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# Development, sensory profile and physicochemical properties of jabuticaba nectar with lyophilized jussara pulp[1]

## Desenvolvimento, perfil sensorial e propriedades físico-químicas de néctar de jabuticaba com polpa de jussara liofilizada

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**ABSTRACT -** Jabuticaba and jussara are both fruits from the Brazilian Atlantic Forest and endangered plant species due to their unsustainable exploitation. In order to protect these plants, it is important to develop products made with these fruits. We have developed a ready-to-drink jabuticaba nectar with the addition of lyophilized jussara pulp (LJP) applying sensory tests, such as acceptance test and Check-All-That-Apply (CATA). Optimal sensory conditions ranged between 150 g $L^{-1}$ and 200 g $L^{-1}$ for sucrose concentration and between 450 mL $L^{-1}$ and 550 mL $L^{-1}$ for jabuticaba pulp concentration. Just-about-right scale showed that the ideal concentration of LJP used as a natural color additive was 7.2 g $L^{-1}$ ($R^2$=0.99902). Affective test showed that nectars added with LJP had higher acceptance means than samples without the colorant ($P$<0.05). LJP addition led to 5.0-fold increase in total phenolic contents. Samples colored with LJP had similar sensory descriptive profiles, as well as nectars without jussara colorant, according to CATA results ($P$>0.05). Jabuticaba nectar added with LJP presented high acceptance among consumers ($P$<0.05), indicating commercial potential for this product.

**Key words:** Affective test. Just-About-Right scale. Check-All-That-Apply. Antioxidant activity. Phenolic compounds.

**RESUMO -** Jabuticaba e jussara são frutos da Mata Atlântica brasileira e são espécies de frutos em risco de extinção devido à sua exploração insustentável. Para proteger essas plantas, é preciso desenvolver novos produtos que as utilizem como matérias-primas. No presente trabalho, desenvolvemos um néctar pronto para consumo de jabuticaba com a adição de polpa de jussara liofilizada (LJP) realizando testes sensoriais como teste de aceitação e *Check-All-That-Apply* (CATA). As condições sensoriais ótimas variaram entre 150 g $L^{-1}$ e 200 g $L^{-1}$ para concentração de sacarose e entre 450 mL $L^{-1}$ e 550 mL $L^{-1}$ para concentração de polpa de jabuticaba. A concentração ideal de LJP como corante natural foi obtida no teste de escala do ideal e foi igual a 7,2 g $L^{-1}$ ($R^2$=0,99902). O teste afetivo mostrou que os néctares com adição de LJP tiveram maiores médias de aceitação do que as amostras sem o corante ($P$<0,05). A adição de LJP aumentou em 5 vezes o teor de fenólicos totais. Amostras com LJP tiveram perfis sensoriais descritivos semelhantes, assim como amostras sem a adição do corante, de acordo com os resultados do CATA ($P$>0,05). O néctar de jabuticaba com adição de LJP foi bem aceito pelos consumidores ($P$<0,05), indicando potencial comercial para esse produto.

**Palavras-chave:** Teste afetivo. Escala do ideal. Check-All-That-Apply. Atividade antioxidante. Compostos fenólicos.

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## INTRODUCTION

Jabuticaba (*Myrciaria jaboticaba*) is a native fruit from the Brazilian Atlantic Forest, mainly found in Southern Brazil (COSTA *et al*., 2013). It is a fruit tree grown at a low-scale by small farmers, and it has high nutritional value, being rich in vitamin C, minerals and fibers (INADA *et al.*, 2015). Furthermore, its dark purple to black peel presents significant quantities of bioactive compounds, such as anthocyanins and phenolic acids (INADA *et al.*, 2015).

Due to its high water and sugar contents, jabuticaba needs to be consumed in two to three days. Besides, its harvest period is very short: the tree produces fruits once or, more rarely, twice a year, between August and November (COSTA *et al*., 2013). These two factors limit the commercialization and the industrial use of jabuticaba. Nevertheless, this fruit presents desirable sensory attributes, and, in Brazil, it is consumed as a fresh fruit or used for producing artisanal products such as jam, wine and liqueur (COSTA *et al*., 2013).

Jussara (*Euterpe edulis*) is another fruit from the same biome, very similar to açaí (*Euterpe oleracea*), with a thin shiny dark purple to black skin and a single seed (BICUDO; RIBANI; BETA, 2014; BORGES *et al.*, 2011). However, jussara fruit is much less commonly eaten than açaí, since the palm trees are mainly exploited for the extraction of the edible palm heart. Jussara palm is not commercially grown and its illegal exploitation without management has contributed to endanger this plant species (INADA *et al.*, 2015). Harvesting of jussara fruits would be a sustainable activity potentially more profitable than extraction of the palm heart, since its pulp may be used to produce beverages, ice cream and jam (BORGES *et al.*, 2011; INADA *et al.*, 2015). The skin of this fruit also presents high contents of anthocyanins and phenolic acids and the fruit's antioxidant activity is higher than those of other berries (INADA *et al.*, 2015).

