



# Physicochemical characteristics and sensory acceptance of jambolan nectars (*Syzygium cumini*)

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## Abstract

The market for ready-to-drink fruit nectars is one of the fastest growing ones, because fruits provide beneficial effects for health maintenance and disease prevention, mainly due to the presence of phenolic compounds and their antioxidant activity. Amongst these, jambolan stands out, but is still little explored. The objective of the present work was to evaluate the influence of different proportions of jambolan pulp, sucrose and water on the physicochemical characteristics and sensory acceptance of jambolan nectars, besides determining the content of some bioactive compounds and the antioxidant capacity of the selected nectar, with a view to adding value to the fruit. Six jambolan nectar formulations were established using a Simplex design. The ingredients significantly affected the Chroma (9.33-11.05), Hue angle (359.36-359.48), apparent viscosity (6.9-64.8 cP) and pH (3.84-3.93) of the jambolan nectars. The formulation with 55 g of jambolan pulp, 5 g of sucrose and 40 g of water per 100 g of nectar presented higher levels of anthocyanins when compared to tropical acai juice and camu-camu nectar. It is feasible to produce jambolan nectar with desirable physicochemical and sensory characteristics, rich in bioactive compounds, thus increasing the possibilities of applying this fruit as an ingredient in the food industry.

**Keywords:** color; total phenolics; anthocyanin; tannins; functional beverage.

**Practical Application:** The food industries have been looking for new food products, which provide in addition to nutritional function for consumers, functional value. The jambolão (*Syzygium cumini*) has vitamins, natural pigments and high potential of industrialization. However, it is largely wasted due to the high production per tree, short shelf life and lack of alternatives of production and food use. The production of nectares presents itself as an effective and healthy alternative to take advantage of these fruits.

## 1 Introduction

The consumption of processed fruit juices and nectars has increased in recent years, mainly due to the practicality offered by the products, concern about the importance of choosing healthier foods and the improvement in quality of life (Faraoni et al., 2012).

Bioactive compounds, such as vitamins A, C and E, carotenoids and phenolic compounds, are natural antioxidants, found mainly in fruits and other plants, and have biological activity benefiting humans as free radical scavengers (Zang et al., 2017). Free radicals are constantly formed in the human body and can damage the DNA, protein and lipid, leading to ageing and many other chronic conditions such as cancer, cardiovascular diseases, diabetes and obesity (Chan et al., 2016; Gomes et al., 2016).

A significant growth in the fruit market has attracted the attention of fruit farmers, distributors and processors in order to meet the demands (Antunes et al., 2013). The demand for these products follows the growth trend of the soft drink market, which has diversified mainly due to the incorporation of new fruit flavors (Figueira et al., 2010), and the fruit jambolan (*Syzygium cumini*) has the potential to elaborate nectars.

Jambolan fruits have a pleasant taste, although somewhat astringent, with purple-colored pulp due to the presence of anthocyanins, which are important sources of phenolic compounds (Cavalcanti et al., 2011). Little has been explored about the

various possibilities of the processing and industrialization of jambolan, much of the fruit being wasted in the off season due to its short shelf life, and more importantly, to a deficiency in processing technologies for this fruit (Pereira et al., 2015). Due to the limited scientific and technological information concerning the use of jambolan in nectars, this study aims to evaluate the influence of different proportions of jambolan pulp, sucrose and water on the physicochemical characteristics and sensory acceptance of jambolan nectars, besides determining the content of some bioactive compounds and the antioxidant capacity of the selected nectar, seeking to add value to the fruit.

## 2 Materials and methods

### 2.1 The obtaining and processing of jambolan pulp

Jambolan (*Syzygium cumini*) fruits were harvested in Goiania city with the correct maturation stage for consumption, and taken to the Vegetable Products Processing Plant in low density polyethylene (LDPE) bags. After a selection process, which eliminated damaged fruit, and those attacked by pests and diseases, they were washed with tap water, sanitized with a sodium hypochlorite solution (200 mg L<sup>-1</sup>) for 20 min, dried at 25 °C and mechanically pulped. Jambolan pulp portions of 1 kg were packed into LDPE bags, frozen, and stored at -18 °C.

Received 15 Sept., 2017

Accepted 07 Aug., 2018

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## 2.2 The processing of jambolan nectars

Granulated sucrose (Cristal®) (5-15 g 100 g<sup>-1</sup>), jambolan pulp (30-50 g 100 g<sup>-1</sup>) and potable water (30-65 g 100 g<sup>-1</sup>) were used to formulate the nectars by way of a Simplex Design, with six mixtures and three replicates at the center point. The jambolan pulp was thawed at 25 °C and homogenized with sucrose and water in an industrial blender. Each sample was filled into a 1 L glass bottle, previously sanitized in boiling water for 20 min. The nectar bottles were then pasteurized at 90 °C for 60 s, cooled under tap water, closed with metal lids and stored at 5 ± 1 °C until analyzed.

## 2.3 The physicochemical characteristics

The instrumental color parameters (L\*, a\* and b\*) were determined in a colorimeter (Hunter-Lab, Color QUEST II, Reston, USA) and the chroma and Hue angle calculated according to AOAC (Association of Official Analytical Chemists, 2012). The pH was determined using a potentiometer, also according to AOAC (Association of Official Analytical Chemists, 2012). The apparent viscosity at 25 °C with a speed of 100 rpm was determined in a viscometer (Brookfield, DV-II+, Middleboro, USA) using spindle n° 2 (LV2) according to the technical manual of the equipment. All the analyses were carried out in triplicate.

