Response surface methodology optimization of blended fruit nectar: cashew apple and açai

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ABSTRACT
There is a growing market for beverages made with mixed fruits, mainly tropical ones. The objective of this work was to develop blended nectars based on açai and cashew apple pulps and to evaluate them by using sensory consumer tests according to a response surface methodology. Nine formulations were prepared by using different total pulp concentrations and açai-to-cashew apple pulp ratios. The formulation with 30.0% of total pulp and an açai-to-cashew apple pulp ratio of 0.84 (that is to say, 13.7% of açai pulp and 16.3% of cashew apple pulp) was the most accepted by consumers (lowest pulp assayed). This mixed nectar showed high vitamin C and anthocyanin contents, and exhibited an attractive dark violet color, suggesting potential commercial success. The data obtained in this study can be used for large-scale production of new mixed fruit nectars, which suggests that they may represent an exciting option for consumers.

KEYWORDS
Nectar; tropical fruits; cashew apple; açai; blend; sensory evaluation; optimization; response surface methodology; functional compounds; phytochemical bioactives

Introduction
The growing interest in new functional foods with special characteristics and health properties has led to the development of new beverages based on fruit juice blends. The proliferation of ready-to-drink beverages has caused the market to focus its interest on these products (Maia et al., 2019; Zulueta et al., 2007). Fruits contain various bioactive compounds with antioxidant activities, such as carotenoids, vitamins C and E, phenolic compounds, which have been shown to significantly contribute to the total antioxidant capacity of the foods (Chaovanalikit and Wrolstad, 2004; Hassimoto et al., 2005; Silva et al., 2014).

Brazil is currently the third fruit producer in the world (after China and India), being a great producer of tropical fruits (FAO, 2018). Although consumers widely accept tropical fruits or important sources of antioxidant compounds, most tropical fruits are highly perishable, and their post-harvest losses are of major concern in tropical countries (Silva et al., 2020). Losses can be reduced by processing the fruits into various products, such as juices or nectars. There is an increasing market demand for beverages formulated from fruit blends, especially from tropical fruits. Mixed fruit beverages present several advantages, such as the possibility of combining different flavors, nutrients, and functional compounds (Jain and Khudiya, 2004; Maia et al., 2019).

Two fruits (cashew apple – which is a pseudofruit but consumed as fruit – and açai) were selected to be used in this work because of their high production in Brazil, high perishability, and the presence of high concentrations of bioactive components. The cashew apple (Anacardium occidentale L.) has its origin in Brazil and is well established in many tropical regions. The cashew apple is nutritious, juicy,
Açai (Euterpe oleracea Mart.) is a fruit native to the Amazon region (Xiong et al., 2020), currently among the most economically significant palm species in the Brazilian Amazon. It has become one of the Amazon estuary export products to other regions in the world. A distinguishing feature of açai fruit pulp is the presence of a phytochemical-enriched lipid fraction with high antioxidant properties (Muñiz-Miret et al., 1996), which potentially represents a valuable product, given its unique sensory characteristics, dark green color, and potential health benefits related to its traditional therapeutic uses (Jobim et al., 2019; Pacheco et al., 2007). Moreover, açai pulp contains high concentrations of antioxidant polyphenols, primarily anthocyanins (Lichtenthäler et al., 2005), which provide its excellent potential as a functional food ingredient (Freitas Castro et al., 2019; Xiong et al., 2020).

The food industry is continually looking for novel, inexpensive, and more stable sources of phytochemical bioactives. Therefore, this work’s purpose was to develop formulations of blended tropical fruit nectars based on cashew apple and açai pulps using sensory consumer tests and a response surface statistical methodology to determine the best proportions for maximum acceptance and functionality. The results of this research could guide the formulation and development of other fruit products with high functional and nutritional values.

Material and methods

Materials

Pasteurized açai (Euterpe oleracea Mart.) pulp of Da Fruta brand (Araçati, Brazil) and cashew apple (Anacardium occidentale L.) pulp supplied by the company Jandaia (Pacajus, Brazil), were used as raw materials to develop the mixed tropical fruit nectar formulations.

Experimental design

The independent variables studied were: açai-to-cashew apple pulp ratio (1:4–4:1) and pulp content (30–60%) (Table 1). Eleven treatments were defined, including four factorial points (±1, ±1), three central points (0, 0) and four axial points ((±α, 0) and (0, ±α)) (Box and Draper, 1987).