The consumption of fruits, fresh and processed, is increasing worldwide due to consumers' growing interest in healthy and nutritious food products (FREITAS; MATTIETTO, 2013). According to the Brazilian legislation, a ready-to-drink tropical fruit nectar is obtained from the dilution in potable water of the edible part of the fruit added with sugars. Jabuticaba-based beverages such as juices and nectars are not commercialized in Brazil. Although jabuticaba depulping produces a juice with pleasant flavor and aroma, its pale brownish pink color does not resemble that of the fresh fruit, impacting its acceptance by frustrating consumers' expectancy (INADA *et al*., 2018). In this sense, the development of a jabuticaba nectar using lyophilized jussara pulp as a natural colorant would be a promising way to use both these fruits in the food industry. The application of sensory tests in the development of new food products is very important, since they are efficient tools to evaluate the product's marketing acceptance and determine ideal attributes for a product (ARES; JAEGER, 2013).

The industrial exploitation of these fruits would have a positive impact by increasing their consumption, avoiding commercial losses and preserving the biodiversity of the Brazilian Atlantic Forest. Therefore, the aim of the present study was to apply sensory evaluation techniques to develop a ready-to-drink jabuticaba nectar added with lyophilized jussara pulp as a natural color additive, optimizing its consumers' acceptance and studying its sensory profile.

## MATERIAL AND METHODS

### Standards and chemicals

Potassium persulfate, 2,4,6-tris(2-pyridyl)-S-triazine (TPTZ), 2,2'-azino-bis (2-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) and (±)-6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox) were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Iron (II) sulfate was purchased from Merck KGaA (Darmstadt, Germany). Anthocyanins and non-anthocyanins standards were purchased respectively from Indofine Chemical Co. (Hillsborough, NJ, USA) and Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). All solvents were HPLC grade from Tedia (Fairfield, OH, USA). HPLC grade water (Milli-Q system, Millipore, Bedford, MA, USA) was used throughout the experiments.

### Jabuticaba pulp and lyophilized jussara pulp

Jabuticaba fruits (*Myrciaria jaboticaba*, cv. Sabará) from Minas Gerais state were purchased at Rio de Janeiro's agricultural trading center in 2014. The fruits were sanitized in 100 ppm solution of sodium hypochlorite for 15 min and the pulp was extracted in a horizontal depulper (INADA *et al.*, 2015). The pulp extracted was stored at -20 °C until the preparation of the nectars.

Jussara palm (*Euterpe edulis*) fruits were obtained in 2014 from Juçaí™ processing (Resende, Rio de Janeiro state, Brazil). The fruits were sanitized in 100 ppm solution of sodium hypochlorite for 15 min and immersed in water at 40 °C for 30 min for peel softening. Then, the fruits were processed in a vertical depulper (INADA *et al.*, 2015) and lyophilized in a freeze dryer (FreeZone®; Labconco, Kansas City, MO) at -50 °C and 0.025 mbar for 48 h. Lyophilized jussara pulp (LJP) was stored at room temperature in desiccator until the preparation of the nectars.

**Simultaneous optimization of jabuticaba nectar acceptance based on pulp and sucrose concentrations using response surface methodology**

Surface response methodology was used to optimize jabuticaba nectar acceptance. Independent variables were jabuticaba pulp and sucrose concentrations and the dependent variable was consumers' overall liking. A five level ($-\alpha$, -1, 0, 1, and $\alpha$), two variable central composite rotatable design (CCRD), with three central points and four axial points was used. Table 1 presents coded and real values for both independent variables. Jabuticaba pulp lowest concentration was chosen according to minimum concentration (30%) of fruit pulp established by the Brazilian official nectars standards.

Acceptance test was carried out with 93 consumers among university students, professors and employees (MEILGAARD; CIVILLE; CARR, 1999). Samples were coded with three-digit numbers and monadically presented to each participant. The presentation order was balanced (MACFIE *et al*., 1989) and a nine cm hedonic line scale ranging from "dislike extremely" and "like extremely" was used. The results were analyzed by a multiple linear regression method, which describes the effects of variables in first and second-order polynomial models (STATISTICA 7.0 - StatSoft, Inc.). Experimental data were fitted to the selected model and regression coefficients obtained.

**Evaluation of nectars' sweetness**

A sweetness ranking test was carried out to verify whether lower sucrose concentrations could be used in the nectar without affecting consumers' perception on the product's sweetness. Five samples, including the sample with optimal acceptance determined in the previous sensory test (210 g $L^{-1}$), and samples with progressively lower sucrose concentrations (200 g $L^{-1}$, 190 g L-, 180 g $L^{-1}$ and 170 g $L^{-1}$) were coded with three-digits numbers and presented all together in balanced order (MACFIE *et al*., 1989) to 86 consumers among university students, professors and employees who were asked to rank them in order of increasing sweetness (MEILGAARD; CIVILLE; CARR, 1999).