## 2.4 Microbiological analysis and sensory acceptance

The coliforms at 35 °C count was determined according to the methodology described by the American Public Health Association (American Public Health Association, 2015). The color, appearance, odor, taste, texture and overall assessment were evaluated by fifty adult consumers of both sexes using a random blocks design (Stone & Sidel, 2012) The sample was served in transparent plastic cups and presented in a monadic sequential form under white light. Water was offered to eliminate residual taste. A nine-point hedonic scale, where nine denoted the highest score (liked extremely) and one denoted the lowest score (disliked extremely) was used. The level of acceptance of the jambolan nectars was previously established as a mean score higher than five (neither liked nor disliked) for all attributes, according to ABNT (Associação Brasileira de Normas Técnicas,

1998). The Ethics Committee approved the research plan (protocol CAAE n° 25778613.0.0000.5083).

## 2.5 Bioactive compounds and antioxidant activity

The total phenolic compounds were determined using the Folin-Ciocalteu method (Waterhouse, 2002). Standard concentrations of gallic acid (0.625-30 µg mL<sup>-1</sup>) were used to prepare a calibration curve and the results were expressed as milligrams of gallic acid equivalents (mg GAE g<sup>-1</sup> of dried extract). The phenolic compound contents were estimated in triplicate and averaged. The total anthocyanin content was estimated by spectrophotometry according to the method described by Barcia et al. (2012). The total condensed tannins content was estimated colorimetrically according to the method of Price et al. (1978) and Brune et al. (1991). Free radical-scavenging activity was measured using the adapted method of Brand-Williams et al. (1995). The antioxidant activity was expressed as mg of Trolox equivalents (mg TE mL<sup>-1</sup>) and also as a percentage of the absorbance of the control DPPH solution.

## 2.6 Analysis of the results

Polynomial models were adjusted to each response by way of Scheffe canonical models for three components: linear and interactions. The level of significance, coefficient of determination and lack of fit were estimated using an analysis of variance (ANOVA). Statistica 7.0 (Statsoft, version 7.0, Tulsa, USA) was used to obtain the experimental design, data analysis and graphics, and the means of the sensory scores were compared using the Tukey test (p<0.05).

## 3 Results and discussion

### 3.1 Physicochemical characteristics

The physicochemical characteristics evaluated were influenced by the components of the mixture (Table 1). All polynomial models were significant (p < 0.01) and explained 79-99% of the responses (Table 2). The lack of fit was only significant for the chrome and apparent viscosity values. However, according to Waszczynskyj et al. (1981), if the mean square for the experimental error is low, the significance tests for the lack of fit must be considered irrelevant and thus all the models can be

**Table 1.** Chroma, hue angle, apparent viscosity and pH of the nectars as a function of the real proportions of jambolan pulp, sucrose and water and of those in the pseudocomponent values, as defined by the Simplex design.

| Formulation | Real Ratio of the Ingredients |         |       | Pseudocomponent                     |                             |                         | Chroma       | Hue angle     | Apparent viscosity (cp) | pH          |
|-------------|-------------------------------|---------|-------|-------------------------------------|-----------------------------|-------------------------|--------------|---------------|-------------------------|-------------|
|             | Pulp                          | Sucrose | Water | Pulp (X <sub>1</sub> ) <sup>1</sup> | Sucrosand (X <sub>2</sub> ) | Water (X <sub>3</sub> ) |              |               |                         |             |
| N1 (A)      | 0.44                          | 0.13    | 0.43  | 0.4                                 | 0.229                       | 0.371                   | 10.09 ± 0.16 | 359.46 ± 0.02 | 7.5 ± 0.01              | 3.88 ± 0.0  |
| N1 (B)      | 0.44                          | 0.13    | 0.43  | 0.4                                 | 0.229                       | 0.371                   | 10.17 ± 0.23 | 359.48 ± 0.01 | 8.4 ± 0.01              | 3.86 ± 0.0  |
| N1 (C)      | 0.44                          | 0.13    | 0.43  | 0.4                                 | 0.229                       | 0.371                   | 10.29 ± 0.19 | 359.45 ± 0.01 | 8.1 ± 0.01              | 3.86 ± 0.01 |
| N2          | 0.55                          | 0.05    | 0.40  | 0.714                               | 0                           | 0.286                   | 10.87 ± 0.22 | 359.48 ± 0.01 | 34.2 ± 0.0              | 3.84 ± 0.0  |
| N3          | 0.50                          | 0.20    | 0.30  | 0.571                               | 0.429                       | 0                       | 9.92 ± 0.31  | 359.45 ± 0.03 | 64.8 ± 0.01             | 3.93 ± 0.01 |
| N4          | 0.30                          | 0.20    | 0.50  | 0                                   | 0.429                       | 0.571                   | 9.33 ± 0.05  | 359.36 ± 0.0  | 12.3 ± 0.02             | 3.91 ± 0.01 |
| N5          | 0.55                          | 0.15    | 0.30  | 0.714                               | 0.286                       | 0                       | 9.53 ± 0.43  | 359.45±0.01   | 12.9 ± 0.02             | 3.84 ± 0.01 |
| N6          | 0.30                          | 0.05    | 0.65  | 0                                   | 0                           | 1                       | 11.05 ± 0.15 | 359.44 ± 0.01 | 6.9 ± 0.02              | 3.91± 0.0   |

<sup>1</sup>X<sub>1</sub> + X<sub>2</sub> + X<sub>3</sub> = 1 or 100%; A, B and C are repeats at the central point.