Nectar production

Nine formulations were prepared using different concentrations of açai and cashew apple pulps (Table 1). The blends were mixed with potable water and sucrose to obtain standardized beverages with the same soluble solids’ content, i.e., 11°Brix. Three batches of 10 L of nectar were processed for each formulation. The additives employed in the formulations were sodium benzoate (260 mg.L⁻¹) and sodium metabisulphite (40 mg.L⁻¹). These blends were heated to 85°C for 60s using water bath thermal equipment. After the heat treatment, the nectar was immediately packaged in 0.20 L glass bottles with plastic caps. The bottles were then chilled with an ice bath until it reaches room temperature and stored in a dry place at room temperature (25 ± 2°C) in darkness.

The formulations were analyzed on the same day after processing, and all samples were analyzed simultaneously.
Table 1. Compositions of the mixed fruit nectars.

| Formulations | Coded variable levels | Uncoded variable levels | Acai pulp (%) | Cashew apple pulp (%) |
|--------------|-----------------------|-------------------------|---------------|-----------------------|
|              | $X_1$                 | $X_2$                   | $X_1$         | $X_2$                  |                        |
| 1            | -1                    | -1                      | 0.8           | 34.4                  | 15.3                   | 19.1                   |
| 2            | 1                     | 1                       | 3.5           | 34.4                  | 26.8                   | 7.6                    |
| 3            | -1                    | -1                      | 0.8           | 55.6                  | 24.7                   | 30.9                   |
| 4            | 1                     | 1                       | 3.5           | 55.6                  | 43.3                   | 12.3                   |
| 5            | -α                    | 0                       | 0.25          | 45.0                  | 10.4                   | 34.6                   |
| 6            | +α                    | 0                       | 4.0           | 45.0                  | 36.0                   | 9.0                    |
| 7            | 0                     | -α                      | 2.1           | 30.0                  | 20.3                   | 9.7                    |
| 8            | 0                     | A                       | 2.1           | 60.0                  | 40.6                   | 19.4                   |
| 9(C)*        | 0                     | 0                       | 2.1           | 45.0                  | 30.5                   | 14.5                   |
| 10(C)*       | 0                     | 0                       | 2.1           | 45.0                  | 30.5                   | 14.5                   |
| 11(C)*       | 0                     | 0                       | 2.1           | 45.0                  | 30.5                   | 14.5                   |

$X_1$: Acai-to-cashew apple pulp ratio; $X_2$: Pulp content; (%) *C*: Central point

Chemical and physicochemical analysis

The formulations resulting from all treatments were submitted to the following analysis, conducted in triplicate: pH by a HI 9321 pHmeter (Hanna Instruments, Villafranca, Padovana, Italy); titratable acidity, according to the method outlined by AOAC (1995) and expressed as “g citric acid/100 ml pulp”; soluble solids (“Brix), measured at 20°C using an automatic Atago PR-101 digital refractometer (Atago, Norfolk, VA, USA); ascorbic acid content, determined according to AOAC (1995); total and reducing sugars, according to AOAC (1990); total phenolics, according to Folin-Ciocalteu method (Zielińska and Kozłowska, 2000), values being calculated from calibration curves obtained from five concentrations of gallic acid; total anthocyanins, according to Francis (1989); carotenoids, according to the methodology described by Higby (1962); centrifugable pulp content, according to IFFJP (1991), using an Excelsa II, model 206MP centrifuge, 370 g for 10 min. Color (soluble brown pigments) was determined, according to Rattanathanalerk et al. (2005) methodology. Color intensity was quantified by measuring the filtrate absorbance at 420 nm against the blank in a Micronal B585 (Micronal) spectrophotometer.

All analyses were performed in triplicate for each formulation batch, and the results were expressed as mean ± SD (n = 3).