**Ideal color determination**

Although the white color of jabuticaba pulp, its peel is dark purple (INADA *et al*., 2015). Therefore, an ideal color determination test was carried out to verify among consumers what color the nectar should present using LJP as a natural color additive.

Nectar samples were prepared with increasingly higher concentrations of LJP (0, 1.5 g $L^{-1}$, 3 g $L^{-1}$, 6 g $L^{-1}$, 12 g $L^{-1}$ and 24 g $L^{-1}$), coded with three-digits numbers and monadically presented in balanced order (MACFIE *et al*., 1989) to 100 consumers among university students, professors and employees. Consumers used a nine-point structured just-about-right scale (MEILGAARD; CIVILLE; CARR, 1999) ranging from "extremely darker than ideal" to "extremely less dark than ideal".

**Table 1** - Coded and real values of independent variables used in the central composite rotatable design (CCRD)

| Sample | Coded value for jabuticaba pulp concentration | Coded value for sucrose concentration | Real value for jabuticaba pulp concentration (g $L^{-1}$) | Real value for sucrose concentration (g $L^{-1}$) |
|---|---|---|---|---|
| 1 | -1 | -1 | 410 | 44 |
| 2 | 1 | -1 | 890 | 44 |
| 3 | -1 | 1 | 410 | 266 |
| 4 | 1 | 1 | 890 | 266 |
| 5 | -1.41 ($-\alpha$) | 0 | 300 | 150 |
| 6 | 1.41 ($\alpha$) | 0 | 1000 | 150 |
| 7 | 0 | -1.41 ($-\alpha$) | 650 | 0 |
| 8 | 0 | 1.41 ($\alpha$) | 650 | 300 |
| 9 | 0 | 0 | 650 | 150 |
| 10 | 0 | 0 | 650 | 150 |
| 11 | 0 | 0 | 650 | 150 |

**Acceptance of nectars with and without LJP addition**

In order to evaluate if LJP addition would affect consumers' liking, an acceptance test was carried out (MEILGAARD; CIVILLE; CARR, 1999). Samples with different LJP concentrations (0, 1.5 g $L^{-1}$, 3 g $L^{-1}$, 4.5 g $L^{-1}$, 6 g $L^{-1}$ and 7.2 g $L^{-1}$) were prepared. The highest concentration of LJP was determined according to ideal color determination. Samples were coded with three-digits numbers and presented monadically in balanced order (MACFIE *et al.*, 1989) to 120 consumers among university students, professors and employees who were asked to evaluate acceptance for overall liking, appearance, aroma, flavor and texture using nine-point structured hedonic scales ranging from "dislike extremely" to "like extremely".

**Evaluation of nectars' sensory profiles using Check-All-That-Apply (CATA) and acceptance of nectars with different sucrose and LJP concentrations**

A Check-All-That-Apply (CATA) Test was applied in order to obtain nectars' sensory profiles. CATA questions are often used in food product development, since it is a simple method to get an insight on consumers' perception of the product and to enable direct identification of drivers of liking (ARES *et al.*, 2010).

Six nectar samples were prepared without LJP and with the ideal LJP concentration (7.2 g $L^{-1}$), in combination with three different sucrose concentrations (180 g $L^{-1}$, 190 g $L^{-1}$ and 210 g $L^{-1}$). Samples were identified with three-digit number and monadically presented in balanced order (MACFIE *et al.*, 1989) to 115 consumers among university students, professors and employees. The group was asked to select all the terms that they considered appropriate to describe the samples in a questionnaire with 18 sensory attribute items related to appearance, aroma, flavor and texture, nine items related to occasions for nectar consumption and three items related to ways of buying the beverage (powder, ready-to-drink or concentrate) (VARELA; ARES, 2012). The sensory attributes selection was performed by a focus group with 10 consumers among university students (VARELA; ARES, 2012). Consumers also answered the same CATA questions to describe the sensory characteristics of their ideal nectar (ARES *et al.*, 2014).

Participants received a different CATA ballot for each sample and each ballot had sensory and non-sensory items listed in a different order to minimize bias results due to attribute order on consumers' responses (ARES; JAEGER, 2013). The ballots also had an acceptance questionnaire with structured nine-point hedonic scales, ranging from "dislike extremely" to "like extremely", in order to evaluate nectars acceptance for overall liking, appearance, aroma, flavor and texture.

**Chemical characterization of nectars evaluated by CATA test**

Total soluble solids (TSS) and pH values were determined in nectars by official methods (ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS, 2000). Instrumental color of nectars was measured in triplicate using Konica Minolta CR-400 colorimeter (Konica Minolta, Tokyo, Japan). The equipment was set to illuminant $D_{65}$ (2° observer angle) and calibrated using a standard white reflector plate. The CIELab color space was used to determine the color components: $L^*$ (lightness; 0 = black, 100 = white), $a^*$ ($-a^*$, greenness; $+a^*$, redness) and $b^*$ ($-b^*$, blueness; $+b^*$, yellowness).

