Characterization of different native american physalis species and evaluation of their processing potential as jelly in combination with brie-type cheese

Paula Nogueira CURI¹, Cynara dos Santos CARVALHO², Derlyene Lucas SALGADO², Rafael PIO¹, Daniel Fernandes da SILVA¹, Ana Carla Marques PINHEIRO², Vanessa Rios de SOUZA²*

Abstract

Faced with the need for greater knowledge of the different physalis species, the aim of this study was to characterize different Native American physalis species (Physalis peruviana L., Physalis pubescens L., Physalis angulata L., Physalis mínimos L. and Physalis ixocarpa Brot) as to their physicochemical characteristics, bioactive compounds and antioxidant activity. Besides that, in order to increase their use and add even more value to this fruit, we also evaluate the influence of these different species on the physicochemical, rheological and sensory characteristics of physalis jelly. In addition, this study evaluated the sensory acceptance of the combination of physalis jellies obtained from different species with brie-type cheese. The Peruviana, Pubences and Angulata, are highlighted for being the nutritionally richest species, with the highest levels of phenolic compounds, vitamin C and antioxidant. Moreover, they stand out for originating the most widely sensory accepted jellies, either in pure form or in combination with brie-type cheese.

Keywords: Physalis L.; different species; characterization; jelly processing; harmonization.

Practical Applications: It was possible to verify which physalis are the nutritionally richest species and which species are more suitable for jelly processing.

1 Introduction

Physalis (Physalis L.) is an exotic fruit which presents various compounds of nutritional and pharmacological interest (Bravo et al., 2015; Bravo & Osorio, 2016; Moura et al., 2016a). Among the physalis species whose fruits are rich in compounds beneficial to human health and have potential as a food stand out Physalis peruviana L., Physalis pubescens L., Physalis angulata L., Physalis mínimos L. and Physalis ixocarpa Brot.

The Physalis peruviana is native to the Andes, widely cultivated in Peru (Zapatá et al., 2002). The Physalis pubescens, better known as “camapú”, is a native species of the Amazon - Brazil. The Physalis angulata L., known as “mullaca” or “juá-de-capote”, is also native to Brazil, specifically the North and Northeast regions (Lima et al., 2013). Physalis minimum L. is a purple-tinged plant with great medical importance in the Indian Tradicional System of Medicine (Chothani & Vaghasiya, 2012; Xu et al., 2016). The Physalis ixocarpa known as tomatillo, Mexican husk tomato, green tomato, berry compote, miltomate or jamberry, is a solanaceous fruit vegetable used to prepare the green sauces of Mexican and Central America cooking.

Consumption of physalis in fresh form is restricted due to limited post-harvest life because it has high enzyme activity, which promotes its rapid darkening, especially after mechanical damage during transport and storage (Bravo & Osorio, 2016). Thus, physalis processing, in the form of products such as jellies, would be an excellent way to increase the use of fruit. Jelly is a noble product, highly accepted by consumers which justify the processing of physalis, which is an exotic fine fruit, nutritionally rich with high added-value.

The physalis jelly falls under the gourmet jellies category, which harmonize perfectly with fine cuisine and can be used in the preparation of sophisticated cold, hot (meat, grilled meats and pork loin) and dessert (fruit salad and ice cream) dishes. The physalis jelly is even highly flavored, harmonizing with fine cheeses such as brie-type cheese.

Given the above, the objective of this work was to characterize different Native American species of physalis as to their physicochemical characteristics, bioactive compounds and antioxidant activity and to evaluate the influence of these different species on the physicochemical, rheological and sensory characteristics of the jelly. In addition, this study aimed to sensorially evaluate the combination of physalis jelly, obtained from different species, with brie-type cheese.

2 Materials and methods

2.1 Ingredients

The jellies were prepared from five physalis species: Physalis peruviana L., Physalis pubescens L., Physalis angulata L., Physalis mínimos L. and Physalis ixocarpa Brot. The fruits were harvested from the Fruit Sector of the Department of Agriculture of...
the Federal University of Lavras, Lavras-MG (Brazil), at their physiological maturity, determined by color and fruit size, and were immediately transported to the Post Harvest Laboratory of the Federal University of Lavras, Minas Gerais - Brazil and cold-stored until processing time (around 24h). The city is situated at 21°14’south latitude and 45°00’ west longitude, at an average altitude of 918 meters. The climate is tropical climate of altitude, with dry winter and rainy summer.

