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# Optimization of native Brazilian fruit jelly through desirability-based mixture design

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**Abstract**

Faced with the need to enhance the availability and add even more value to Brazilian native fruits, combined with the demand and the great importance of developing mixed fruit products, the objective of this work was to evaluate the processing potential of jabuticaba, pitanga and cambuci in the preparation of jellies, based on sensory and nutritional characteristics, through desirability-based mixture design. Given the high sensory and nutritional quality of the jellies obtained through this study we found that the development of mixed jelly containing the Brazilian Native fruits jabuticaba, pitanga and cambuci is perfectly feasible and of great interest. According to the sensory and nutritional characteristics the fruit mixed jelly should contain: 40-100% jabuticaba, 0-30% cambuci and 0-20% pitanga.

**Keywords:** mixed fruit jelly; nutritional quality; sensory acceptance; desirability function.

**Practical Application:** It was possible to verify that the mixed jelly containing the Brazilian Native fruits is feasible.

## 1 Introduction

Brazil has the most biodiversity in the world, with a huge amount of fruit species, many of them unknown or underutilized and also presenting low commercial value (Leterme et al., 2006; Mattietto et al., 2010; Souza et al., 2012b). Many native species provide fruits with unique sensory characteristics, high concentrations of nutrients and exotic characteristics, which progressively increases their consumption in the domestic and international market (Alves et al., 2008; Rufino et al., 2010; Cardoso et al., 2011). Brazilian native fruits have been subjected to many studies around the world and have attracted great interest of the scientific community (Mattietto et al., 2010; Almeida et al., 2011; Dembitsky et al., 2011; Cardoso et al., 2011; Souza et al., 2015).

Among the Brazilian Native fruits, the cambuci, jabuticaba and pitanga stand out. The cambuci [*Campomanesia phaea* (Berg) Landr.] is a native species found in large scale on the slope of the Serra do Mar area called Atlantic Costal Forest, one of the types of vegetation at risk of extinction in Brazil (Maluf & Pisciottano-Ereio, 2005). The fruits have a color that varies from light to dark green and yellow, a citrus and pleasant aroma, however, this fruit has *in natura* consumption limitations due to its high acidity, astringency and their nonuniform shape and size. Furthermore, it has great potential for industrialization due to its high pulp yield, pectin and ascorbic acid content (Vallilo et al., 2005; Bianchini et al., 2016). The jabuticaba (*Myrciaria* spp.) is another species of Brazilian biodiversity. It is found throughout the country, from the state of Para to that of Rio Grande do Sul (Sato & Cunha, 2007). Its fruits are berry type with reddish bark, almost black, and a whitish pulp. They have a pleasant taste, besides being a rich source of a wide range of phenolic compound, as flavonoids and anthocyanins (Wu et al., 2013; Pereira et al., 2016). The pitanga (*Eugenia uniflora* L.) is also a Brazilian Native fruit, common in central Brazilian to northern Argentina (Donadio et al., 2002). It is a fruit that has colorations ranging from orange and dark red to purple and has good economic capacity due to its high vitamins, minerals and carotenoids (Lima et al., 2002; Freitas et al., 2016).

The fruit processing industries are always striving to develop differentiated products that meet changing consumer demands. In the juice, jams and jellies segment, a new market is expanding for products composed of two or more fruits (Matsuura et al., 2004; Acosta et al., 2009; Souza et al., 2012a; Pelegrine et al., 2015). The preparation of mixed products allows the development of new flavor, color, texture and consistency characteristics, as well as allowing an increase in nutritional value (Yadav et al., 2013; Sobhana et al., 2015). According to Zotarelli et al. (2008), mixed fruit products combine nutritional characteristics of two or more fruits, in addition to ensuring considerable sensory characteristics, gradually obtaining a favored market environment. Fruit combinations can also help to intensify the use of certain fruits which singly do not provide a product with desirable characteristics, cost reduction, one that can supply shortages and presents seasonal availability. Besides that, it can compensates for extremely strong flavors, especially acidity, astringency or bitterness of some fruit and promotes improvements in the nutritional and sensory characteristics of the processed product (Bates et al., 2001; Sousa et al., 2013; Souza et al., 2014).

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Faced with the need to increase the availability and add even more value to Brazilian Native fruits, the objective of this work was to evaluate the processing potential of jabuticaba, pitanga and cambuci in the preparation of jellies, based on sensory and nutritional characteristics, through desirability-based mixture design.