Phenolic compounds in nectars were determined in duplicate directly after centrifugation (11,300 × *g*, 10 min) and filtration through a 0.45 µm PTFE filter unit (Millipore, Barueri, Brazil). The liquid chromatography system (Shimadzu®) included a quaternary pump LC-20AT, automatic injector SIL-20AHT, diode-array detector (DAD) SPD-M20A, system controller CBM-20A and degasser DGU-20A5. Chromatographic separation of phenolic compounds was achieved using a C18 reverse phase column (INADA et *al.*, 2015). Identification of all phenolic compounds was performed by comparison with retention time and absorption spectrum of the respective standard. Quantification was performed by external calibration. Data were acquired by LC solution software (Shimadzu Corporation®, version 1.25, 2009). Results were expressed as µg per 100 mL.

The antioxidant activity of nectars was determined directly after centrifugation (11,300 × *g*, 10 min) in triplicate using FRAP (Ferric Reducing Antioxidant Power) and TEAC (Trolox Equivalent Antioxidant Capacity) assays. The FRAP assay was performed according to Benzie and Strain (1996) with slight modifications. Results were expressed as micromoles of $Fe^{2+}$ equivalents per 100 mL. The TEAC assay was performed according to Re *et al*. (1999) with slight modifications. Results were expressed as micromoles of Trolox equivalents per 100 mL.

**Ethical committee**

This study was approved by the Federal University of Rio de Janeiro Ethical Committee (process number 38796514.3.0000.5257). All consumers signed the consent form, which contained information about the project, and they authorized the use of their responses in the study.

**Statistical analysis**

Analysis of Variance (ANOVA) was performed on XLSTAT 2015.4.01 (Addinsoft) to verify model validity. Friedman test (SIEGEL; CASTELLAN, 1988) was applied to verify if samples were statistically different at a 5% significance level (item 2.3), using Newell and Mac table. Regressions analyses were performed to evaluate ideal color determination test results.

ANOVA followed by Fisher's LSD test, both at a 5% significance level, were performed on XLSTAT 2015.4.01 (Addinsoft) to analyze nectars acceptance means. Cluster analysis (agglomerative hierarchical clustering using Euclidean distance for Ward method) was also used. Comparisons between clusters for each sample (independent samples Student's t-test) and among samples within each cluster (ANOVA followed by Fisher's test) were performed on XLSTAT 2015.4.01 (Addinsoft). Chi-square tests were performed on XLSTAT 2015.4.01 (Addinsoft) to compare demographic data between clusters.

CATA results were evaluated by the frequency that each item was selected for each sample. Cochran's Q test at a 5% significance level was performed on XLSTAT 2015.4.01 (Addinsoft) in order to assess statistical differences (VARELA; ARES, 2012). Acceptance means were analyzed with ANOVA followed by Fisher's LSD test both at a 5% significance level (XLSTAT 2015.4.01, Addinsoft). Cluster analysis, multiple factor analysis and internal preference mapping were also applied. Comparisons between clusters for each sample (independent samples Student's t-test) and among samples within each cluster (ANOVA followed by Fisher's test) were performed on XLSTAT 2015.4.01 (Addinsoft). Chi-square tests were performed on XLSTAT 2015.4.01 (Addinsoft) to compare demographic data and frequencies of consumption between clusters.

Student's unpaired t-test was performed in order to compare chemical characterization of nectars, using GraphPad Prism software for Windows, version 5.04 (GraphPad Software, San Diego, CA). Results were considered significant when $P<0.05$.

## RESULTS AND DISCUSSION

**Optimization of jabuticaba nectar regarding pulp concentration, sweetness and color**

Both independent variables (jabuticaba pulp and sucrose concentrations) presented significant ($P<0.05$) linear and quadratic effects on the dependent variable (consumers' overall liking). ANOVA showed that the model is significant, providing $F$-test value higher than the critical value and $R^2$ higher than 0.98 ($P<0.0001$). Therefore, the acceptance model can be described with coded values according to Equation 1:

$$Acceptance = 5.41 - 0.307*(JPC) - 0.289*(JPC)^2 + 0.861*(SC) - .824*(SC)^2 \quad (1)$$

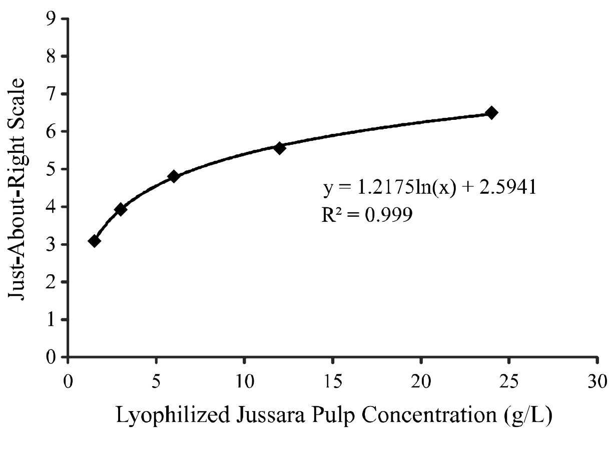
where: *JPC* is the jabuticaba pulp concentration and *SC* is the sucrose concentration.