The following ingredients were used for the preparation of the jellies: physalis fruit juice, sucrose and high-methoxyl pectin (Danisco, SP, Brazil).

2.2 Jelly Processing

Five physalis jellies were prepared and the variation among the formulations was only the physalis species. The preparation of the jelly was conducted in the Plant Product Processing Laboratory. After discard of the fruit with physical or microbiological damage and manual removal of the leaves, the physalis were washed in potable water. To obtain the pulp used in the jelly preparation, the fruits were homogenized with 50% water for about 5 min in an industrial Poli. LS-4 blender with a 4.0 L capacity at 3500 rpm (Metalúrgica Siemsen Ltda, Brusque, Brazil). The obtained pulp was then finely sieved to obtain the clarified juice.

The percentages of ingredients used for preparation of the jellies were 59.25% clarified physalis juice, 40% sucrose and 0.75% high methoxyl pectin. For the preparation of jellies, sugar was added in the fruit pulp and the processing was carried out in an open pot heated by a gas flame (Macanuda, SC, Brazil). After boiling, pectin (powdered) was added. Finally, when the soluble solids reached 65° Brix, heating was stopped. The total soluble solids were determined using an RT-82 portable refractometer. The hot jelly was then finely sieved to obtain the clarified juice.

The total acidity, soluble solids and pH analysis were performed according to Gennadios et al. (1996) through the Instituto Adolfo Lutz (2005). The color (L*, a* and b*), were made in the fresh fruits of the different species. The fruits of different physalis species were also further characterized as to phenolic compound content, vitamin C content and antioxidant activity (ABTS and DPPH method). The soluble solids, pH, total acidity, color (L*, a* and b*) and texture profile analysis were conducted in the jellies.

2.3 Analysis

The physalis fruit and physalis jelly analyses were performed in the Post Harvest Laboratory in three repetitions. To characterize the physalis, the analysis of length, diameter, unit weight, total soluble solids, total acidity, SS / total acidity (ratio), pH and color (L*, a* and b*), were made in the fresh fruits of the different species. The fruits of different physalis species were also further characterized as to phenolic compound content, vitamin C content and antioxidant activity (ABTS and DPPH method). The soluble solids, pH, total acidity, color (L*, a* and b*) and texture profile analysis were conducted in the jellies.

2.4 Physical and physicochemical analysis

The total acidity, soluble solids and pH analysis were performed according to the Instituto Adolfo Lutz (2005). The color was determined according to Gennadios et al. (1996) though a Minolta CR 400 colorimeter (Konica Minolta, São Paulo, Brazil) with standards and D65 CIELab, where L* ranges from 0 (black) to 100 (white), a* is green (-) to red (+) and b* is blue (-) to yellow (+).

The length and diameter of fruit were measured with the aid of a digital caliper 150 mm (Kingtools, São Paulo, SP), and average fruit weight was determined by individual weighing of each fruit with the aid of a AUX220 semi - analytical scale, (Shimadzu of Brazil, São Paulo, SP).

2.5 Bioactive compounds and antioxidant activity

Preparation of antioxidant and phenolic extracts

The extracts were performed according to the method described by Larrauri et al. (1997). Briefly, 5g of samples were weighed and extracted with 20 mL of methanol/water (50:50, v/v) and after centrifugation (25,400g for 15 min) 20 mL of acetone/water (70:30, v/v) was added to the supernatant. After a second centrifugation, methanol and acetone extracts were combined and brought to a final volume of 50 mL with distilled water.

Total phenolics

The total phenolic analysis was performed according to the Folin–Ciocalteu method with some modifications (Singleton et al., 1999). 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 Biotech, Cambridge, England). Aqueous solutions of gallic acid were used for calibration. The results are expressed in g gallic acid equivalents (GAE)/100 g.

Antioxidant activity

The antioxidant capacity was determined through the reduction of DPPH (2,2-diphenyl-1-picrylhydrazyl) (Sigma ChemicalCo., St.louiz, USA) by the antioxidant present in the sample; a method proposed by Brand-Williams et al. (1995) with a few modifications. Therefore, 50 µL of the extracts in methanol obtained in 3:2:1 were taken and 250 µL of methanol solution of DPPH (0.05 M) was added. Using a spectrophotometer, the absorbance decrease readings at 515 nm were performed at both the initial time and after 30 minutes. The results were expressed in percentage of sequestration.