Sensory evaluation

Sensory evaluations were conducted for each nectar to determine the most acceptable mixed nectar by the panelists. A group of 70 non-trained panelists, being 57 women and 13 men between 20 to 45 years of age who were not familiar with the mixed nectar flavor, was recruited as suggested by Stone and Sidel (1993) in a laboratory test. The tests were applied in individual booths equipped with daylight fluorescent lamps. The nectars were served monadically, under controlled conditions. All consumers evaluated samples from all treatments. The samples (30 mL) were served at normal consumption temperature (12 ± 1°C) in small 1oz glass cups randomly numbered with three-digit numbers. They were presented in balanced order for each assessment (Macfie et al., 1989). Flavor and overall impression were evaluated using a nine-point structured hedonic scale (Meilgaard et al., 1999). For data analysis, numerical values were associated with each category, from 1 (“disliked it very much”) to 9 (“liked it very much”). Purchase intention was also evaluated using a 5-point scale ranging from ‘would definitely not buy’ (1) over ‘maybe not buy, maybe buy’ (3) to ‘would definitely buy’ (5).
Statistical analysis

The juice proportions were defined by response surface methodology to the mixture using Statistica, version 9.0 (StatSoft, 2010). For each physicochemical or sensory attribute, the linear, quadratic, and cubic model was fitted from the analytical results. The models obtained were evaluated (significance, P ≤ .05), determination coefficients (R²), regression significance, and the lack of fit. The contour plots were used to analyze the behavior of each attribute studied as a function of the açai-to-cashew apple pulp ratios and select the best formulation, i.e., the one presenting the best acceptance.

The optimized formulation was defined as the best accepted based on the desirability approach (Response Optimizer function in Statistica). The criteria were based on maximization of the following parameters: – ascorbic acid (lower value: 20 mg/100 mL; target value: 30 mg/100 mL); – flavor (lower score: 6; target score: 7); – overall impression (lower score: 6; target score: 7); – purchase intention (lower score: 3; target score: 4).

Results

Physical and physicochemical analyses

The physicochemical parameters of the cashew apple and açai pulps used in this study as raw materials to develop the blended tropical fruit nectar formulations are shown in Table 2.

Table 3 presents the physical and physicochemical determinations from the different blended tropical fruit nectar formulations. The resulting regression coefficients of equations for ascorbic acid, pH, titratable acidity, total anthocyanins, color, and total phenols were suitable (Table 4). However, concerning soluble solids, total and reducing sugars, and total carotenoids, the models’ low significance may be attributed to the minimal variations among the different treatments, generating small variations in responses. The models probably were not able to accurately predict the behavior of the responses.

The reducing sugars, total sugars, total carotenoids, ascorbic acid content, pH, titratable acidity, total anthocyanins, color, and total phenols were determined, and a second-order polynomial of the following form was fitted to the data of all the responses and the results are reported in Table 4:

\[ Y = \beta_0 + \beta_i x_i + \beta_j x_j + \beta_{ij} x_i^2 + \beta_{ij} x_i x_j + \beta_{ij} x_j^2 \]

Where Y is the measured response, \( \beta_0 \), the intercept term, \( \beta_i \), \( \beta_j \), \( \beta_{ij} \), \( \beta_{ij} \), and \( \beta_{ij} \), the constant coefficients. The variable \( x_i x_j \) represents the first-order interactions between \( x_i \) and \( x_j \) for \( j < i \).

The treatments with a higher amount of cashew apple pulp contained higher ascorbic acid contents, as observed in Figure 1A. A decrease in pH was observed as the pulp concentration increased (60%), and the açai-to-cashew apple pulp ratio decreased (Figure 1A).

Despite the variation in the nectars’ titratable acidity, values were all relatively low, from 0.19% to 0.46%. A positive correlation was observed between the açai-to-cashew apple pulp ratio and titratable acidity (Figure 1C).

Table 2. Physicochemical analysis of pasteurized cashew apple and açai pulps.

| Parameters*       | Cashew apple pulp | Açai pulp  |
|-------------------|-------------------|------------|
| Titratable acidity (citric acid %) | 0.6 ± 0.0         | 0.5 ± 0.0  |
| pH                | 3.8 ± 0.0         | 3.7 ± 0.0  |
| Soluble solids (*Brix) | 10.0 ± 0.0       | 2.3 ± 0.0  |
| Ascorbic acid (mg/100 mL) | 151.3 ± 9.3     | 20.6 ± 6.9 |
| Total phenols (mg gallic acid/100 g) | 108.3 ± 5.6     | 98.5 ± 7.4 |
| Total anthocyanins (mg/100 g) | -                | 13.2 ± 0.8 |
| Total carotenoids (mg/100 g) | 1.0 ± 0.1        | 2.4 ± 0.2  |
| Reducing sugars (g/100 g)   | 3.5 ± 1.3        | 0.4 ± 0.0  |
| Total sugars (g/100 g)      | 3.8 ± 0.2        | 1.1 ± 0.1  |