**Table 2.** Polynomial models, lack of fit (LF), level of significance (p) and coefficient of determination (R<sup>2</sup>) for chroma (C\*), hue (H°) (degrees), apparent viscosity (AV) and pH of the experimental nectars according to the pseudocomponents for jambolan pulp (x<sub>1</sub>), sugar (x<sub>2</sub>) and water (x<sub>3</sub>).

|    | Model   | p    | LF   | R <sup>2</sup> |
|----|---|------|------|----------------|
| C* | $y = 9.50x_1 + 13.91x_2 + 11.05x_3 - 6.01x_1x_2 + 4.51x_1x_3 - 12.02x_2x_3$       | 0.02 | 0.00 | 0.99           |
| H° | $y = 359.42x_1 + 359.50x_2 + 359.44x_3 - 0.33x_1x_3 - 0.42x_2x_3$                 | 0.03 | 0.22 | 0.95           |
| AV | $y = -1.56x_1 + 568.89x_2 + 6.90x_3 - 728.12x_1x_2 + 163.29x_1x_3 - 962.17x_2x_3$ | 0.00 | 0.00 | 0.99           |
| pH | $y = 3.79x_1 + 4.07x_2 + 3.91x_3 - 0.31x_2x_3$                                    | 0.07 | 0.15 | 0.79           |

The effects in italic were not significant at the 5% probability level, but were maintained to improve the fit of the model.

used for predictive purposes. The effects of the jambolan pulp, sucrose and water were significant for all the responses, except for the apparent viscosity of the jambolan pulp. The interactions between sugar (x<sub>2</sub>) and water (x<sub>3</sub>) were significant for chroma\* and apparent viscosity, but not for Hue angle and pH (Table 2).

The ingredients jambolan pulp (x<sub>1</sub>), sugar (x<sub>2</sub>) and water (x<sub>3</sub>), and the interaction between jambolan pulp and water (x<sub>1</sub>x<sub>3</sub>) influenced the increase in saturation, but the interactions of sugar with pulp (x<sub>1</sub>x<sub>2</sub>) and water (x<sub>2</sub>x<sub>3</sub>) influenced it negatively (Table 2).

Nectars with higher color saturation (chroma) were observed in the chart area between points F, G and H (Figure 1A) in formulations with jambolan pulp concentrations of 34 to 50 g 100 g<sup>-1</sup>, sugar of 5 to 6 g 100 g<sup>-1</sup> and water of 45 to 61 g 100 g<sup>-1</sup>, that is, greater color purity or intensity relative to white.

Jambolan nectars have greater red and blue color intensities due to the presence of anthocyanins in the fruit pulp (Ayyanar & Subash-Babu, 2012). Soares et al. (2014) evaluated the intensity of the jambolan fruit color, and found values from 56.44 to 65.15% higher than the maximum value found in the present study, due to the processing of the nectars when the fruits were pulped, removing the epicarp, where the highest anthocyanin concentrations are found. The highest values were observed for the hue angle in the area between the points D, E and F (Figure 1B), where the formulations ranged from 39 to 53 g 100g<sup>-1</sup>jambolan pulp, 5 to 7 g 100 g<sup>-1</sup> sucrose and 42 to 56 g 100 g<sup>-1</sup> water. The lowest values were found between the points 4, A, B and C, where the jambolan pulp contents ranged from 30 to 31 g 100 g<sup>-1</sup>, sucrose from 14 to 20 g 100 g<sup>-1</sup> and water from 49 to 56 g 100 g<sup>-1</sup>. The interactions between pulp and water (x<sub>1</sub>x<sub>3</sub>) and between sucrose and water (x<sub>2</sub>x<sub>3</sub>) had a negative effect on the hue angle, but the x<sub>2</sub>x<sub>3</sub> interaction was not significant (Table 2).

The nectars presented H° values from 359.38 to 359.5, indicating a red color with a tendency to blue due to the presence of anthocyanins, the natural pigment present in jambolan. Thus the higher the amount of jambolan pulp, the higher the H° of the nectars. Silva et al. (2010), also noted the contribution of anthocyanins to the color tone (H°), evaluating the formulations and stability of anthocyanins extracted from jaboticaba skins (*Myrciaria ssp.*) and noted that the higher the value of H°, the nearer the hue was to red. The jaboticaba skins have a high anthocyanin content which explains the red-purple color of these fruits.

The model that best fitted the apparent viscosity was the full quadratic one, where although the pulp jambolan pulp content (x<sub>1</sub>) was not significant, its interactions showed a strong influence on the apparent viscosity. The highest values for apparent viscosity at 100 rpm were found between points 3, D, E and F (Figure 1C), where the jambolan pulp content ranged from 36 to 51g 100 g<sup>-1</sup>, sucrose from 19 to 20 g 100 g<sup>-1</sup> and water from 30 to 37g 100 g<sup>-1</sup>. The highest jambolan pulp concentration used in the formulations provided an increase in the total soluble solids content, and hence the amount of free water in the mixture decreased, increasing the apparent viscosity, which is greatly affected at concentrations above 20 °Brix (Magerramov et al., 2007). This explains the fact that the point N3, which had a higher sugar content (20 g 100 g<sup>-1</sup>), had a higher apparent viscosity than the other experimental formulations. With the increase in spindle rotation speed, the viscosities of the nectars decreased. Regardless of the formulation used, all the nectar samples analyzed presented non-Newtonian and pseudoplastic fluid behavior, since there was a decrease in apparent viscosity due to the increase in shear rate applied (Schramm, 2006).