For the ABTS assay, the procedure followed the method of Re et al. (1999) with minor modifications. Firstly, 5 mL of aqueous ABTS solution (7 μM) was mixed with 88 μL of 140 μM - (2.45 mM final concentration) potassium persulphate to generate the ABTS radical cation. After 16h 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 decrease of absorbance at 734 nm was measured after 6 min against a blank in a spectrophotometer (Ultrospec 2000 Pharmacia Biotech, Cambridge, England). Ethanolic solutions of known Trolox concentrations were used for calibration. The results are expressed as micromoles of Trolox equivalents (TEs) per gram of fresh weight (µmol of TEs/g of f.w.).
**Physalis processing potential**

**Ascorbic acid**

The ascorbic acid analysis was performed through the colorimetric method with 2,4-dinitrophenylhydrazine (2,4-DNPH) described by Strohecker & Henning (1967). The samples were analyzed at an absorbance of 520 nm against a blank in a spectrophotometer (Ultrospec 2000 Pharmacia Biotech, Cambridge, England). The results are expressed in mg ascorbic acid/100 g of fresh weight.

**2.6 Texture profile**

The texture profile analyses (TPA) of the jellies were performed in penetration mode under the conditions described by Souza et al. (2014a, p. S1778):

- a pre-test speed of 1.0 mm/s, a test speed of 1.0 mm/s, a post-test speed of 1.0 mm/s, a time interval between penetration cycles of 10 s, a distance of 40.0 mm and a compression with a 6.0 mm diameter cylindrical aluminum probe using a Stable Micro Systems TA-XT2i texturometer (Goldaming, England).

The jelly samples were compressed by 30%. The parameters analyzed were hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness (Friedman et al., 1963).

**2.7 Sensory analysis**

The physalis jellies obtained from different species were also subjected to sensory analysis. Sensory analysis took place in two sessions. In a first session the panelists evaluated the five physalis jelly formulations in pure form, in a second session the panelists evaluated the five jellies formulations in combination with brie cheese.

The panelists, who were students and office staff of the university, were recruited based on their regular consumption of fruit jams and jellies, available time and no restrictions related to the consumption of any product ingredients. The participants were informed about the sensory tests and provided written consent.

On the first day, an acceptance test was conducted with the 90 consumers (50 female and 40 male – between 18-60 years old), in which the evaluated attributes were color, taste, consistency and overall liking, through a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like) (Stone & Sidel, 1993). In this session each taster assessed, on average, 5 grams of each jelly formulation. On the second day, the same 90 consumers were first asked to score their overall liking through a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like) (Stone & Sidel, 1993). Next, they completed a CATA questionnaire with terms related to satisfaction of consumption of each of the brie cheese and physalis jelly combinations (Adams et al., 2007). In this session each taster assessed, on average, 6 grams of each sample (2 g of brie cheese and 4g of physalis jelly). Attributes related to harmonization, i.e., satisfaction of consumption of physalis jelly with brie cheese, previously surveyed in a focus group with the aid of 12 panelists (8 female and 4 male – between 18-60 years old) were: attractive appearance, pleasant combination, perfect combination, balanced flavor, delicious taste, unpleasant taste, unpleasant combination, unpleasant appearance.

In both days the samples were served in plastic cups coded with 3 digits in a monadic manner and in a balanced block design to avoid order effects (Wakeling & Macfie 1995). The test was carried out in individual booths under white light and ventilation (Souza et al., 2014b). The tasters were instructed in the use of the hedonic scale and to drink water between samples. The sensory analyses were performed according to the local Ethics Committee – approval number 893.639.

**2.8 Statistical analysis**

To compare the physalis species regarding the physicochemical characteristics, bioactive compounds and antioxidant activity and to compare the physalis jellies regarding the physicochemical, rheological and sensory characteristics, initially a univariate statistical analysis (ANOVA) and Tukey mean test at a significance level of 5% (p ≤ 0.05) were conducted.

For easy viewing of the jelly formulation sensory acceptability and to correlate with the physicochemical and rheological parameters, a 3-way external preference map obtained by PARAFAC (Nunes et al., 2011) was elaborated. A 3-way array was arranged from matrices of i rows (i samples) and j + m columns (j consumers + m physicochemical measurements) (Souza et al., 2014b). 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; Souza et al., 2014b).

The acceptance data for the different combinations of jelly and brie cheese were also analyzed through internal preference mapping. Matrices for each attribute with 5 lines (samples) and 90 columns (consumers) were staked according to overall liking. The acceptance matrices were previously standardized (correlation matrix) and then plotted. In order to understand the best combination, the frequency of the sensory attributes of the jelly with brie cheese were analyzed by principal component analysis (PCA). Data were arranged in a matrix and after the standardization (correlation matrix), PCA was applied.