*Results represent mean values of triplicate determinations ± standard deviation (SD).
Table 3. Chemical characterization of blended tropical fruit nectars pasteurized composed of cashew apple and açai pulps (mean values of triplicate determinations ± standard deviation).

| Uncoded variable levels | pH | Titratable acidity (% citric acid) | Reducing sugars (g/100 g) | Total sugars (g/100 g) | Total carotenoids (mg/100 g) | Color (gallic acid mg/100 g) | Total phenols (mg/100 mL) | Ascorbic acid (mg/100 mL) | Total anthocyanin (mg/100 g) |
|-------------------------|----|---------------------------------|--------------------------|------------------------|----------------------------|----------------------------|--------------------------|--------------------------|--------------------------|
| X₁ X₂                    |    |                                 |                          |                        |                            |                            |                          |                          |                          |
| 0.8 34.4                 | 3.98 ± 0.00 | 0.26 ± 0.00                  | 9.20 ± 0.21             | 8.80 ± 1.34            | 0.28 ± 0.04                | 0.44 ± 0.03                | 38.70 ± 2.96              | 22.44 ± 4.53              | 1.71 ± 0.39              |
| 3.5 34.4                 | 3.96 ± 0.00 | 0.19 ± 0.00                  | 9.30 ± 1.25             | 9.30 ± 1.25            | 0.61 ± 0.10                | 0.72 ± 0.01                | 40.45 ± 0.21              | 6.41 ± 0.00               | 4.12 ± 0.00              |
| 0.8 55.6                 | 3.92 ± 0.00 | 0.42 ± 0.042                 | 7.90 ± 0.29             | 8.30 ± 0.82            | 0.98 ± 0.24                | 0.69 ± 0.01                | 58.30 ± 0.70              | 38.46 ± 0.00              | 3.18 ± 1.40              |
| 3.5 55.6                 | 3.89 ± 0.00 | 0.36 ± 0.049                 | 7.40 ± 0.35             | 8.30 ± 0.39            | 0.64 ± 0.5                 | 1.12 ± 0.01                | 62.55 ± 1.62              | 9.62 ± 4.53               | 6.75 ± 0.25              |
| 0.25 45.0                | 3.96 ± 0.00 | 0.39 ± 0.00                  | 10.00 ± 0.07            | 8.60 ± 4.53            | 1.34 ± 0.04                | 0.37 ± 0.00                | 50.60 ± 4.10              | 51.28 ± 0.00              | 1.71 ± 0.75              |
| 4.0 45.0                 | 3.91 ± 0.00 | 0.36 ± 0.049                 | 7.70 ± 0.48             | 8.70 ± 0.17            | 0.70 ± 0.02                | 0.92 ± 0.04                | 54.20 ± 0.848             | 9.62 ± 4.53               | 6.06 ± 0.14              |
| 2.1 30.0                 | 3.96 ± 0.00 | 0.26 ± 0.00                  | 7.90 ± 0.23             | 9.20 ± 0.18            | 1.14 ± 0.11                | 0.58 ± 0.03                | 32.40 ± 1.69              | 12.82 ± 0.00              | 2.93 ± 0.18              |
| 2.1 60.0                 | 3.86 ± 0.00 | 0.46 ± 0.091                 | 9.70 ± 0.14             | 8.90 ± 0.02            | 0.77 ± 0.03                | 1.05 ± 0.06                | 70.95 ± 3.04              | 28.85 ± 4.53              | 6.92 ± 0.43              |
| 2.1 45.0                 | 3.87 ± 0.00 | 0.26 ± 0.00                  | 11.50 ± 0.13            | 9.60 ± 0.05            | 0.51 ± 0.02                | 0.87 ± 0.03                | 54.50 ± 2.54              | 19.23 ± 9.06              | 5.47 ± 0.32              |
| 2.1 45.0                 | 3.91 ± 0.00 | 0.26 ± 0.00                  | 6.60 ± 0.58             | 8.50 ± 0.19            | 0.53 ± 0.05                | 0.78 ± 0.03                | 49.90 ± 0.70              | 16.03 ± 4.53              | 4.86 ± 0.25              |
| 2.1 45.0                 | 3.92 ± 0.00 | 0.26 ± 0.00                  | 6.60 ± 0.33             | 8.80 ± 0.25            | 1.01 ± 0.21                | 0.79 ± 0.02                | 54.25 ± 4.313             | 25.64 ± 0.00              | 7.36 ± 0.10              |

X₁: Açai-to-cashew apple pulp ratio; X₂: Pulp content (%)
Figure 1D shows the surface response obtained for total anthocyanin content, considering the acai pulp’s influence.