Benitez et al. (2009) showed that the viscosity of a colloidal dispersion of solids in syrups is increased by increasing the sucrose-particle interaction and by lowering the water activity of the syrups. Sucrose has a higher molecular mass than glucose or fructose, and therefore has a higher AV in a solution of the same concentration (Šimunek et al., 2013). Glucose and fructose are present in jambolan pulp (Lago et al., 2006) but have less influence on the AV of the nectar due to the higher concentration of sucrose.

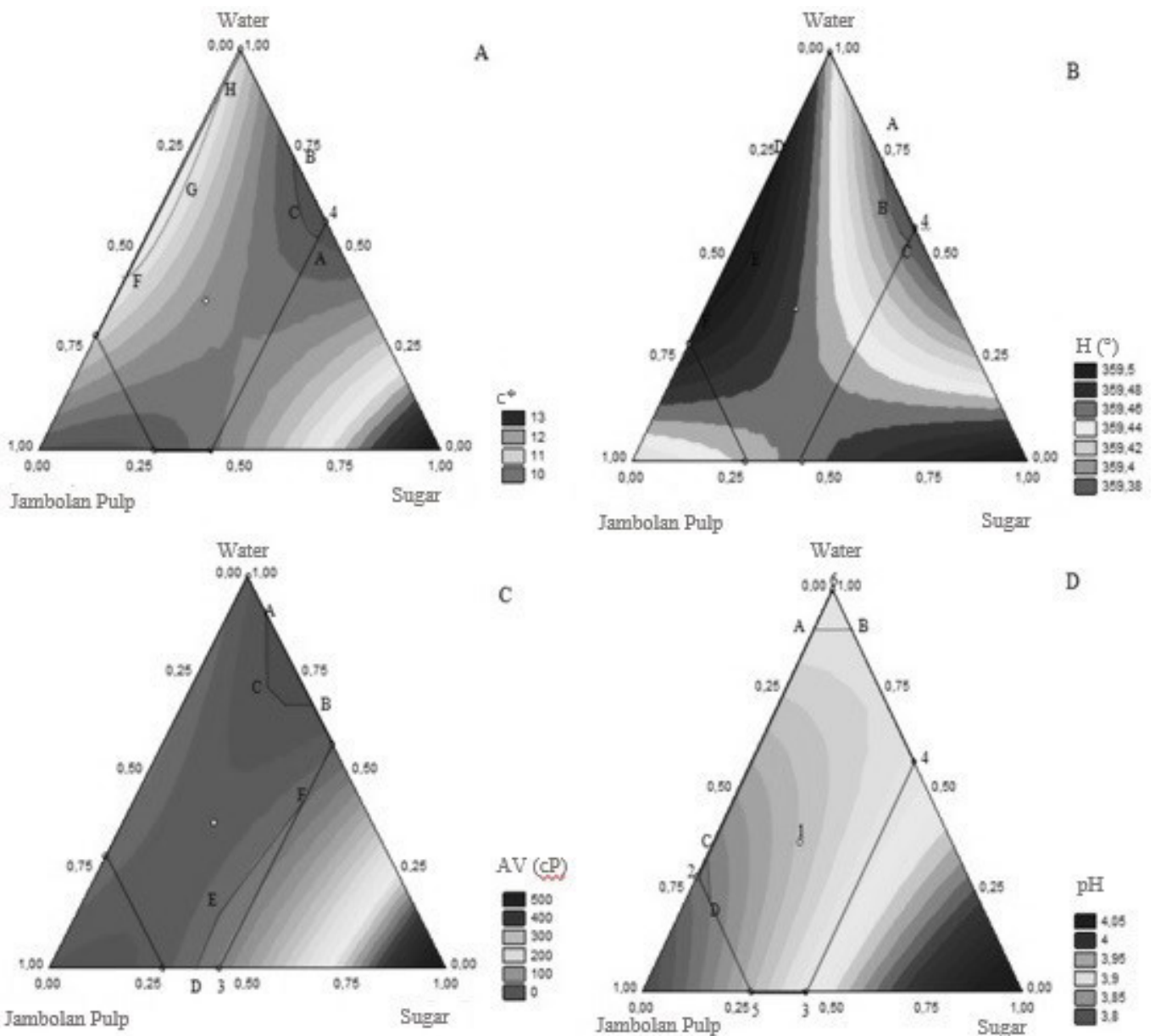
The pH varied from 3.86 to 3.91 in the nectar formulations. The lowest pH value was found in the formulation with the highest pulp and water contents (N6), and therefore it can be concluded that the jambolan pulp has an acid characteristic. Higher sucrose levels lead to lower acidity in the experimental nectars, or higher pH values. Fruit pulps contain organic acids, and thus the greater the jambolan pulp concentration in the nectar formulation, the greater the amount of acid present and the lower the pH value, contributing to improving the shelf life and microbiological risk. The pH value found was similar to that of the fresh fruit, 3.7 (Pereira et al., 2015), demonstrating that this parameter was not changed by processing and that pasteurization did not affect the pH value. Chim et al. (2013) evaluated the pH value of acerola nectar and found a value of 3.7. The final pH of fruit nectars should be below 4.0 (Roesler et al., 2007), in accordance with the values found for the jambolan nectars. Another important parameter affecting the pH of the jambolan nectars was the presence of anthocyanins. In aqueous solutions, anthocyanins