## 2 Materials and methods

### *2.1 Ingredients*

We used the native fruits jabuticaba, pitanga and cambuci for the jelly preparation. The jabuticaba fruits were collected in Lavras and the pitanga fruits in Carmo da Cachoeira, both in Minas Gerais, the climate is classified as tropical of altitude, with dry winter and rainy summer and humid subtropical climate, respectively (Köppen climate classification: Cwa). The cambuci fruits were collected in the Serra da Mantiqueira, the regional climate is the Cwb type, mesothermal or tropical altitude with a dry summer and rainy winter. All fruits were collected in the physiological mature stage, determined by color and size, and then were immediately conducted to Postharvest Laboratory of the Federal University of Lavras, Minas Gerais- Brazil and kept refrigerated at 10 °C until the time of analysis and processing. To the best knowledge of the fruit used, soluble solids, titratable acidity, ratio, pH, color (L*, a*, b*, chroma and hue) of jabuticaba, pitanga and cambuci characteristics are shown in Table 1.

In addition to the fruit it was used sucrose and high-methoxyl pectin to the jelly elaboration (Danisco, SP, Brasil).

### *2.2 Experimental design*

In this study, a centroid mixture design (Cornell, 1983) was used to determine and optimize the proportions of jabuticaba ($X_1$), pitanga ($X_2$) and cambuci ($X_3$) in the jellies based on their nutritional and sensory attributes. The design and experimental levels for the 3 factors are presented in Table 2.

### *2.3 Jellies processing*

After discarding the fruit with physical or microbiological damage, manual removal of the leaves and washing with chlorinated drinking water (4 mg/L), the fruits were homogenized for 5 minutes in an industrial Poly. LS-4 mixer with a 4.0 L capacity at 3500 rpm to obtain pulp. For acquisition of the clarified juice the pulp was sieved. The jelly processing was conducted in the Plant Products Processing Laboratory of the Federal University of Lavras, Minas Gerais- Brazil. The percentages of the ingredients used for the preparation of jellies were: 60% clarified fruit juice, 38.5% sugar and 1.5% high methoxyl pectin.

For the jelly processing, the mixed juices were initially prepared according to the design (Table 2) and then sucrose was added. Processing was conducted in an open pan heated by a gas flame (Macanuda, SC, Brazil). Pectin was added when boiling was achieved, and when the soluble solids content reached 65 °Brix (refractometer measured by RT-82 laptop) cooking was stopped. The hot jellies were then poured into 250 mL sterile bottles and stored in a refrigerator at ±7 °C. The jelly formulations obtained were subjected to physicochemical, nutritional and rheological analysis which were performed in the Post Harvest Laboratory in three repetitions and submitted to sensory analysis which was conducted in the Sensory Analysis Laboratory.

### *2.4 Physicochemical analysis*

To characterize the mixed jelly formulations the analyzes of titratable acidity, total soluble solids and pH were performed according to the method adapted by the Instituto Adolfo Lutz (2005) and the color analyses (L*, a*, b*, chroma and °Hue) was conducted according to the method described by Gennadios et al. (1996) using a Minolta CR 400 colorimeter with standards and D65 CIELab.

### *2.5 Bioactive compounds and antioxidant activity*

For total phenolics and antioxidant activity analysis the extraction was done with methanol (50:50, v/v) and then acetone (70:30, v/v) according to the method described by Larrauri et al. (1997).

The determination of total phenolics was performed according to the Folin-Ciocalteu adapted method (Waterhouse, 2002). The extracts (0.5 mL) were mixed with 2.0 of distilled water and 0.25 mL of Folin-Ciocalteu reagent (10%) and 0.25 mL of saturated sodium carbonate solution. The tubes were then placed in a bath at 37 °C for 30 minutes for color development. The absorbance was measured at 750 nm against a blank in a spectrophotometer (Ultrospec 2000 Pharmacia Bioteche, Cambridge, England). Aqueous solutions of gallic acid were used for calibration. The results are expressed in g gallic acid equivalents (GAE)/100 g. The antioxidant activity was determined by the ABTS assay method described by Re et al. (1999) with some modifications. Firstly, 5 mL of aqueous ABTS solution (7 μM) was mixed with 88 μL of 140 μM - (2.45 mM final concentration)

