 45°C per mL. The results of the microbiological evaluations are represented in Table 4.

Table 4. Microbiological profile of bocaiuva pulp beverage subjected to heat treatment.

	microorganism count		
Sample	Salmonella sp.	Coliforms a 35°C (NMP mL^{-1})	Coliforms a 45°C (NMP mL^{-1})
B1030	Abs. in 25 g	<3	< 1.0 x 10
B1050	Abs. in 25 g	<3	< 1.0 x 10
B1080	Abs. in 25 g	<3	< 1.0 x 10
B1530	Abs. in 25 g	<3	< 1.0 x 10
B1550	Abs. in 25 g	<3	< 1.0 x 10
B1580	Abs. in 25 g	<3	< 1.0 x 10
B2030	Abs. in 25 g	<3	< 1.0 x 10
B2050	Abs. in 25 g	<3	< 1.0 x 10
B2080	Abs. in 25 g	<3	< 1.0 x 10

Abs. = absente

The extracts are in satisfactory hygienic-sanitary conditions, in accordance with the microbiological standards recommended by the legislation, therefore being considered suitable for consumption and indicating that the heat treatment was efficient to inactivate and reduce the microbiota present in the fruits.

Conclusion

The extraction temperature influenced the technological parameters, mainly the viscosity, which had a considerable increase after extraction at 80 C, observed in the beverage with a ratio of 1:10 (bocaiuva pulp / water mm^{-1}). In addition, the viscosity found is higher than that found in other studies carried out with vegetable drinks.

The values of titratable acidity in terms of % of citric acid were less than 0.1 %, indicating low levels of organic acids influencing the result with low soluble solids giving the *a. aculeata* qualities suitable for natural consumption. The pH of the beverages remained in a range close to neutrality (pH 6-8), which is a favorable parameter, since many of the proteins are precipitated at acidic or very alkaline pH, contributing to an unfavorable aspect in beverages. It was possible to observe a correlation in the parameters of acidity, soluble solids and pH, which contribute to the sensory characteristics and the sweet and sour taste of the fruit on the palate, in addition to having been noticed in the multivariate statistics, the correlation between pH and soluble solids in the beverage with and without treatment in the proportion 1:10 and at the temperature of 50 and 80°C.

It was also possible to elaborate a bocaiuva pulp beverage with great technological and nutritional potential and with a guarantee of food safety, being absent from pathogenic microorganisms. In this way, large-scale production and inclusion in commerce could be a viable alternative for the local population, encouraging the consumption of healthier products from a nutritional point of view, easily accessible and that value the natural resources of the Cerrado, contributing for the country's economy. However, there is a need to carry out new studies to determine the composition of nutrients, bioactive compounds, minerals and the development of new products for the use of *A. aculeata* fruits.

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