The browning intensity was positively correlated with pulp concentration and acai-to-cashew apple pulp ratio (Figure 1E).

There is a significant positive effect \((p \leq 0.05)\) between the increasing cashew apple pulp and total phenols content in all treatments (Figure 1F). The highest content phenolic compounds found in cashew apple pulp being 108.3 mg gallic acid /100 g, although the acai pulp is very rich in these compounds.

**Sensory analysis**

Spectrum sensory analysis of all beverage attributes varied in a significant manner \((p \leq 0.05)\) (Table 6, Figure 2). Flavor evaluation showed that formulation 7 (20.3% acai pulp and 9.7% cashew apple pulp) received the best results, followed by formulations 1 (15.3% acai pulp and 19.1% cashew apple pulp) and 6 (36.0% acai pulp and 9.0% cashew apple pulp) (Figure 2). Moreover, formulation 7 also presented significantly higher mean scores for purchase intention (PI), grade 3 (“maybe would
“buy”) than the ones that contained lower total pulp content and higher açai-to-cashew apple pulp ratio. The sensory acceptance was reported to be strongly favored by an increase in açai-to-cashew apple pulp ratio. That is to say, the predominance of açai pulp improved product acceptance. Moreover, a decrease in total pulp content tended to favor acceptance. Interestingly, an increase was found in overall impression (OI) scores as the total pulp content, and açai-to-cashew apple pulp decreased, being the best scores attributed to the sample with 30% of total pulp (Table 5).

As indicated in Figure 2, the resulting fitted models of equations for all sensory attributes were suitable, showing significant regressions, reasonable residual values, non-significant lack of fit, and satisfactory determination coefficients to evaluate the sensory attributes of the nectar as a function of total pulp content and açai-to-cashew apple pulp ratio, being that all $R^2$ higher than 0.8 which

![Figure 2. Response surface for sensorial attributes of blended tropical fruit nectars composed of cashew and açai pulps: (a) taste; (b) global impression and (c) purchase intention.](image)

### Table 5. Sensory attributes of blended tropical fruit nectar composed of cashew apple and açai pulps (mean values of triplicate determinations ± standard deviation).

| Uncoded variable levels | Açai pulp (%) | Cashew apple pulp (%) | Flavor | Overall impression | Purchase intention |
|-------------------------|---------------|------------------------|--------|-------------------|--------------------|
| $X_1$                  | $X_2$         |                        |        |                   |                    |
| 0.8                    | 34.4          | 15.31                  | 19.09  | 6.1 ± 1.7         | 6.0 ± 1.5         | 3.2 ± 1.0         |
| 3.5                    | 34.4          | 26.76                  | 7.64   | 5.5 ± 2.0         | 5.6 ± 1.9         | 2.8 ± 1.2         |
| 0.8                    | 55.6          | 24.74                  | 30.86  | 4.7 ± 2.1         | 4.9 ± 2.0         | 2.5 ± 1.1         |
| 3.5                    | 55.6          | 43.26                  | 12.34  | 5.1 ± 2.2         | 5.2 ± 2.1         | 2.7 ± 1.2         |
| 0.25                   | 45.0          | 10.40                  | 34.6   | 5.2 ± 2.1         | 5.2 ± 2.0         | 2.8 ± 1.2         |
| 4.0                    | 45.0          | 36.00                  | 9.00   | 5.9 ± 2.0         | 5.8 ± 1.9         | 3.2 ± 1.2         |
| 2.1                    | 30.0          | 20.31                  | 9.69   | 6.6 ± 1.6         | 6.5 ± 1.7         | 3.4 ± 1.1         |
| 2.1                    | 60.0          | 40.62                  | 19.38  | 4.5 ± 2.0         | 4.8 ± 1.9         | 2.4 ± 1.1         |
| 2.1                    | 45.0          | 30.46                  | 14.53  | 5.7 ± 2.0         | 5.9 ± 1.9         | 3.1 ± 1.2         |
| 2.1                    | 45.0          | 30.46                  | 14.53  | 5.5 ± 2.1         | 5.6 ± 2.0         | 3.0 ± 1.2         |
| 2.1                    | 45.0          | 30.46                  | 14.53  | 5.7 ± 1.9         | 5.7 ± 1.8         | 3.0 ± 1.2         |