Model coefficients shows that sucrose concentration has a stronger influence on jabuticaba nectar acceptance than jabuticaba pulp concentration since both linear and quadratic coefficients for sucrose are higher than those for jabuticaba pulp. According to the model, optimal sensory conditions were 520 mL $L^{-1}$ (real value) for jabuticaba pulp concentration and 210 g $L^{-1}$ (real value) for sucrose concentration.

Nectars samples with sucrose concentrations of 190 g $L^{-1}$, 200 g $L^{-1}$and 210 g $L^{-1}$ showed equivalent ($P>0.05$) rank sums of sweetness (276, 286 and 276, respectively), which were higher than those with sucrose concentrations of 180 g $L^{-1}$ and 170 g $L^{-1}$ (229 and 223, respectively). Therefore, it was possible to reduce sucrose concentration in jabuticaba nectar to 190 g $L^{-1}$ without consumers detecting differences on nectar sweetness.

Just-about-right ideal color scale data provided a logarithmic model ($R^2 = 0.99902$), confirming Stevens' power law, which states that the relation between attribute perception and physical stimulus intensity is logarithmical (LAWLESS; HEYMANN, 2010). From the model (Figure 1), LJP concentration was calculated as 7.2 g $L^{-1}$. In comparison with other studies that used from 1 mg $L^{-1}$ to 2 mg $L^{-1}$ of fruit extracts as colorant in fruit juices (DUANGMAL; SAICHEUA; SUEEPRASAN, 2008; REIN; HEINONEN, 2004), the ideal concentration of LJP could be considered high.

**Figure 1** - Logarithmic regression obtained from Ideal Color Determination Test



This result may be explained by the dark color of jabuticaba peel, which probably influences consumers' perception that jabuticaba nectar should also show the same dark color. According to Brazilian legislation, natural pigments such as chlorophylls, carotenoids and anthocyanins from fruits and vegetables can be used *quantum satis*, which means that no maximum level is specified. Therefore, since LJP is a natural edible product and could be considered a natural colorant, this amount or higher concentrations of this colorant would not represent a safety issue.

**Acceptance of nectars with and without LJP addition**

ANOVA and Fisher's LSD test showed that the sample with the highest LJP concentration (7.2 g $L^{-1}$) had the highest acceptance means for overall liking (7.5), aroma (6.6) and flavor (7.5) ($P$<0.05), while the sample without LJP had the lowest acceptance means (5.4, 3.6 and 5.5 for overall liking, appearance and texture, respectively).

Cluster analysis segmented consumers into two groups: cluster 1 with 57 consumers and cluster 2, with 63. Student's t-tests between clusters for each sample were applied to validate the segmentation. There were significant differences ($P$<0.05) between the two clusters for all samples, indicating that segmentation was valid. ANOVA followed by Fisher's LSD test showed that for cluster 2, samples with higher concentrations of LJP (3 g $L^{-1}$, 4.5 g $L^{-1}$, 6 g $L^{-1}$and 7.2 g $L^{-1}$) were equally preferred ($P$>0.05) by consumers, while for cluster 1, the sample with 7.2 g $L^{-1}$ was preferred ($P$<0.05) by consumers. For cluster 2, samples with the lowest concentration of LJP and without LJP had lower acceptance ($P$<0.05) than same samples for cluster 1. Despite these differences, acceptance of the products was similar between both clusters: most consumers preferred ($P$<0.05) samples with LJP addition, which suggests that the use of this natural color would increase jabuticaba nectar acceptance.

**Sensory profiles and acceptance of nectars with different sucrose and LJP concentrations and chemical analysis of samples**

Samples with different sucrose concentrations and added with LJP had similar sensory profiles, since there was no significant difference ($P$>0.05) for several attributes, such as "with pieces", "açaí color", "guava color", "glossy", "homogeneous" and "açaí flavor" (Table 2).

Likewise, samples with different sucrose concentrations and without LJP had similar sensory profiles, as no significant difference was found ($P$>0.05) for the same attributes. However, for aroma attributes and some flavor attributes, such as "jabuticaba aroma", "sweet aroma", "sweet taste", "sour taste" and "jabuticaba flavor", there was no significant difference among all six samples, showing that LJP addition as a natural color additive did not modify aroma and flavor attributes.

Consumption occasions more indicated by consumers were "breakfast", "snack" and "picnic" (Table 3). Concerning these CATA questions, consumers did not discriminate between samples with or without LJP as they did for sensory attributes, since for several items there was no significant difference among six or five samples. "Ready-to-drink" was the most indicated way of buying the beverage and there was no significant difference among samples for options "concentrate" and "powder" (Table 3).

CATA results for the ideal product showed that the necessary attributes were "açaí color", "glossy", "homogeneous" and "jabuticaba flavor" and negative attributes were "with pieces", "guava color" and "opaque" (Figure 2).