**Table 1**. Physicochemical properties of jabuticaba, pitanga and cambuci.

| Fruits | SS | TA | Ratio | pH | L* |
|---|---|---|---|---|---|
| **Jabuticaba** | 12.0 ± 0.47 | 1.40 ± 0.05 | 8.57 ± 0.54 | 3.55 ± 0.03 | 12.53 ± 0.48 |
| **Pitanga** | 12.0 ± 0.10 | 1.01 ± 0.00 | 11.88 ± 0.60 | 3.23 ± 0.02 | 34.07 ± 2.36 |
| **Cambuci** | 2.4 ± 0.20 | 1.06 ± 0.03 | 2.26 ± 0.25 | 2.87 ± 0.08 | 57.97 ± 0.01 |
| Fruits | a* | b* | C* | Hue | |
| **Jabuticaba** | 7.46 ± 0.64 | -4.03 ± 0.61 | 8.49 ± 0.73 | 28.3 ± 2.25 | |
| **Pitanga** | 32.14 ± 3.68 | 21.80 ± 4.30 | 32.86 ± 9.40 | 18.3 ± 0.84 | |
| **Cambuci** | -3.91 ± 0.01 | 10.46 ± 0.01 | 11.17 ± 0.50 | 69.4 ± 0.05 | |

Mean value ± standard deviation of fruit; *n* = 3. Soluble Solids (SS): °Brix, Total acidity (TA): g citric acid/100 g f.w.

**Table 2**. Composition of mixed jelly samples according to the centroid mixture design.

| Formulation | Jabuticaba(%)* | Pitanga (%)* | Cambuci (%)* |
|---|---|---|---|
| **F1** | 100 | 0 | 0 |
| **F2** | 0 | 100 | 0 |
| **F3** | 0 | 0 | 100 |
| **F4** | 50 | 50 | 0 |
| **F5** | 50 | 0 | 50 |
| **F6** | 0 | 50 | 50 |
| **F7** | 33 | 33 | 33 |

*Percentage of the fruit juice in the jelly, considering that the juice represents 60% of the formulation.

potassium persulphate to generate the ABTS radical cation. After 16 h in a dark room, this reagent was diluted with ethanol to obtain an absorbance of 0.7 ± 0.05 units at 734 nm. Then, 30 μL of the sample, or the reference substance, were mixed with 3 mL of the ABTS radical. The absorbance decrease at 734 nm was measured after 6 min against a blank in a spectrophotometer (Ultrospec 2000 Pharmacia Bioteche, Cambridge, England). For calibration, ethanolic solutions of known Trolox concentration were used. The results were expressed as micromoles of Trolox equivalents (TEs) per gram of fresh weight (μmol of TEs/g of f.w.). The ascorbic acid analysis was performed though the colorimetric method with 2,4-dinitrophenylhydrazine (2,4-DNPH) described by Strohecker & Henning (1967). The sample readings were performed under an absorbance of 520 nm. The samples were analyzed at an against a blank in a spectrophotometer (Ultrospec 2000 Pharmacia Bioteche, Cambridge, England). The results are expressed in mg ascorbic acid/100 g of fresh weight.

### 2.6 Texture profile analysis

The texture profile analyses (TPA) of the jellies were made in penetration mode under the conditions described by Souza et al. (2014). The jelly samples were compressed by 30%. The parameters analyzed were hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness.

### 2.7 Sensory analysis

An acceptance test was conducted with 80 consumers (40 women and 40 men), among them students and office staff between 18 and 40 years of age, where the evaluated parameters were color, taste, texture and overall liking, through a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like) (Stone & Sidel, 1993). Sensory evaluation of the seven jelly formulations was performed in two sessions, in the first session the consumers evaluated 4 jelly formulations and in the second session the same consumers evaluated the 3 remaining formulations. The sensorial analysis was performed after being approved by the local ethics committee (approval number 1.091.594). The participants were informed about the sensory tests and provided written consent. Each taster assessed, on average, 5 grams of each of the jelly formulations which were offered in 50 mL plastic cups coded with 3 digits displayed monadic and in a balanced order (Wakeling & MacFie, 1995).

The cabins in which the tests were performed were individual, with ventilation and white light at a temperature of 25 °C. The hedonic scale was used by the tasters, in addition to being instructed to drink water from one sample to another.

