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

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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 Aplications: 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 (Zapata 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

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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 jellies were poured into sterile 250 mL glass vials, cooled at room temperature and stored at 7 °C until analysis.

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 Bioteche, 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 Bioteche, 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.).

Ascorbic acid

The ascorbic acid analysis was performed though 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 Bioteche, 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-type 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% ($p \le 0.05$) were conducted.

For easy viewing of the jelly formulation sensory acceptance 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 Ixocarpa 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 of citric acid / 100 g, the ratio ranged from 2.60 to 31.7 and the pH ranged from 3.57 to 4.18 (Table 1). Through the average table (Table 1) it can be seen that the Peruviana, Angulata and Pubences species stood out for higher soluble solids and acidity and the Minimum species stood out due to higher ratio and higher pH. The values found for soluble solids and acidity are in agreement with those of other studies conducted by Bravo et al. (2015) and Moura et al. (2016b).

These parameters often indicate the fruit destination, since they identify which fruits are more suitable for fresh consumption or for processing. The higher the sugars and organic acids content, the higher the soluble solids. Generally consumers opt for sweeter fruits, so the fruit with the highest acceptance are those with high soluble solids and high total sugars content (Souza et al., 2012). Acidity is one of the factors that compromise the classification of fruit-based flavor, fruit with acidity levels ranging from 0.08 to 1.95% usually has a mild flavor and are well accepted for consumption as fresh fruit (Paiva et al., 1997; Souza et al., 2012). However, one of the ways most commonly used for fruit flavor evaluation is through the TSS / TTA ratio (ratio). The highest values for this variable is due to the high level of soluble solids and low level of acidity, and the higher the ratio, the greater the fruit sweetness relative to its acidity, which is usually reflects in higher sensory acceptance.

Importantly, the Mínima species, despite being the species with smaller dimensions and weight, appears to be the most suitable species for fresh consumption. The highest ratio and pH presented showed that this species has high sweetness and low acidity, which probably reflects in a high balance between sweet-acid that is very important and desirable for fresh fruit consumption. For coloration, it can be seen by the average table (Table 1) that the Peruviana, Angulata and Pubences species stood out for presenting similar and higher L* and b* values. These physalis species are very similar to each other in size and color, all of which have a more yellowish color (higher b* values), typical of these species. The Ixocarpa highlighted by presenting the highest a* value and it also showed the lowest b* values, resulting in its purplish color, typical of this species. The Mínima species is a yellow-green species (lower a* value).

In relation to bioactive compounds and antioxidant activity through the average table (Table 2), it can be seen that the Pubences, Peruviana and Angulata species stood out for presenting the highest total phenolic contents (25.54, 24.91 and 24.18 mg GAEs/100 g respectively), the Pubences species characterized by having higher antioxidant activity (78.58% of sequestration) by DPPH method, however the Angulata species highlighted by presenting the highest antioxidant activity (12.9 μM of trolox/gram fruit) by the ABTS method. In relation to the vitamin C content, it appears that the Angulata and Pubences stand out for presenting the highest levels (75.44 mg/100 g and 72.87 mg/100 g, respectively).

Tavarini et al. (2008), Santos et al. (2013) and Souza et al. (2015) reported that the bioactive contents and total antioxidant capacity varies depending on the cultivar.

According to Vasco et al. (2008) classification all physalis species can be classified as having a low phenol concentration (< 100 mg GAEs.100 g^{-1}). Following the ascorbic acid classification proposed by Ramful, et al. (2011) all physalis species, except for Ixocarpa, are classified with high vitamin C content (> 50 mg.100 g^{-1}), showing that this fruit is a very good source of this vitamin.

3.2 Physalis jellies

Physicochemical characterization

The average values and the average test of the physicochemical properties evaluated for the different physalis jelly formulations are shown in Table 3. Except for soluble solids, pH, color parameter L* and gumminess, all parameters were significant ($p \leq 0.05$) for the jelly made with different physalis species.

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.