Acceptance test results showed that nectars with LJP had higher ($P$<0.05) acceptance means for overall liking, appearance and texture than nectars without LJP. However, for aroma and flavor, consumers did not discriminate between nectars with or without LJP ($P$>0.05), which means that overall impression was mainly related to appearance and texture. Furthermore, from a biological point of view, the aforementioned increase in phenolic compounds, which have been described to present protective effects against cardiovascular diseases, diabetes, cancers and other chronic diseases (COSTA *et al*., 2017; KRUGER *et al*., 2014; SANCHO; PASTORE, 2012), reinforces the advantage of LJP addition to jabuticaba nectar.

A multiple factor analysis was performed to combine descriptive (CATA results) with affective (acceptance results) tests data. Results clearly showed the separation between two groups of samples (with or without LJP). Attributes that were more associated to nectars with LJP addition were "glossy", "homogeneous", "açaí color", "viscous" and "açaí flavor". So, these can be defined as drivers of liking, since these samples also had higher acceptances among consumers than nectars prepared without LJP.

Cluster analysis segmented consumers into two groups: cluster 1 with 85 consumers and cluster 2, with 30. Segmentation was valid according to Student's t-tests between clusters for each sample. ANOVA followed by Fishers' LSD test showed that for both clusters, samples with LJP addition were preferred ($P$<0.05) by consumers, regardless sugar concentration ($P$>0.05). Regarding samples without LJP, for cluster 1, samples with the highest

**Table 2 -** Sensory attributes and frequencies[a] that each attribute was indicated (CATA Test)

| Sensory attributes | Without LJP[b] | | | With 7.2 g $L^{-1}$ LJP | | |
|---|---|---|---|---|---|---|
| | 180 g $L^{-1}$ sucrose | 190 g $L^{-1}$ sucrose | 210 g $L^{-1}$ sucrose | 180 g $L^{-1}$ sucrose | 190 g $L^{-1}$ sucrose | 210 g $L^{-1}$ sucrose |
| With pieces (appearance) | 102b | 104 b | 106 b | 22 a | 24 a | 19 a |
| Açaí color | 0 a | 0 a | 0 a | 81 b | 87 b | 83 b |
| Guava color | 46 b | 52 b | 43 b | 5a | 6 a | 5 a |
| Glossy | 18 a | 18 a | 16 a | 43 b | 43 b | 51 b |
| Opaque | 48 a | 48 a | 49 a | 43 a | 45 a | 37 a |
| Homogeneous (appearance) | 2 a | 2 a | 4 a | 63 b | 63 b | 71 b |
| Jabuticaba aroma | 63 a | 60 a | 56 a | 49 a | 57 a | 63 a |
| Sweet aroma | 62 a | 59 a | 61 a | 69 a | 62 a | 62 a |
| Sweet taste | 74 a | 87 a | 85 a | 79 a | 76 a | 88 a |
| Sour taste | 40 a | 32 a | 35 a | 27 a | 32 a | 28 a |
| Guava flavor | 13 a | 15 a | 14 a | 6 a | 7 a | 8 a |
| Açaí flavor | 2 a | 0 a | 1 a | 34 b | 32 b | 25 b |
| Jabuticaba flavor | 56 a | 56 a | 55 a | 52 a | 57 a | 56 a |
| Astringent | 21 b | 17 ab | 19 ab | 17 ab | 16 ab | 8 a |
| Soil | 5 a | 5 a | 6 a | 18 a | 12 a | 8 a |
| With pieces (texture) | 113 b | 113 b | 113 b | 23 a | 26 a | 29 a |
| Viscous | 12 a | 12 a | 14 ab | 28 ab | 34 b | 24 b |
| Homogeneous (texture) | 3 a | 2 a | 1 a | 82 b | 77 b | 79 b |