### 2.8 Statistical analysis

Initially, to compare the Native Brazilian fruit jelly formulations regarding their sensory acceptance, physicochemical characteristics, rheological properties, bioactive compounds and antioxidant activity, a univariate statistical analysis (ANOVA) and Tukey mean test were used to verify if there was a difference between samples at a significance level of 5% ($p \leq 0.05$). For easy viewing of the mixed jelly formulations sensory acceptance and to correlated with the physicochemical and rheological parameters, a 3-way external preference map obtained by PARAFAC (Nunes et al., 2011, 2012) was elaborated using the SensoMaker software, version 1.6 (Pinheiro et al., 2013). The PARAFAC model was optimized using the value of Core Consistency Diagnostics (CORCONDIA) to choose the number of factors (Bro, 1997; Nunes et al., 2011). PARAFAC procedures and the construction of a 3-way preference map and 3-way external preference map were previously mentioned in detail (Nunes et al., 2011, 2012). The SensoMaker version 1.6 was used for data analysis (Pinheiro et al., 2013)

Lastly, in order to optimize formulations of mixed Brazilian Native fruit jelly, each nutritional parameter was converted into individual desirability (*d*) that were then aggregated into a composite desirability (*D*) by geometric mean (Equation 1). Each individual desirability was computed based on Larger-The-Best (LTB) approach.

$$d = \left( \frac{\hat{y} - L}{U - L} \right)^{r}, L \leq \hat{y} \leq U \quad (1)$$

where, $\hat{y}$ is the measured response, $U$ is the upper and $L$ is the lower specification limit of the response. The $r$ value allows changing the shape of $d$; a small value for $r$ implies that the individual desirability value is high unless the response gets very far to the maximum value (Derringer & Suich, 1980; Costa et al., 2011). Based on the predicted model equation, a contour plot of the desirability ($D$) was generated and the optimum region was obtained. The analyses of variance was used to examine the significance of the data fit to the model and the triangular contour plots generated from the polynomial equations were created using the Chemoface software version 1.6 (Nunes et al., 2012).

## 3 Results and discussion

### 3.1 General exploration

Sensory, physicochemical and rheological analysis of mixed Brazilian Native fruit jelly. Figure 1 shows the 3-way external preference map that represents the distribution of consumers, samples, consumer sensory attributes related to acceptance, physicochemical and rheological properties. The PARAFAC was fixed with 2 factors, which led to a corcondia value of 77.37% and a variance value of 37.93%. Mean scores for the sensory attributes, physicochemical characteristics and rheological properties of the mixed Brazilian Native fruit jelly formulations are shown in Table 3, Table 4 and Table 5, respectively.

Through PARAFAC (Figure 1) and Table 3, it appears that in general all formulations were well accepted for all sensory attributes evaluated, with overall average scores situated between the hedonic terms "like slightly" and "liked very much". It is found that specifically the Formulations F1 (100% jabuticaba) and F3 (100% cambuci) were slightly less accepted than others, specifically for the attributes consistency and color, respectively. However this lower acceptance for these two attributes did not reflect in acceptance for the significantly lower overall liking attribute. Through the sensory data it can be seen that the Brazilian native fruits studied, in isolation or combined, give rise to jellies with high sensory quality, however, the cambuci and jabuticaba fruits lead to jelly with greater acceptance when mixed together or with pitanga than when isolated.

As verified in this present work, Souza et al. (2012a) found that the Brazilian Cerrado fruits (marolo, soursop, passion fruit sweet, murici and jenipapo), when combined, result in jellies with a much higher sensory quality than when prepared with these isolated fruits. Souza et al. (2014), found that the mixture of three varieties of raspberry (yellow, black and red raspberry) results in a jelly with much better sensory characteristics than when prepared with each variety in isolation. Several other studies have shown results similar to those found and discussed herein (Abdullah & Cheng, 2001; Silva Pereira et al., 2008; Oludemi & Akanbi, 2013; Pelegrine et al., 2015). Through PARAFAC (Figure 1) it is possible to check the possible factors

**Table 3**. Sensory characteristics of the mixed fruit jellies.

| Formulations | Color | Taste | Consistency | Overall Liking |
|---|---|---|---|---|
| **F1** | 7.77[a] | 6.65[a] | 5.23[c] | 6.35[a] |
| **F2** | 7.05[b] | 6.34[a] | 6.56[ab] | 6.50[a] |
| **F3** | 5.90[c] | 6.37[a] | 7.19[a] | 6.30[a] |
| **F4** | 7.62[ab] | 6.68[a] | 7.15[a] | 6.93[a] |
| **F5** | 7.74[ab] | 6.79[a] | 6.68[ab] | 6.91[a] |
| **F6** | 7.28[ab] | 6.45[a] | 6.73[a] | 6.65[a] |
| **F7** | 7.73[ab] | 6.68[a] | 5.89[bc] | 6.67[a] |
| **SS** | 223.29 | 14.51 | 243.68 | 29.5 |
| **MS** | 37.21 | 2.42 | 40.61 | 4.92 |
| **F** | 16.09 | 0.65 | 12.33 | 1.68 |
| $\mathbf{p_{value}}$ | <0.001 | 0.68 | <0.001 | 0.12 |