Species	AL (mm)	AD (mm)	UW (g)	SS (°Brix)	TA (%)	pH	Ratio	L*	a*	b*
Peruviana	21.16^{b}	20.98^{b}	5.93^{c}	10.00^{b}	1.82^{ab}	3.57^{e}	5.56^{b}	45.07^{a}	9.30^{a}	30.28^{a}
Angulata	21.57^{b}	22.01^{b}	6.27^{c}	11.33^{a}	2.30^{a}	3.69^{d}	4.93^{b}	41.57^{b}	8.85^{ab}	29.37^{a}
Pubences	20.30^{b}	21.99^{b}	5.24^{d}	8.33^{c}	1.59^{b}	3.87^{c}	5.45^{b}	41.97^{b}	9.20^{a}	27.23^{ab}
Mínima	13.11^{c}	13.99^{c}	1.67^{e}	4.66^{d}	0.15^{d}	4.18^{a}	31.7^{a}	32.42^{c}	3.82^{b}	7.98^{b}
Ixocarpa	26.12^{a}	30.33^{a}	13.13^{a}	2.33^{e}	0.91^{c}	4.05^{b}	2.60^{b}	26.64^{c}	11.26^{a}	2.96^{c}

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.

Cultivars	Total phenolics	Antioxidant capacity-DPPH	Antioxidant capacity-ABTS	Ascorbic acid
Peruviana	24.91^{b}	75.06^{b}	6.19^{b}	54.47^{c}
Angulata	24.18^{c}	75.28^{b}	12.90^{a}	75.44^{a}
Pubences	25.54^{a}	78.58^{a}	1.83^{d}	72.87^{ab}
Mínima	14.82^{d}	75.14^{b}	5.53^{c}	71.05^{b}
Ixocarpa	15.09^{d}	73.10^{b}	2.98^{d}	26.38^{d}

Mean values with common letters in the same column indicate that there is no significant difference between samples ($p \leq 0.05$) by Tukey's mean test. Abbreviations: DPPH: 2-diphenyl-1-picryhydrazyl 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 3. 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.

Cultivars	SS	pH	TA	L*	a*	b*	Hard	Adhe	Spr	Cohe	Gum	Chew
Peruviana	68.33^{a}	3.64^{a}	1.16^{ab}	32.65^{a}	2.31^{c}	12.33^{a}	0.22^{b}	0.47^{b}	0.95^{b}	0.39^{b}	0.08^{a}	0.08^{b}
Pubences	72.33^{a}	3.87^{a}	0.74^{cd}	32.49^{a}	3.40^{ab}	10.20^{ab}	0.14^{bc}	0.01^{c}	4.19^{a}	1.09^{a}	0.13^{a}	0.58^{a}
Angulata	72.67^{a}	3.61^{a}	0.91^{bc}	33.11^{a}	2.77^{bc}	10.80^{ab}	0.35^{a}	0.85^{a}	0.96^{b}	0.40^{b}	0.14^{a}	0.14^{b}
Ixocarpa	69.67^{a}	3.95^{a}	0.41^{d}	31.78^{a}	4.21^{a}	8.93^{ab}	0.06^{c}	0.07^{c}	1.77^{b}	0.79^{a}	0.05^{a}	0.09^{b}
Mínima	71.67^{a}	3.71^{a}	1.49^{a}	30.99^{a}	1.78^{c}	6.72^{b}	0.06^{c}	0.06^{c}	1.00^{b}	0.06^{b}	0.18^{a}	0.07^{b}

Mean values with common letters in the same column indicate that there is no significant difference between samples ($p \leq 0.05$) 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 tthe 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 Mínima 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 Mínima 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 Mínima 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 ($p \leq 0.05$) (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 - corcondia value of 91% and a variance value of 42%.

Table 4. Sensory characteristics of the physalis jellies obtained from different species.

Formulations	Color	Taste	Consistency	Overall Liking
Peruviana	7.65^{a}	7.09^{ab}	7.20^{a}	7.23^{a}
Pubences	7.84^{a}	7.16^{ab}	6.37^{b}	7.01^{a}
Angulata	7.72^{a}	7.28^{a}	7.40^{a}	7.34^{a}
Ixocarpa	6.04^{b}	6.84^{ab}	6.94^{ab}	6.79^{ab}
Mínima	5.57^{b}	6.56^{b}	6.99^{ab}	6.43^{b}

Mean values with common letters in the same column indicate that there is no significant difference among samples ($p \leq 0.05$) from Tukey's mean test.