$X_1$: Açai-to-cashew apple pulp ratio; $X_2$: Pulp content.
Table 6. Regression coefficients of the second-order polynomial and their significance.

| Coefficients | Flavor | Overall Impression | Purchase intention |
|--------------|--------|-------------------|-------------------|
| $\beta_0$    | 5.71   | 5.77              | 3.07              |
| $\beta_{12}$ | 0.10   | 0.09              | 0.03              |
| $\beta_1$    | -0.13  | -0.14             | -0.06             |
| $\beta_2$    | -0.60  | -0.30             | -0.28             |
| $\beta_{12}$ | 0.25   | 0.19              | 0.15              |
| $R^2$        | 0.89   | 0.79              | 0.62              |
| $R^2$ adj.   | 0.78   | 0.79              | 0.62              |
| $F_{reg}$    | 44.77  | 47.63             | 23.53             |
| $(F/F_{reg})_{eq}$ | 8.87   | 9.43              | 4.66              |
| $F_{tot}$    | 121.47 | 57.04             | 284.53            |
| $(F/F_{tot})_{tot}$ | 6.4    | 2.98              | 14.85             |

$\beta_0$: mean; $\beta_1$: proportions of açaí/cashew apple pulps; $\beta_2$: pulp content.

represents good equation fitting, except by the appearance attribute which showed an $R^2$ of 0.77. The flavor, overall impression, and purchase intention were positively correlated to açaí-to-cashew apple pulp ratio and total pulp content, that 1.18 being the optimum açaí-to-cashew apple pulp ratio (16.3% açaí pulp/13.7% cashew apple pulp) for this blended tropical fruit nectar formulation.

Optimization

The optimized formulation’s maximum desirability was found with the minimum açaí-to-cashew apple ratio (0.25) and minimum pulp content (30%). The composite desirability was 0.40. The values for the responses at the optimized point were the following:
- Ascorbic acid: 29.57 mg/100 mL (desirability: 0.95);
- Flavor: 6.47 (desirability: 0.47);
- Overall impression: 6.17 (desirability: 0.17);
- Purchase intention: 3.35 (desirability: 0.35).

Discussion

The measurement of titratable acid, pH, SS, reducing and total sugars, total carotenoids, and ascorbic acid of the commercial cashew apple pulp are clear to those reported in the literature (Emelike and Obinna-Echem, 2020). The same was observed for acai pulp. The values are close to previously published data (Tonon et al., 2008; Xiong et al., 2020). Different quantitative results were found in this study concerning the other physicochemical parameters studied, such as ascorbic acid and total phenols.

The total phenols and anthocyanins contents in cashew-apple and acai pulps were quite different than those reported by Cavalcante et al. (2005). Our data supported Michodjehoun-Mestres et al. (2009)’s studies that concluded that cashew apples, whatever their origin, showed in their skin and flesh a constant relative distribution pattern for phenolic compounds. The differences found can be associated with studied raw material (time of year, species, cultivation conditions) that may have influenced the content of phenolic compounds and anthocyanins.

Concerning the nectars, in this study, all pH levels were below 4.0, ranging from 3.22 to 3.49. According to Silva et al. (2015), the microbiological stability of fruit juices can be associated with pH below 3.8. All formulations in this research had a pH lower than that established, confirming this product’s microbiological stability and safety, considering that most pathogenic bacteria do not multiply at these pH values (FDA, 2020; Jay and Anderson, 2001).

The pH measurement results of the blended tropical fruit nectars were consistent with those obtained by Sousa et al. (2007) with blends consisting of cashew apple, acerola, papaya, passion fruit, and guava. There is a mixture of the tropical fruits in nectar, and they have close pH values, which does not result in a great change in the final value.
All formulations were dark violet, maybe due to the addition of higher anthocyanin-rich açai pulp besides high acidity levels in these formulations. Anthocyanins are labile compounds subject to numerous detrimental reactions during processing and storage, such as transforming monomeric forms into oligomeric or polymeric pigments, resulting in color changes toward brownish-red hues generally more stable (Darniadi et al., 2019; Sousa Sabino et al., 2021).