Mean values with common letters in the same column indicate that there is no significant difference among samples (p ≤ 0.05) from Tukey's mean test. F1 = jabuticaba; F2 = pitanga; F3 = cambuci; F4 = 50% jabuticaba and 50% pitanga; F5 = 50% jabuticaba and 50% cambuci; F6 = 50% pitanga and 50% cambuci; F7 = 33% jabuticaba, 33% pitanga and 33% cambuci; SS = sum square; MS = mean square.

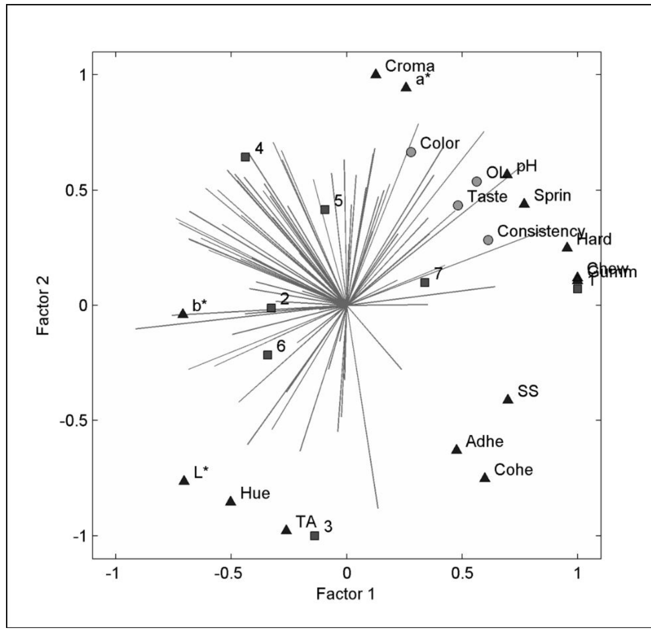


**Figure 1**. Three-way external preference map for sensory attributes (color, taste, consistency and overall liking (ol)), physicochemical characteristics (color L*, a*, and b*, ph, total acidity [TA], and rheological properties (hardness [hard], adhesiveness [adhe], springiness [sprin], cohesiveness [cohe], gumminess [gummi] and chewiness [chew] for the mixed brazilian native fruit jelly formulations. 1 = jabuticaba; 2 = pitanga; 3 = cambuci; 4 = 50% jabuticaba and 50% pitanga; 5 = 50% jabuticaba and 50% cambuci; 6 = 50% pitanga and 50% cambuci; 7 = 33% jabuticaba, 33% pitanga and 33% Cambuci.

Table 4. Total soluble solids (SS), total acidity (TA), pH and color (l*, a*, b*, c* and hue) of the mixed fruit jellies.

| Formulations | SS | TA | pH | L* | a* | b* | C* | Hue |
|---|---|---|---|---|---|---|---|---|
| **F1** | 71.00[a] | 0.38[f] | 3.72[a] | 11.78[d] | 15.91[b] | -2.01[d] | 16.04[bc] | 7.39[c] |
| **F2** | 58.67[c] | 0.59[d] | 3.36[b] | 29.02[b] | 7.62[c] | 10.56[a] | 13.02[c] | 54.21[b] |
| **F3** | 71.00[a] | 1.33[a] | 3.06[d] | 32.90[a] | 0.95[d] | 2.01[c] | 2.22[d] | 63.94[a] |
| **F4** | 63.66[b] | 0.45[e] | 3.39[b] | 19.51[c] | 23.49[a] | 4.44[b] | 23.91[a] | 10.66[c] |
| **F5** | 66.00[b] | 0.32[f] | 3.27[bc] | 17.82[c] | 18.53[b] | 1.86[c] | 18.62[b] | 5.69[c] |
| **F6** | 64.00[b] | 0.94[b] | 3.14[cd] | 28.93[b] | 6.63[c] | 10.92[a] | 12.77[c] | 58.75[ab] |
| **F7** | 69.00[a] | 0.78[c] | 3.27[bc] | 18.20[c] | 22.94[a] | 4.69[b] | 23.40[a] | 11.53[c] |
| **SS** | 365.90 | 2.33 | 0.81 | 1069.09 | 1376.39 | 400.45 | 998.12 | 13146.10 |
| **MS** | 60.98 | 0.39 | 0.13 | 178.18 | 229.40 | 66.74 | 166.35 | 2191.02 |
| **F** | 49.26 | 636.37 | 32.50 | 179.07 | 173.68 | 128.32 | 102.81 | 313.22 |
| $\mathbf{p_{value}}$ | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