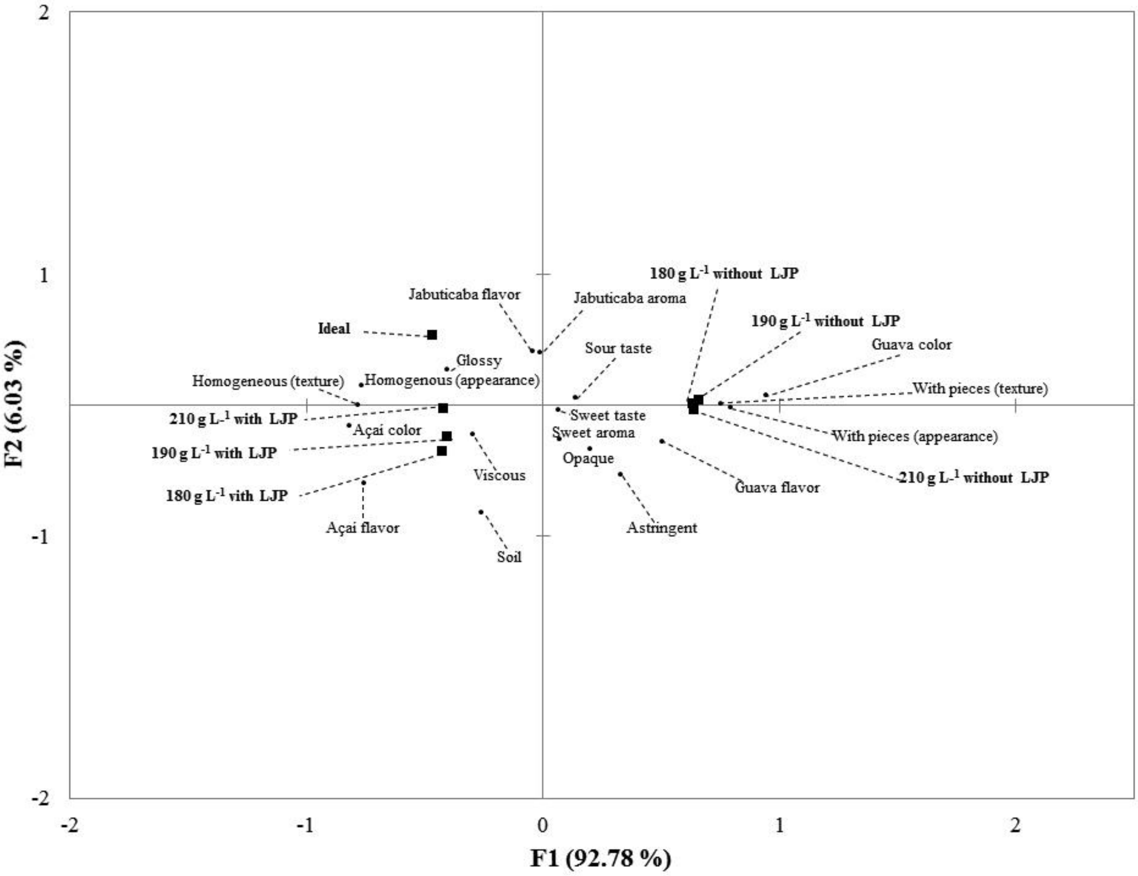
[a]Different letters in a row indicate significant difference between samples (*P*<0.05), according to Cochran's Q test. [b]LJP: Lyophilized jussara pulp

**Table 3 -** Frequencies indicated for the occasions for nectar consumption and ways of buying the beverage (CATA Test)[a]

| Sucrose Concentration | Without LJP[b] | | | With 7.2 g $L^{-1}$ LJP | | |
|---|---|---|---|---|---|---|
| | 180 g $L^{-1}$ | 190 g $L^{-1}$ | 210 g $L^{-1}$ | 180 g $L^{-1}$ | 190 g $L^{-1}$ | 210 g $L^{-1}$ |
| Occasions for nectar consumption | | | | | | |
| Breakfast | 62 a | 68 ab | 68 ab | 72 ab | 82 b | 80 b |
| Snack | 71 a | 80 ab | 81 ab | 88 ab | 92 b | 92 b |
| Lunch | 33 a | 39 ab | 39 ab | 46 ab | 53 b | 56 b |
| Dinner | 31 ab | 28 a | 29 ab | 37 ab | 45 b | 45 b |
| On the beach | 23 a | 22 a | 29 a | 34 a | 36 a | 34 a |
| After physical exercise | 24 a | 16 a | 22 a | 31 a | 27 a | 30 a |
| Picnic | 50 a | 48 a | 50 a | 57 a | 57 a | 63 a |
| To quench thirst | 4 a | 3 a | 4 a | 10 a | 13 a | 15 a |
| Mixed with alcoholic beverage | 17 a | 22abc | 21 ab | 34 bc | 36 bc | 38 c |
| Ways of buying the beverage | | | | | | |
| Ready-to-drink | 77 a | 77 a | 79 a | 92 ab | 97 b | 97 b |
| Concentrate (to dilute in water) | 50 a | 50 a | 51 a | 58 a | 52 a | 57 a |
| Powder | 11 a | 16 a | 14 a | 13 a | 11 a | 14 a |

[a]Different letters in a row indicate significant difference between samples (*P*<0.05), according to Cochran's Q test. [b]LJP: Lyophilized jussara pulp

**Figure 2 -** CATA results (sensory attributes) for samples with lyophilized jussara pulp (with LJP) and different sucrose concentrations (180 g $L^{-1}$, 190 g $L^{-1}$ and 210 g $L^{-1}$), and samples without lyophilized jussara pulp (without LJP) and different sucrose concentrations (180 g $L^{-1}$, 190 g $L^{-1}$ and 210 g $L^{-1}$), including the ideal sample




sugar concentration had higher overall liking scores ($P$<0.05) than samples with less sugar, while for cluster 2, overall liking means for these samples did not differ significantly ($P$>0.05). For cluster 2, samples without LJP addition had lower ($P$<0.05) overall liking means when compared with results of cluster 1. This result also suggests that the use of this natural color would increase jabuticaba nectar acceptance, since for both clusters, samples with LJP addition were preferred ($P$<0.05) by consumers.