According to De Rosso et al. (2008), although all açai fruits came from the Amazonic region, different amounts of water are allowed to be added to obtain the commercial açai pulp, influencing the levels of color and the stability of the compounds. Lichtenthäler et al. (2005) found levels of anthocyanins in açai pulp made from fruits collected from the same trees in different years ranged from 88 to 211 mg/L, while Xiong et al. (2020) found levels ranging from 5.21 to 7.91 total proanthocyanidin equivalents per g for industrially processed pulp.

The higher ascorbic acid values occurred in the samples with pulp content ranging from 45% to 60%, presenting an açai-to-cashew apple pulp ratio of 0.25. This has similarities to the result obtained by Carvalho et al. (2007) in a blended beverage consisting of coconut water and cashew apple juice containing caffeine (12.5% cashew apple juice and 87.5% coconut water containing 100 mg of caffeine L$^{-1}$). The ascorbic acid content increased when higher contents of cashew juice were used in the formulation.

The ascorbic acid content varied amongst the treatments from 10 to 50 mg.100 mL$^{-1}$. These values are equivalent to those found in whole orange juice, considered a good source of vitamin C and consumed worldwide. Food products added cashew-apple pulp have been developed aiming to increase vitamin C levels. Jain and Khudiya (2004) developed a blended beverage consisting of coconut water and cashew apple juice. Similarly, Akinwale (2000) reported vitamin C enrichment of fruit juices by blending with cashew apple juice.

Even so, a daily consumption dose of 200 mL (the content of the packaging used) of the formulation would provide 133.3 and 166.67% of the recommended daily intake of vitamin C, i.e., 75 mg and 60 mg, for both male and female adults, respectively (Wu et al., 2019).

The presence of a higher pulp proportion (60%) correlated positively with anthocyanin content. Noteworthy is that the different formulations showed a higher variation of total anthocyanin content. Açai pulp can be considered a good source of anthocyanins compared to other known red fruits such as raspberry (Badin et al., 2020) and the tropical berry camu-camu (Grigio et al., 2021). Morata et al. (2019) reported the possibility of using anthocyanins as a natural pigment in beverages, enabling the development of drinks with new flavors and colors.

Schauss et al. (2006) reported a total anthocyanin content of 3.19 mg g$^{-1}$ (on a dry basis) in a freeze-dried acai fruit pulp and two anthocyanins, cyanidin 3-glucoside, and cyanidin 3-rutinoside, were found to be predominant. However, differently from those authors’ reports, the highest value found in this study was 7.36 mg/100 g. Anthocyanins are labile compounds subjected to numerous detrimental reactions during processing and storage (Wrolstad et al., 2005). Recently, Jensen et al. (2008) investigated in vitro and in vivo antioxidant and anti-inflammatory properties of a juice blend containing a mixture of fruits and berries with known antioxidant activity, including acai as the predominant ingredient. The data suggested that within 2 h of consumption, a statistically significant decrease in serum lipid peroxidation. This effect was likely attributed to the influence of polyphenols on increasing serum antioxidant capacity.

It stands out the possibility of synergistic effects of the bioactive compounds present in formulations (phenolic compounds and anthocyanins), which positively influences health properties. Combining some phytochemicals is already recognized for anti-cancer and anti-oxidant activities, and the synergism can improve these activities (Leena et al., 2020).

In general, the results of this investigation concerning the sensory acceptance of this novel blended tropical fruit nectar are in accordance to nectars of different formulations (Cavalcante et al., 2005; Zanatta et al., 2005), which varied from 5 (“neither liked nor disliked”) to more than 7 (“liked moderately”), representing a new product that the beverage industries can market.
Conclusions

The formulation with 13.7% açai pulp and 16.3% cashew apple pulp was the most accepted by consumers. This mixed nectar presented good sensory acceptance attributes and high vitamin C and anthocyanin contents improved by cashew apple pulp and açai pulp compositions, respectively, and attractive violet-dark color, suggesting potential commercial success. However, the flavor of the beverage should be optimized in future product development. Opportunities exist for developing and marketing mixed tropical fruit beverages incorporating the health benefits of the tropical fruits' synergistic effect of bioactive compounds.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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