have different structures depending on the pH value. Generally, in an extremely acidic medium (pH 1-2), anthocyanins have an intensely red color due to the predominance of the flavilic cation. In a medium with a pH above 2, a balance was observed between the flavilic cation and a structure known as the carbinol pseudobase. With an increase in the pH value to around 6, the anthocyanins may even become colorless (Março et al., 2008). Therefore the pH of the nectars contributed to the stability of this pigment, the color being attractive for the consumers. The models used were validated by comparing the results found for the nectar selected by way of the acceptance test, with the results found for the model, comparing the physical and chemical properties ( $c^*$ , H, AV and pH) (Table 3).

In relation to the physical and chemical results, it can be affirmed that the predicted model was in agreement with the values found analytically, that is, the mixture of jambolan pulp, sucrose and water showed characteristics similar to those predicted by the model.

### 3.2 Microbiological analysis and sensory acceptance

According to the microbiological analyses, the absence of coliforms at 35 °C / g was obtained, in accordance with the standards established by item "17.a" of Resolution - RDC n° 12 of the National Sanitary Surveillance Agency of the Ministry of Health Act of January 2, 2001 (Brasil, 2001).



**Figure 1.** Chroma ( $c^*$ ) (A), hue (H) (B), apparent viscosity (AV) (C) and pH (D) as a function of the jambolan pulp, sugar and water contents (pseudocomponents). The areas demarcated between the numbered points show the experimental space analyzed.

**Table 3.** Physicochemical characterization of the most accepted nectar. Data obtained in the validation test, estimated by the model, and percentage variation between the determined and estimated responses.

| Parameter               | Determined in the validation test | Estimated by model | Variation (%) |
|-------------------------|-----------------------------------|--------------------|---------------|
| Chroma                  | 10.60 ± 0.08                      | 9.53               | 10.09         |
| Hue angle               | 333 ± 0.55                        | 359.44             | 7.36          |
| Apparent viscosity (cp) | 13.75 ± 1.26                      | 12.90              | 6.58          |
| pH                      | 3.82 ± 0.00                       | 3.87               | 1.29          |

**Table 4.** Average scores obtained in the acceptance test for the nectars with different formulations, containing jambolan pulp, sucrose and water.

| Attribute*         | Experimental Nectar       |                          |                           |                           |                          |                          |
|--------------------|---------------------------|--------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
|                    | N1                        | N2                       | N3                        | N4                        | N5                       | N6                       |
| Color              | 7.6 ± 1.62 <sup>a</sup>   | 6.8 ± 2.01 <sup>ab</sup> | 7.0 ± 1.96 <sup>ab</sup>  | 7.1 ± 1.35 <sup>ab</sup>  | 7.4 ± 1.31 <sup>a</sup>  | 6.4 ± 1.97 <sup>b</sup>  |
| Odor               | 4.7 ± 1.86                | 4.9 ± 1.76               | 5.3 ± 1.97                | 5.3 ± 1.60                | 5.4 ± 1.96               | 5.0 ± 1.77               |
| Flavor             | 5.3 ± 1.80 <sup>abc</sup> | 4.4 ± 1.95 <sup>c</sup>  | 5.4 ± 1.97 <sup>abc</sup> | 5.5 ± 1.63 <sup>abc</sup> | 5.7 ± 1.75 <sup>a</sup>  | 4.6 ± 1.97 <sup>bc</sup> |
| Texture            | 5.1 ± 1.81 <sup>ab</sup>  | 4.5 ± 1.88 <sup>b</sup>  | 5.4 ± 1.77 <sup>ab</sup>  | 6.0 ± 1.30 <sup>a</sup>   | 5.1 ± 1.90 <sup>ab</sup> | 5.0 ± 1.94 <sup>b</sup>  |
| Appearance         | 6.8 ± 1.59                | 6.2 ± 2.04               | 6.7 ± 1.74                | 6.8 ± 1.25                | 6.9 ± 1.35               | 6.0 ± 1.87               |
| Overall assessment | 5.9 ± 1.36 <sup>ab</sup>  | 5.1 ± 1.64 <sup>b</sup>  | 5.9 ± 1.47 <sup>ab</sup>  | 6.1 ± 1.39 <sup>a</sup>   | 6.0 ± 1.65 <sup>ab</sup> | 5.3 ± 1.49 <sup>b</sup>  |

\*Means followed by different letters in the same line differed significantly according to the Tukey test ( $p < 0.05$ ). The experimental nectars used in the sensory analysis were: N1 (44;13;43), N2 (55;5;40), N3 (50;20;30), N4 (30;20;50), N5 (55;15;30) and N6 (30;5;65) (jambolan pulp; sugar; water), respectively.