LJP addition in nectars resulted in a 1.2% increase of pH values, from 3.24 to 3.28 (Table 4), which was expected since jussara pulp presents higher pH values (4.8) than jabuticaba pulp (3.3) (INADA *et al*., 2015). Nevertheless, the low pH values found in all nectars favors anthocyanins' stability and limits microorganisms' growth. On average, LJP addition led to increase of 3.6% of total soluble solids, from 22.0 to 22.8 °Brix (Table 4).

Six phenolic compounds were identified in nectars without LJP, including gallic, ellagic and *trans*-cinnamic acids, myricetin-3-*O*-rhamnoside, delphinidin-3-*O*-glucoside and cyanidin-3-*O*-glucoside (Table 4). After LJP addition, eight phenolic compounds were identified, including four of the aforementioned compounds (gallic, ellagic and *trans*-cinnamic acids, and cyanidin-3-*O*-glucoside), and 3,4-dihydroxybenzoic, 3,4-dihydroxyphenylacetic and 4-hydroxyphenylacetic acids, and cyanidin-3-*O*-rutinoside. These compounds have already been described in the literature regarding jabuticaba and jussara pulps, respectively (BICUDO; RIBANI; BETA, 2014; BORGES *et al*., 2011; COSTA *et al*., 2013; INADA *et al*., 2015). Nectars with LJP showed 5- and 61-fold higher contents of total phenolic compounds and total anthocyanins, respectively, than those without LJP (Table 4).

On average, LJP addition led to decreases in $L^*$ (29%) and $b^*$ values (50%) and to an increase in $a^*$ values (151%) (Table 4), indicating that the nectars became darker, bluer and redder, respectively, which is in agreement with

**Table 4 -** Physicochemical and chemical characterization of jabuticaba nectars with and without lyophilized jussara pulp (LJP)[a]

| | Nectar without LJP | Nectar with 7.2 g $L^{-1}$ LJP |
|---|---|---|
| pH | 3.24 ± 0.02 b | 3.28 ± 0.02 a |
| TSS[b] (°Brix) | 22.0 ± 0.6 a | 22.8 ± 0.7 a |
| Instrumental color | | |
| L* | 34.46 ± 0.71 a | 24.41 ± 0.57 b |
| a* | 4.95 ± 0.19 b | 12.40 ± 0.41 a |
| b* | 4.78 ± 0.50 a | 2.41 ± 0.11 b |
| Phenolic compounds (µg/100 mL) | | |
| Gallic acid | 2.611±160 a | 2.510 ± 102 a |
| 3,4-Dihydroxybenzoic acid | ND[c] | 66 ± 54 |
| 3,4-Dihydroxyphenylacetic acid | ND | 52 ± 18 |
| 4-Hydroxyphenylacetic acid | ND | 53 ± 6 |
| Ellagic acid | 10 ± 2 b | 47 ± 11 a |
| *trans*-Cinnamic acid | 184 ± 4 a | 139 ± 4 b |
| Myricetin-3-*O*-rhamnoside | 39 ± 5 | ND |
| Delphinidin-3-*O*-glucoside | 44 ± 1 | ND |
| Cyanidin-3-*O*-glucoside | 159 ± 9 b | 600 ± 105 a |
| Cyanidin-3-*O*-rutinoside | ND | 11.776 ± 1.088 |
| Total phenolic compounds | 3.047 ± 181 b | 15.243 ± 1.388 a |
| Antioxidant activity | | |
| FRAP (µmol $Fe^{2+}$/100 mL) | 546 ± 12 b | 901 ± 71 a |
| TEAC (µmol Trolox/100 mL) | 266 ± 19 b | 380 ± 61 a |

[a]Results expressed as mean±SD for triplicates of nectars with sucrose addition (180, 190 and 210 g.$L^{-1}$). Different letters in each line indicate significant difference between nectars (Student's unpaired *t* test, $P$<0.05). [b]Total Soluble Solids. [c]Not detected

the increase of anthocyanins contents. Similar results were observed by Rein and Heinonen (2004) which observed an average decrease of 12% in *L** values and an average increase of 64% in *a** values of fruit juices due to the addition of grape skin extract. Moreover, Khandare *et al.* (2011) observed a 50% increase of *a** and a 27% decrease of *b** values due to a 2-fold increase in anthocyanins contents of black carrot submitted to enzymatic processing. As expected, on average, LJP addition to nectars lead to 65% and 43% increases in antioxidant activity measured by FRAP and TEAC assays, respectively (Table 4), which is related to the increase in total phenolic compounds contents.

## CONCLUSIONS

1. Optimal jabuticaba pulp and sucrose concentrations for the nectar were 520 mL $L^{-1}$ and 210 g $L^{-1}$, respectively. Sucrose concentration could be reduced to 190 g $L^{-1}$;
2. LJP at a concentration of 7.2 g $L^{-1}$ was considered ideal by consumers;
3. LJP addition led to a 61-fold increase in anthocyanins;
4. Nectars with LJP presented higher acceptance than nectars without the pulp addition, indicating that this would be a product with high commercial potential, since its characteristics were similar to the ideal product defined by the same consumers.

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