The SensoMaker software version 1.6 was used for data analysis (Pinheiro et al., 2013).

**3 Results and discussion**

**3.1 Physalis Species**

The average values and the average test of the physical and physicochemical properties evaluated for the different species are shown in Table 1. The average values and the average test of the bioactive compounds and antioxidant activity are shown in Table 2.

Regarding the size and weight parameters of the different physalis species, through Table 1, it is possible to verify that the Ixocarpus species stood out with the higher unit weight (13.13g) and larger dimensions (26.12 mm in average length and 30.33 mm of average diameter). It is important to highlight that for fresh consumption, larger fruits are more attractive.

The different physalis species showed wide variability in the physicochemical characteristics, the soluble solids content ranged from 2.33 to 11.33 °Brix, acidity ranged from 0.15 to 2.30g
Table 1. Average length (AL), average diameter (AD), unit weight (UW), total soluble solids (SS), total acidity (TA), solids/acidity (ratio), pH and color (L*, a* and b*) in different physalis species.

<table>
<thead>
<tr>
<th>Species</th>
<th>AL (mm)</th>
<th>AD (mm)</th>
<th>UW (g)</th>
<th>SS (ºBrix)</th>
<th>TA (%)</th>
<th>pH</th>
<th>Ratio</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peruviana</td>
<td>21.16b</td>
<td>20.98ab</td>
<td>5.93b</td>
<td>10.00c</td>
<td>1.82ac</td>
<td>3.57c</td>
<td>5.56c</td>
<td>45.07c</td>
<td>9.30c</td>
<td>30.28c</td>
</tr>
<tr>
<td>Angulata</td>
<td>21.57b</td>
<td>22.01b</td>
<td>6.27b</td>
<td>11.33c</td>
<td>2.30b</td>
<td>3.69b</td>
<td>4.93b</td>
<td>41.57b</td>
<td>8.85b</td>
<td>29.37b</td>
</tr>
<tr>
<td>Pubences</td>
<td>20.30c</td>
<td>21.99b</td>
<td>5.24c</td>
<td>8.33c</td>
<td>1.59c</td>
<td>3.87c</td>
<td>5.45b</td>
<td>41.97c</td>
<td>9.20b</td>
<td>27.23b</td>
</tr>
<tr>
<td>Minima</td>
<td>13.31a</td>
<td>13.99ab</td>
<td>1.67b</td>
<td>4.66c</td>
<td>0.15d</td>
<td>4.18c</td>
<td>31.7b</td>
<td>32.42c</td>
<td>3.82b</td>
<td>7.98c</td>
</tr>
<tr>
<td>Ixocarpa</td>
<td>26.12c</td>
<td>30.33b</td>
<td>13.13b</td>
<td>2.33c</td>
<td>0.91b</td>
<td>4.05b</td>
<td>2.60b</td>
<td>26.64c</td>
<td>11.26b</td>
<td>2.96c</td>
</tr>
</tbody>
</table>

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. Total acidity: g citric acid/100 g F.w.

Table 2. The total phenolics, antioxidant capacity (DPPH and ABTS) and ascorbic acid in different physalis species.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Total phenolics</th>
<th>Antioxidant capacity-DPPH</th>
<th>Antioxidant capacity-ABTS</th>
<th>Ascorbic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peruviana</td>
<td>24.91c</td>
<td>75.06a</td>
<td>6.19a</td>
<td>54.74c</td>
</tr>
<tr>
<td>Angulata</td>
<td>24.18a</td>
<td>75.28b</td>
<td>12.90b</td>
<td>75.44a</td>
</tr>
<tr>
<td>Pubences</td>
<td>25.54a</td>
<td>78.58a</td>
<td>1.83f</td>
<td>72.87f</td>
</tr>
<tr>
<td>Minima</td>
<td>14.82a</td>
<td>75.14a</td>
<td>5.53f</td>
<td>71.05f</td>
</tr>
<tr>
<td>Ixocarpa</td>
<td>15.09d</td>
<td>73.10d</td>
<td>2.98f</td>
<td>26.38f</td>
</tr>
</tbody>
</table>