Mean values with common letters in the same column indicate no significant difference among samples (p ≤ 0.05) by Tukey's mean test (*n* = 3). Soluble Solids (SS) in °Brix; Total acidity (TA) in g citric acidy/100 g fw; F1 = jabuticaba; F2 = pitanga; F3 = cambuci; F4 = 50% jabuticaba and 50% pitanga; F5 = 50% jabuticaba and 50% cambuci; F6 = 50% pitanga and 50% cambuci; F7 = 33% jabuticaba, 33% pitanga and 33% cambuci; SS = sum square; MS = mean square.

that negatively influence the acceptance of color and consistency of Formulations F3 (100% cambuci) and F1 (100% jabuticaba), respectively. In Table 4 shows that Formulation F3 stands out by presenting the highest color parameters L* and Hue values, thus characterizing a lighter and more yellowish formulation than the others, which well reflects the fruit characteristics (cambuci) that originated it. Table 5 presents Formulation F1 standing out as it having one of the highest values for all the texture parameters - hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness – thus characterizing as being a formulation with a more rigid consistency, elastic and rubbery. Thus, there have been indications that consumers have a preference for jellies with a more vivid color - darker and redder while also preferring softer/less consistent jellies.

### *3.2 Nutritional characteristics of mixed Brazilian Native fruit jelly*

Mean scores and mean test for total phenolics, antioxidant activity and ascorbic acid of mixed Brazilian Native fruit jelly formulations are shown in Table 6.

Regarding nutritional characteristics, Table 6 shows that Formulation F1, made with 100% jabuticaba, stood out by having the highest phenolic compound content and antioxidant activity. In addition, this formulation, along with formulation F3 (made with 100% cambuci) and F6 (made with 50% pitanga and 50% cambuci), had the highest vitamin C content.

Jabuticaba according to Wu et al. (2013) and Pereira et al. (2016), are among the fruits with the highest phenolic and vitamin C content, even being higher than the consecrated red fruits. Dessimoni-Pinto et al. (2011) found that jabuticaba results in a jelly with high phenolic content. Pitanga is a fruit that has stood out in particular, due to its high vitamin C content (Lima et al., 2002; Freitas et al., 2016), being even higher than in orange. According to Bianchini et al. (2016) the fruit of the cambuci tree also have been highlighted for being an excellent source of vitamin C. Thus, it can be seen that when jabuticaba is mixed with cambuci or with pitanga the jellies obtained have a higher phenolics content and antioxidant activity than jellies obtained from these two fruits, isolated (Table 6). Cambuci, when combined with pitanga, provides jellies with higher vitamin C content when compared to jelly prepared only with pitanga (Table 6). From these results it is clear that jabuticaba seems to be the fruit that contributes to obtain a nutritionally richer jelly. According to Silva Pereira et al. (2008) and Sobhana et al. (2015), it was also found that the development of mixed products is an excellent alternative to add nutritional value since mixed products can combine the nutritional characteristics of two or more fruits, yielding improved nutritional characteristics of the final product when compared the product made with only one fruit.

An interesting fact noted is that in some cases the phenolic content and vitamin C, as well as antioxidant activity, does not reflect the average or expected value in the jelly obtained by combining two or three fruits, i.e. there is a synergistic effect among the fruits. For example, jelly Formulation F7 (33% jabuticaba, 33% pitanga and 33% cambuci) showed lower vitamin C content than in the jelly of any one of the three isolated fruits (F1, F2 and F3); however Formulation F6 (50% pitanga 50% cambuci) showed a higher vitamin C content than the jellies prepared with these fruits individually (Table 6). This increase or decrease observed in the bioactive compound content or antioxidant activity, when elaborating a mixture of two or more fruits, can be related to chemical reactions (synergistic effect) that can occur among the fruits, which should be better studied.