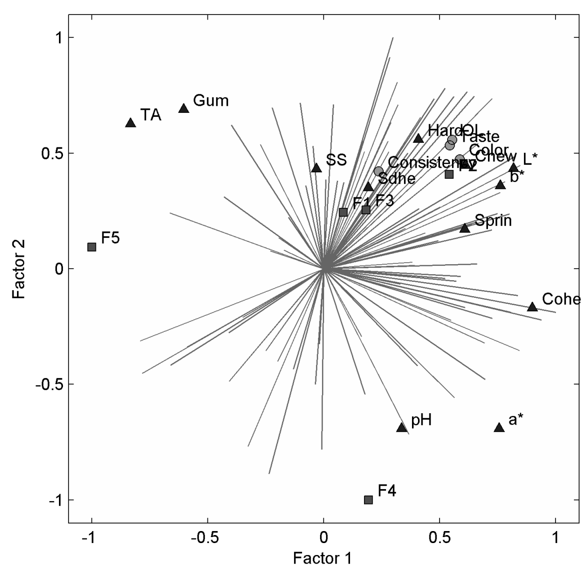

Figure 1. Three-way external preference map (TWEPM) for sensory attributes and physicochemical properties for the physalis jellies. *Peruviana (F1); Pubences (F2); Angulata (F3); Ixocarpa (F4) and Mínima (F5). SS: Soluble Solids; TA: Total acidity; Hard.: Hardness; Adhe.: Adhesiveness; Sprin: Springiness; Cohe: Cohesiveness; Gummi: Gumminess; Chew: Chewiness.

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.

Table 5. Sensory characteristics of the physalis jellies, obtained from different species, combined with brie cheese.

Formulations	Overall Liking
Peruviana	7.09[ab]
Pubences	6.93[ab]
Angulata	7.21[a]
Ixocarpa	6.48[b]
Mínima	6.48[b]

Mean values with common letters in the same column indicate that there is no significant difference among samples ($p \leq 0.05$) from Tukey's mean test.

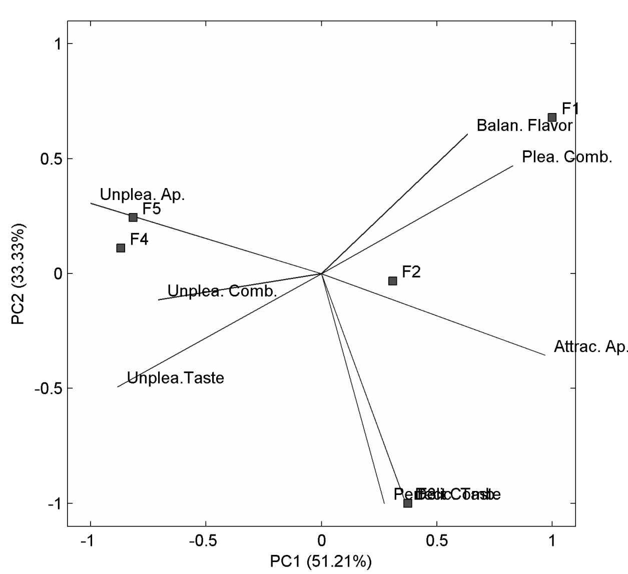

Figure 2. Principal Component Analysis (PCA) for the positive and negative attributes of the physalis jellies with brie cheese. Peruviana (F1); Pubences (F2); Angulata (F3); Mínima (F4) and Ixocarpa (F5). Attractive Appearance (Attrac. Ap.); Pleasant Combination (Plea. Comb.); Perfect Combination (Perfect Comb.); Balanced Flavor (Balan. Flavor); Delicious Taste (Delic. Taste); Unpleasant Taste (Unplea.Taste); Unpleasant Combination (Unplea. Comb.); Unpleasant Appearance (Unplea. Ap.).

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.

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References

Adams, J., Williams, A., Lancaster, B., & Foley, M. (2007). Advantages and uses of check-all-that-apply response compared to traditional scaling of attributes for salty snacks. In *Proceedings of the 7th Pangborn Sensory Science Symposium*, Minneapolis, USA.