Mean values with common letters in the same column indicate that there is no significant difference between samples (p ≤ 0.05) by Tukey's mean test. Abbreviations: DPPH: 2-diphenyl-1-picrylhydrazyl radical scavenging activity; GAE: gallic acid equivalent. Total phenolics (mg GAEs/100 g F.w.); Antioxidant capacity – DPPH (% sequestration); Antioxidant capacity – ABTS (µM trolox/gram of fruit); Ascorbic acid (mg/100 g F.w.).
Table 4. Soluble Solids (SS), pH, total acidity (TA), color (L*, a* and b*), hardness (Hard N), adhesiveness (Adhe N/s), springiness (Sprin), cohesiveness (Cohe), gumminess (Gummi) and chewiness (Chew) in physalis jelly.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>SS</th>
<th>pH</th>
<th>TA</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>Hard</th>
<th>Adhe</th>
<th>Sprin</th>
<th>Cohe</th>
<th>Gummi</th>
<th>Chew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peruviana</td>
<td>68.33</td>
<td>3.64</td>
<td>1.16</td>
<td>3.26</td>
<td>2.31</td>
<td>12.33</td>
<td>0.22</td>
<td>0.47</td>
<td>0.95</td>
<td>0.39</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Pubences</td>
<td>72.33</td>
<td>3.87</td>
<td>0.74</td>
<td>3.49</td>
<td>3.40</td>
<td>10.20</td>
<td>0.14</td>
<td>4.19</td>
<td>1.09</td>
<td>0.13</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Angulata</td>
<td>72.67</td>
<td>3.61</td>
<td>0.91</td>
<td>33.11</td>
<td>2.77</td>
<td>10.80</td>
<td>0.35</td>
<td>0.85</td>
<td>0.96</td>
<td>0.40</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Ixocarpa</td>
<td>69.67</td>
<td>3.95</td>
<td>0.41</td>
<td>31.78</td>
<td>4.21</td>
<td>8.93</td>
<td>0.06</td>
<td>0.07</td>
<td>1.77</td>
<td>0.79</td>
<td>0.05</td>
<td>0.09</td>
</tr>
<tr>
<td>Minima</td>
<td>71.67</td>
<td>3.71</td>
<td>1.49</td>
<td>30.99</td>
<td>1.78</td>
<td>6.72</td>
<td>0.06</td>
<td>1.00</td>
<td>0.06</td>
<td>0.18</td>
<td>0.18</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Mean values with common letters in the same column indicate that there is no significant difference between samples (p ≤ 0.05) by Tukey’s mean test. Total acidity: g citric acid/100 g f.w.

The soluble solids of different physalis species jelly ranged from 68.33 to 72.67 °Brix (Peruviana and Angulata, respectively) (Table 3). As expected, the soluble solids did not statistically differentiate between the formulations, this because, although the species of physalis showed different soluble solids, during the preparation of the jelly the final brix degree was fixed.

The pH values ranged from 3.61 to 3.95, since the acidity ranged from 0.41 to 1.49 g citric acid/100 g (Table 3). Through the average table (Table 3) it can be seen that Pubences and Ixocarpa species jelly stood out due to the higher pH (3.87 and 3.95, respectively) and consequently lower acidity (0.74 and 0.41 g citric acid/100 g, respectively).

Jellies elaborated with the Peruviana, Angulata and Pubences species characterized by have the highest L* and b*, and then characterized by being the lighter and more yellowish formulations. Jelly made with the Ixocarpa species characterized by higher a* values, resulting in its red-purplish color and jelly made with the Minima presented the lowest value of a*, presenting as more greenish. It can be verified that the jelly retained the typical coloring of the fruit in fresh form. The darkening displayed, as indicated by the parameter L*, was due to concentration and the reactions that occur during heating, such as the Maillard reaction.

Regarding texture, one can see in the average table (Table 3), that the jelly obtained with the Peruviana and Angulata species stood out for having the highest hardness (0.22 and 0.35) and adhesiveness values (0.47 and 0.85 N/s, respectively). The jelly obtained from the Pubences species showed higher springiness (4.19), cohesiveness (1.09) and chewiness (0.58) and jellies produced by the Minima species showed the highest gumminess values (0.18N).

Thus, the jellies obtained by Peruviana and Angulata species characterized by being more rigid, firm and adhesive. The Pubences species characterized by producing a more cohesive and elastic jelly and Minima species characterized by giving rise to a gummier jelly (Friedman et al., 1963).

A number of factors can explain the change of texture among the jellies prepared from different physalis species; the amount of sugar, pH, acidity and soluble pectin content present in each species are the main variables that may influence gelling and consequently, the final product texture (Souza et al., 2014a).