In general, even with strict thermal processing, most of the Brazilian Native fruit jellies (except F2 and F7) classify as having medium levels of vitamin C and most (except for F2 and F6) even have average phenolic compound content, according to the fruit classification described by Vasco et al. (2008) and Ramful et al. (2011), respectively. This fact shows that actually, many native fruits, such as cambuci, pitanga and jabuticaba,

**Table 5**. Hardness (Hard n), adhesiveness (Adhe n/s), springiness (Sprin), cohesiveness (Cohe), gumminess (Gummi) and chewiness (Chew) of the mixed fruit jellies.

| Formulations | Hard | Adhe | Sprin | Cohe | Gummi | Chewi |
|---|---|---|---|---|---|---|
| **F1** | 1.52$^{a}$ | 0.57$^{a}$ | 0.99$^{a}$ | 0.38$^{a}$ | 0.57$^{a}$ | 0.56$^{a}$ |
| **F2** | 0.61$^{c}$ | 0.22$^{c}$ | 0.96$^{ab}$ | 0.28$^{b}$ | 0.17$^{c}$ | 0.16$^{c}$ |
| **F3** | 0.40$^{d}$ | 0.66$^{a}$ | 0.94$^{b}$ | 0.39$^{a}$ | 0.16$^{c}$ | 0.15$^{c}$ |
| **F4** | 0.55$^{c}$ | 0.26$^{bc}$ | 0.95$^{ab}$ | 0.26$^{b}$ | 0.14$^{c}$ | 0.14$^{c}$ |
| **F5** | 0.59$^{c}$ | 0.46$^{ab}$ | 0.97$^{ab}$ | 0.33$^{ab}$ | 0.20$^{c}$ | 0.19$^{c}$ |
| **F6** | 0.56$^{c}$ | 0.61$^{a}$ | 0.96$^{ab}$ | 0.34$^{ab}$ | 0.19$^{c}$ | 0.18$^{c}$ |
| **F7** | 1.19$^{b}$ | 0.65$^{a}$ | 0.96$^{ab}$ | 0.33$^{ab}$ | 0.39$^{b}$ | 0.37$^{b}$ |
| **SS** | 3.08 | 0.61 | 0.003 | 0.04 | 0.47 | 0.46 |
| **MS** | 0.51 | 0.10 | 0.001 | 0.01 | 0.08 | 0.08 |
| **F** | 18320 | 15.88 | 3.22 | 8.77 | 90.76 | 90.15 |
| **$p_{value}$** | <0.001 | <0.001 | <0.05 | <0.001 | <0.001 | <0.001 |

Mean values with common letters in the same column indicate no significant difference among samples (p ≤ 0.05) by Tukey's mean test (*n* = 3). F1 = jabuticaba; F2 = pitanga; F3 = cambuci; F4 = 50% jabuticaba and 50% pitanga; F5 = 50% jabuticaba and 50% cambuci; F6 = 50% pitanga and 50% cambuci; F7 = 33% jabuticaba, 33% pitanga and 33% cambuci; SS = sum square; MS = mean square.

**Table 6**. The total phenolics, antioxidant capacity (ABTS) and ascorbic acid content of the mixed fruit jellies.

| Formulations | Total phenolics | Antioxidant capacity – ABTS | Ascorbic acid |
|---|---|---|---|
| **F1** | 183.04$^{a}$ | 18.81$^{a}$ | 37.85$^{a}$ |
| **F2** | 69.58$^{e}$ | 2.77$^{d}$ | 23.23$^{c}$ |
| **F3** | 119.94$^{d}$ | 5.30$^{c}$ | 32.98$^{ab}$ |
| **F4** | 138.34$^{c}$ | 5.52$^{c}$ | 23.41$^{c}$ |
| **F5** | 164.88$^{b}$ | 8.24$^{b}$ | 30.26$^{b}$ |
| **F6** | 77.47$^{e}$ | 2.12$^{e}$ | 35.92$^{a}$ |
| **F7** | 120.45$^{d}$ | 2.75$^{d}$ | 21.64$^{c}$ |
| **SS** | 31541.1 | 612.05 | 784.65 |
| **MS** | 5256.85 | 102.01 | 130.77 |
| **F** | 303.568 | 9940.43 | 36.25 |
| **$p_{value}$** | <0.001 | <0.001 | <0.001 |