The nectars that obtained the highest scores in the acceptance test were N1 (44; 13; 43) and N5 (55; 15; 30) (jambolan pulp; sucrose; water, respectively) (Table 4) while the lowest score was obtained by N6 (30; 5; 65). However in relation to odor and appearance, the tasters found no differences between the samples.

The nectars N5, N4 and N1 were accepted (average scores > 5), but N5 was considered the best formulation because it obtained the highest scores in relation to color and flavor, that is, it has the greatest potential for commercialization amongst the other nectars studied, and was selected for the chemical analysis. On the other hand, the formulations N1 and N2 obtained scores below 5.0 for odor and flavor, which was probably related to the lower sucrose content used in these formulations, since Brazilian consumers prefer sweeter tastes (Hansen et al., 2008).

### 3.3 Bioactive compounds

The total phenolic compound contents found in the jambolan nectars (Table 5) were higher than that found by Liu et al. (2014) when evaluating mango nectars after high hydrostatic pressure (HHP, 600 MPa/1 min) and high temperature short time (HTST, 110 C/8.6 seconds) treatments, obtaining 92 mg GA 100 mL<sup>-1</sup>.

Thus the jambolan nectar showed higher values for total phenolic content in relation to the mango nectar, these compounds being responsible for the antioxidant activity of the fruit. The antioxidant activity has a direct relationship with many bioactive functions of the polyphenols, such as the anti-inflammatory, antimicrobial and anti-carcinogenic activities, and when included in the diet, can help in the prevention of certain non-communicable diseases (Singh et al., 2016).

It was observed that the anthocyanin content in the nectar (Table 5) was lower than that found in the jambolan pulp, 211 mg of cyanidin-3-glycoside 100 g<sup>-1</sup> (Faria et al., 2011). Anthocyanins are highly unstable and easily susceptible to degradation and

**Table 5.** Bioactive compounds and antioxidant activity of the nectar formulated with 55 g 100 g<sup>-1</sup> jambolan pulp; 15 g 100 g<sup>-1</sup> sucrose; and 30 g 100 g<sup>-1</sup> water (mean ± standard deviation).

| Parameter                             | Value                    |
|---------------------------------------|--------------------------|
| Total phenolic compounds <sup>1</sup> | 598.51 ± 5.32            |
| Anthocyanin <sup>2</sup>              | 65.897 ± 0.50            |
| Condensed tannins <sup>3</sup>        | 12.075 ± 1.92            |
| Hydrolyzed tannins <sup>4</sup>       | 0.040 ± 0.00             |
| Antioxidant Activity <sup>5</sup>     | 1620.25 ± 0.00 or 85.09% |

<sup>1</sup>mg gallic acid g<sup>-1</sup>; <sup>2</sup>mg cyanidin-3-glycoside 100 g<sup>-1</sup>; <sup>3</sup>g catechin 100 g<sup>-1</sup>; <sup>4</sup>g of gallic acid 100 g<sup>-1</sup>; <sup>5</sup>mg TE g<sup>-1</sup>.

some factors may affect their stability and composition such as the pH value, temperature, oxygen, light, enzymes, and the presence of other substances such as ascorbic acid and sugars (Cavalcanti et al., 2011), and the pasteurization of the nectar may have influenced the decrease in anthocyanin content when compared to the fruit.

Cesar (2007) determined an anthocyanin content of 8.07 mg 100 g<sup>-1</sup> for tropical acai juice, 87.75% lower than that found in the present work. Camu-camu nectars also showed low anthocyanin values of 2.51 mg 100 mL<sup>-1</sup> at zero storage time (Maeda et al., 2007). According to Faria et al. (2011), there is a condensation reaction between ascorbic acid and the anthocyanins present in the camu-camu fruit and thus the higher the concentration of this vitamin in the system, the higher the degradation rate of the anthocyanin pigment. Jambolan pulp shows low values for carotenoids, thus higher levels of anthocyanins.

The sum of the hydrolyzed and condensed tannins was 12.115 g 100 g<sup>-1</sup>, and the condensed tannin content was higher than that of hydrolyzed tannins, positively influencing the sensory aspect, since condensed tannins have less protein complexing capacity than hydrolyzed tannins, resulting in less astringency (Barcia et al., 2012).

Blueberry nectar (Moraes et al., 2008) showed a greater % inhibition (74%) than jambolan nectar, and thus the jambolan nectar presented greater antioxidant capacity. A substance functions as an antioxidant when it is capable of delaying, retarding or preventing the oxidation mediated by free radicals, mainly due to its redox properties, which play an important role in the adsorption and elimination of free radicals, in the decomposition of peroxides and in the reduction of oxidants (Yu & Ahmedna, 2013; Singh et al., 2016).

## 4 Conclusions

The ingredients significantly affected the color coordinates (chroma and hue angle), apparent viscosity and pH value of the experimental jambolan nectars. The nectar formulated with 55 g 100 g<sup>-1</sup> jambolan pulp, 5 g 100 g<sup>-1</sup> sucrose and 40 g 100 g<sup>-1</sup> water was accepted by the tasters and presented higher levels of anthocyanins when compared to tropical acai juice and camu-camu nectar. It is feasible to produce jambolan nectars with desirable physicochemical and sensory characteristics, rich in bioactive compounds, thus increasing the possibilities of applying the fruit as an ingredient in the food industry.

## Acknowledgements

The authors are grateful for the financial support of CAPES - Coordination for the Improvement of Higher Education Personnel.