3.3 Sensory evaluation of physalis jelly formulations

Significant difference was verified, among the jellies obtained from different physalis species, for color, taste, consistency and overall liking (p ≤ 0.05) (Table 4). Figure 1 shows the 3-way external map that represents the distribution of consumers, samples, consumer sensory attributes related to acceptance and physicochemical and texture properties (Souza et al., 2014b). The PARAFAC was fixed with 2 factors - corrodia value of 91% and a variance value of 42%.

In Table 4, it can be seen that generally all physalis jellies showed good acceptability for all attributes, with the overall average scores located between the hedonic terms “liked slightly” and...
“liked very much”. The only exception was the color acceptance attribute of jelly obtained from the Mínima species.

According to TWEPM (Figure 1) and the average table (Table 4) it can be verified that jelly obtained from the Peruviana, Pubences and Angulata species were the most accepted, followed by Ixocarpa and at last the Mínima. The most widely accepted formulations had higher average acceptance scores located between the hedonic terms “liked moderately” and “liked very much” since the less accepted jellies showed average acceptance scores located between the hedonic terms “indifferent” and “liked moderately”.

Thought TWEPM (Figure 1) and the average table for the physicochemical and sensory parameters (Tables 3 and 4, respectively), it can be seen that the most accepted jellies (Peruviana, Pubences and Angulata) were characterized by being the rigider and firmer jellies (hardness), lighter (higher L*) and with typical yellowness (higher b*). The jelly obtained from the Ixocarpa species, characterized by being less acidic (higher pH) with a typical purple/red color (higher a*). The jelly obtained with the Mínima species, which was less accepted sensorially, characterized as being a more acidic and gummier jelly.

From the sensory acceptance results it can be seen that the physalis processing is feasible due to high sensory acceptance of the jellies obtained. Due to higher sensory acceptance the Peruviana, Pubences and Angulata species are those most indicated for jelly processing, followed by the Ixocarpa cultivar. It has been found that consumers have a preference for the color yellow which is known as typical for this fruit, that provides a lighter, more rigid and firm physalis jelly.

### 3.4 Sensory evaluation of physalis jelly formulations with brie cheese

The average values and the average test of the acceptance test for the different physalis species with brie cheese are shown in Table 5.

Thought Table 5, it is seen that, in general, all physalis jelly formulations had good harmonization with brie cheese, due to good sensory acceptance, with average scores located between the hedonic terms “liked slightly” and “liked very much”. According to the average table (Table 5), the combinations obtained from Peruviana, Pubences and Angulata were the most accepted, followed by combination obtained with Ixocarpa and Mínima cultivars.

The PCA was elaborated to correlate the positive and negative attributes selected by the panelists with the formulations of physalis jelly with brie cheese in order to better understand the best combinations (Figure 2).

According to the PCA (Figure 2) one can clearly see that the most accepted combinations by the consumer (Peruviana, Pubences and Angulata) were characterized by the attributes attractive appearance, pleasant combination, perfect combination, balanced flavor and delicious taste and the least accepted combinations (Mínima and Ixocarpa) were characterized by the negative attributes unpleasant taste, unpleasant combination and unpleasant appearance. From the frequency of each sensory attribute (data not shown) it was found that the attractive appearance was the most selected attribute by the tasters to describe the most accepted combinations (Peruviana, Pubences and Angulata), and in the middle 2/3 of the consumers selected this option.

This data indicates that the factor that may most influenced the acceptability of the combination of physalis jelly with brie cheese was the appearance, and the tasters preferred the combination of cheese with yellow coloring and rigid physalis jelly. It appears that the appearance, in particular a color typical of the Minimum (green) and Ixocarpa species (purple) species had lower acceptability.

### 4 Conclusions

The different native American physalis species studied (Physalis peruviana L., Physalis pubescens L., Physalis angulata L., Physalis mínimos L. and Physalis ixocarpa Brot) exhibited wide physical and physicochemical variability among each
other, which resulted in jellies with different physicochemical, rheological and sensory characteristics. The Peruviana, Pubences and Angulata stood out for being the nutritionally richest species, with the highest levels of phenolic compounds, vitamin C and antioxidant activity. Despite the nutritional value, the Mínima appear to be the most suitable species for fresh consumption. Peruviana, Pubences and Angulata are the most suitable species for processing due to higher sensory accepted of the jellies, either in pure form or in combination with brie-type cheese.

Acknowledgements

To FAPEMIG, CNPq and CAPES for the financial support.

References


Physalis processing potential

Physalis peruviana. San