Mean values with common letters in the same column indicate that there is no significant difference among samples (p ≤ 0.05) by Tukey's mean test (*n* = 3). Total phenolics = (mg GAEs/100 g f.w.); Antioxidant capacity = ABTS g f.w./g; Ascorbic acid (mg/100 g f.w.); ABTS = 3- etibenzotiazolina-6 ácido sulfônico; GAE = gallic acid equivalent; F1 = jabuticaba; F2 = pitanga; F3 = cambuci; F4 = 50% jabuticaba and 50% pitanga; F5 = 50% jabuticaba and 50% cambuci; F6 = 50% pitanga and 50% cambuci; F7 = 33% jabuticaba, 33% pitanga and 33% cambuci; SS = sum square; MS = mean square.

are nutritionally very rich fruits, and even with the possible high heat degradation still result in products rich in phenolic compounds and vitamin C.

### *3.3 Mixed Brazilian Native fruit jelly optimization*

Since, in general, all formulations were well accepted for all the sensory attributes evaluated, the optimization was performed only taking into account the nutritional characteristics. The equation predicted for the desirability function of the nutritional properties (total phenolics, antioxidant activity and ascorbic acid) was obtained thought response surface methodology analysis (RSREG), based on the response type: Larger-The-Best (LTB) and using a user-specified parameter (r) of 0.5 (Equation 2). A linear model was fitted which presented $R^2$ values greater than 0.8 and significant ($p \leq 0.05$) regressions and no significant lack-of-fit ($p \geq 0.05$), indicating that it was suitable for predictions (Henika, 1982).

$$Y = 0.9047X_1^* - 0.0820X_2 + 0.5300X_3^* \quad (2)$$

Desirability Equation: * significant coefficient ($p \leq 0.05$); Jabuticaba ($X_1$), pitanga ($X_2$) and cambuci ($X_3$).

Based on the predicted nutritional desirability equation, a contour plot was generated and the optimum region for sensory acceptance obtained.

Through the contour curve it is possible to see the optimum region where the most nutritionally rich formulations are, i.e. the region which concomitantly has the formulations with the best total phenolics and, ascorbic acid content and antioxidant activity. According to the contour curve generated it is possible to verify that the Native Brazilian mixed fruit jelly must contain 40-100% jabuticaba, 0-30% cambuci and 0-20% pitanga (Figure 2). As previously noted, it was already expected that the mixed formulation would contain higher jabuticaba content, followed followed by higher cambuci content. This is because it had been found that the jelly obtained from jabuticaba was noted for its higher richness in phenolic compounds and antioxidant activity and the jelly obtained from jabuticaba and cambuci had stood out for presenting the highest vitamin C levels (Table 6).

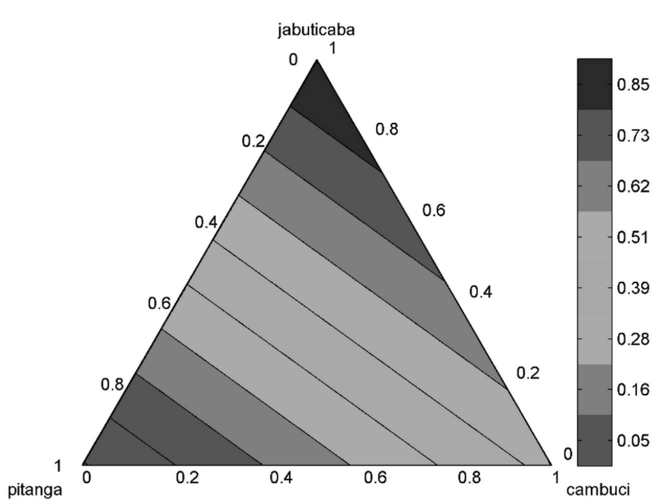


**Figure 2**. Contour plot for nutritional desirability function for mixed native fruit jelly.

In this study we found that, when combined, jellies may have better organoleptic and nutritional characteristics than when prepared from only one fruit. Allied to this fact, the use of three fruits in the development of mixed products is extremely important, since it may contribute to their increased use and add value to the fruits.

## 4 Conclusions

Given the high sensory and nutritional quality of the jellies obtained through this study we found that the development of mixed jelly containing the Brazilian Native fruits jabuticaba, pitanga and cambuci is perfectly feasible and of great interest. According to the sensory and nutritional characteristics the fruit mixed jelly should contain: 40-100% jabuticaba, 0-30% cambuci and 0-20% pitanga.

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