## References

- American Public Health Association – APHA. (2015). *Compendium of methods for the microbiological examination of foods*. Washington: APHA.
- Antunes, A. E. C., Liserre, A. M., Coelho, A. L. A., Menezes, C. R., Moreno, I., Yotsuyanagi, K., & Azambuja, N. C. (2013). Acerola nectar with added microencapsulated probiotic. *LWT – Food Science and Technology*, 54(1), 125-131.
- Associação Brasileira de Normas Técnicas – ABNT. (1998). *NBR 14141: escalas utilizadas em análise sensorial de alimentos e bebidas*. Rio de Janeiro: ABNT.
- Association of Official Analytical Chemists – AOAC. (2012). *Official methods of analysis* (19th ed). Washington: AOAC.
- Ayyanar, M., & Subash-Babu, P. (2012). *Syzygium cumini* (L.) skeels: a review of its phytochemical constituents and traditional uses. *Asian Pacific Journal of Tropical Biomedicine*, 2(3), 240-246. [http://dx.doi.org/10.1016/S2221-1691\(12\)60050-1](http://dx.doi.org/10.1016/S2221-1691(12)60050-1). PMID:23569906.
- Barcia, M. T., Pertuzatti, P. B., Jacques, A. C., Godoy, H. T., & Zambiasi, R. (2012). Bioactive compounds, antioxidant activity and percent composition of jambolan fruits (*Syzygium cumini*). *The Natural Products Journal*, 2(2), 129-138. <http://dx.doi.org/10.2174/2210315511202020129>.
- Benitez, E. I., Genovese, B. D., & Lozano, J. E. (2009). Effect of typical sugars on the viscosity and colloidal stability of apple juice. *Food Hydrocolloids*, 23(2), 519-525. <http://dx.doi.org/10.1016/j.foodhyd.2008.03.005>.
- Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *Wissenschaft Technologie. Lebensmittel*, 28(1), 25-30.
- Brasil. Ministério da Saúde. (2001). Aprova o regulamento técnico sobre padrões microbiológicos para alimentos. (Resolução RDC nº 12, de 2 de janeiro de 2001). *Diário Oficial [da] República Federativa do Brasil*. Retrieved from: [www.anvisa.gov.br](http://www.anvisa.gov.br)
- Brune, M., Hallberg, L., & Skanberg, A. (1991). Determination of iron binding phenolic groups in foods. *Journal of Food Science*, 56(1), 128-131. <http://dx.doi.org/10.1111/j.1365-2621.1991.tb07992.x>.
- Cavalcanti, R. N., Santos, D. T., & Meireles, M. A. A. (2011). Non-thermal stabilization mechanisms of anthocyanins in model and food systems – an overview. *Food Research International*, 44(2), 499-509. <http://dx.doi.org/10.1016/j.foodres.2010.12.007>.
- Cesar, L. T. (2007). *Obtenção de suco clarificado de açaí (Euterpe oleracea mart.) com utilização de pectinase e quitosana* (Dissertação de mestrado). Universidade Federal do Ceará, Fortaleza.
- Chan, C., Gan, R., & Corke, H. (2016). The phenolic composition and antioxidant capacity of soluble and bound extracts in selected dietary spices and medicinal herbs. *International Journal of Food Science & Technology*, 51(3), 565-573. <http://dx.doi.org/10.1111/ijfs.13024>.
- Chim, J. F., Zambiasi, R. C., & Rorigues, R. S. (2013). Vitamin C stability in acerola juice under different storage conditions. *Brazilian Journal of Agro-industrial Products*, 15(4), 321-327.
- Faraoni, A. S., Ramos, A. M., Guedes, D. B., Oliveira, A. N., Lima, T. H. S. F., & Sousa, P. H. M. (2012). Development of a mixed juice of mango, guava and acerola using mixture design. *Ciência Rural*, 42(5), 911-917. <http://dx.doi.org/10.1590/S0103-84782012005000014>.
- Faria, A. F., Marques, M. C., & Mercadante, A. Z. (2011). Identification of bioactive compounds from jambolan (*Syzygium cumini*) and antioxidant capacity evaluation in different pH conditions. *Food Chemistry*, 126(4), 1571-1578. <http://dx.doi.org/10.1016/j.foodchem.2010.12.007>. PMID:25213929.
- Figueira, R., Nogueira, A. M. P., Venturini, W. G., Fo., Ducatti, C., Queiroz, E. C., & Pereira, A. G. S. (2010). Physical-chemical analysis and legality in orange beverages. *Alimentos e Nutrição*, 21(2), 267-272.
- Gomes, S. M. C., Ghica, M.-E., Rodrigues, I. A., Gil, E. S., & Oliveira-Brett, A. M. (2016). Flavonoids electrochemical detection in fruit extracts and total antioxidant capacity evaluation. *Talanta*, 154(1), 284-291. <http://dx.doi.org/10.1016/j.talanta.2016.03.083>. PMID:27154676.
- Hansen, D. D. S., Silva, S. A., Fonseca, A. A. O., Hansen, O. A. D. S., & França, N. O. (2008). Chemical characterization of fruit native Baiano Reconcavo jenipapeiros aiming to natural consumption and industrialization. *Revista Brasileira de Fruticultura*, 30(4), 964-969. <http://dx.doi.org/10.1590/S0100-29452008000400021>.
- Lago, E. S., Gomes, E., & Silva, R. (2006). Production of jambolan (*Syzygium cumini* Lamarck) jelly: processing, physical-chemical properties and sensory evaluation. *Food Science and Technology (Campinas)*, 26(4), 847-852. <http://dx.doi.org/10.1590/S0101-20612006000400021>.
- Liu, F., Wang, Y., Li, R., Bi, X., & Liao, X. (2014). Effects of high hydrostatic pressure and high temperature short time on antioxidant activity, antioxidant compounds and color of mango nectars. *Innovative Food Science & Emerging Technologies*, 21, 35-43. <http://dx.doi.org/10.1016/j.ifset.2013.09.015>.
- Maeda, R. N., Pantoja, L., Yuyama, L. K. O., & Chaar, J. M. (2007). Stability of ascorbic acid and anthocyanin on camu-camu (*Myrciaria dubia* McVaugh) nectar. *Food Science and Technology (Campinas)*, 26(1), 70-74. <http://dx.doi.org/10.1590/S0101-20612006000100012>.
- Magerramov, M. A., Abdulagatov, A. I., Azizov, N. D., & Abdulagatov, I. M. (2007). Effect of temperature, concentration and pressure on the viscosity of pomegranate and pear juice concentrates. *Journal of Food Engineering*, 80(2), 476-489. <http://dx.doi.org/10.1016/j.jfoodeng.2006.05.030>.

- Março, P. H., Poppi, R. J., & Scarmínio, I. S. (2008). Analytical procedures for identifying anthocyanins in natural extracts. *Quimica Nova*, 31(5), 1218-1223.
- Moraes, J. O., Pertuzatti, P. B., Corrêa, F. V., & Salas-Mellado, M. M. (2008). Estudo do mirtilo (*Vaccinium ashei* Reade) no processamento de produtos alimentícios. *Food Science and Technology (Campinas)*, 27, 18-22. <http://dx.doi.org/10.1590/S0101-20612007000500003>.
- Pereira, R. J., Cardoso, M. G., Vilas Boas, E. V. B., & Pereira, R. J. (2015). Aspectos de qualidade e composição centesimal dos frutos de *Syzygium Cumini* (L.) Skeels e *Syzygium Paniculatum* Gaertn. *Revista Ceres*, 7(1), 60-74.
- Price, M. L., Van Scoyoc, S. V., & Butler, L. G. A. (1978). Critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. *Journal of Agricultural and Food Chemistry*, 26(5), 1214-1218. <http://dx.doi.org/10.1021/jf60219a031>.
- Roesler, R., Malta, L. G., Carrasco, L. C., Holanda, R. B., Sousa, C. A. S., & Pastore, G. M. (2007). Antioxidant activity of cerrado fruits. *Food Science and Technology (Campinas)*, 27(1), 53-60. <http://dx.doi.org/10.1590/S0101-20612007000100010>.
- Schramm, G. (2006). *Reologia e reometria – fundamentos teóricos e práticos*. São Paulo: Artliber Ltda.
- Silva, G. J. F., Constant, P. B. L., Figueiredo, R. W., & Moura, S. M. (2010). Formulation and stability of anthocyanins's colorants formulated with peels jaboticaba (*Myrciaria ssp.*). *Brazilian Journal of Food and Nutrition*, 21(3), 429-436.
- Šimunek, M., Jambrak, A. R., Dobrović, S., Herceg, Z., & Vukušić, T. (2013). Rheological properties of ultrasound treated apple, cranberry and blueberry juice and nectar. *Journal of Food Science and Technology*, 51(12), 1-17. PMID:25477626.
- Singh, J. P., Kaur, A., Singh, N., Nim, L., Shevkani, K., Kaur, H., & Arora, D. S. (2016). In vitro antioxidant and antimicrobial properties of jambolan (*Syzygium cumini*) fruit polyphenols. *LWT – Food Science and Technology*, 65, 1025-1030.
- Soares, J. C., Caliari, M., Soares, M. S., Jr., & Dourado, K. K. F. (2014). Physical and chemical characterization in fruit jambolan different trees. *Revista Magistra*, 25, 650-654.
- Stone, H., & Sidel, J. L. (2012). *Sensory evaluation practices* (2nd ed.). Toronto: Academic Press.
- Waszczynskyj, N., Rao, C. S., & Silva, R. S. F. (1981). Extraction of proteins from wheat bran: application of carbohydrases. *Cereal Chemistry*, 58, 264-266.
- Waterhouse, A. L. (2002). Polyphenolics: determination of total phenolics. In R. E. Erolstad. *Current protocols in food analytical chemistry* (pp. 111-118). New York: John Wiley & Sons.
- Yu, J., & Ahmedna, M. (2013). Functional components of grape pomace: their composition, biological properties and potential applications. *International Journal of Food Science & Technology*, 48(2), 221-237. <http://dx.doi.org/10.1111/j.1365-2621.2012.03197.x>.
- Zang, S., Tian, S., Jiang, J., Han, D., Yu, X., Wang, K., Li, D., Lu, D., Yu, A., & Zhang, Z. (2017). Determination of antioxidant capacity of diverse fruits by electron spin resonance (ESR) and UV-vis spectrometries. *Food Chemistry*, 221(15), 1221-1225. <http://dx.doi.org/10.1016/j.foodchem.2016.11.036>. PMID:27979081.