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free-radical method to evaluate antioxidant activity. *Food Science and Technology (Campinas.)*, 28(1), 25-30. http://dx.doi.org/10.1016/S0023-6438(95)80008-5.

Bravo, K., Sepulveda-Ortega, S., Lara-Guzman, O., Navas-Arboleda, A. A., & Osorio, E. (2015). Influence of cultivar and ripening time on bioactive compounds and antioxidant properties in Cape gooseberry (Physalis peruviana L.). *Journal of the Science of Food and Agriculture*, 95(7), 1562-1569. PMid:25131258. http://dx.doi.org/10.1002/jsfa.6866.

Bravo, K., & Osorio, E. (2016). Characterization of polyphenol oxidase from Cape gooseberry (Physalis peruviana L.) fruit. *Food Chemistry,* 197(1), 185-190.

Bro, R. (1997). PARAFAC. Tutorial and applications. *Chemometrics and Intelligent Laboratory Systems*, 38(2), 149-171. http://dx.doi.org/10.1016/S0169-7439(97)00032-4.

Chothani, D. L., & Vaghasiya, U. H. (2012). A phyto-pharmacological overview on Physalis minima Linn. *Indian Journal of Natural Products en Resources,* 3(4), 77-482.

Friedman, H. H., Whitney, J. E., & Szczesniak, A. S. (1963). The texturometer: a new instrument for objective texture measurement. *Journal of Food Science*, 28(4), 390-396. http://dx.doi.org/10.1111/j.1365-2621.1963.tb00216.x.

Gennadios, A., Weller, C. L., Hanna, M. A., & Froning, G. W. (1996). Mechanical and barrier properties of egg albumen films. *Journal of Food Science*, 61(3), 585-589. http://dx.doi.org/10.1111/j.1365-2621.1996.tb13164.x.

Instituto Adolfo Lutz – IAL. (2005). *Normas Analíticas do Instituto Adolfo Lutz*. São Paulo: IAL.

Larrauri, J. A., Ruperez, P., & Saura-Calixto, F. (1997). Effect of drying temperature on the stability of polyphenols and antioxidant activity of red grape pomace peels. *Journal of Agricultural and Food Chemistry*, 45(4), 1390-1393. http://dx.doi.org/10.1021/jf960282f.

Lima, C. S. M., Severo, J., Andrade, S. B., Affonso, L. B., Rombaldi, C., & Rufato, A. R. (2013). Qualidade pós-colheita de physalis sob temperatura ambiente e refrigeração. *Revista Ceres*, 60(3), 311-317. http://dx.doi.org/10.1590/S0034-737X2013000300002.

Moura, P. H. A., Coutinho, G., Pio, R., Bianchini, F. G., & Curi, P. N. (2016a). Plastic covering, planting density, and prunning in the production of cape gooseberry (*Physalis peruviana* l.) in subtropical region. *Revista Caatinga*, 29(2), 367-374. http://dx.doi.org/10.1590/1983-21252016v29n213rc.

Moura, P. H. A., Pio, R., Curi, P. N., Rodrigues, L. C. A., Bianchini, F. G., & Bisi, R. B. (2016b). Cobertura plástica e densidade de plantio na qualidade das frutas de Physalis peruviana L. *Revista Ceres,* 63(3), 334-339. http://dx.doi.org/10.1590/0034-737X201663030009.

Nunes, C. A., Pinheiro, A. C. M., & Bastos, S. C. (2011). Evaluating consumer acceptance tests by three-way internal preference mapping obtained by parallel factor analysis (PARAFAC). *Journal of Sensory Studies*, 26(2), 167-174. http://dx.doi.org/10.1111/j.1745-459X.2011.00333.x.

Paiva, M. C., Manica, I., Fioravanço, J. C., & Kist, H. (1997). Caracterização química dos frutos de quatro cultivares e de duas seleções de goiabeira. *Revista Brasileira de Fruticultura*, 19(1), 57-63.

Pinheiro, A. C. M., Nunes, C. A., & Vietoris, V. (2013). SensoMaker: a tool for sensorial characterization of food products. *Ciência e Agrotecnologia*, 37(3), 199-201. http://dx.doi.org/10.1590/S1413-70542013000300001.

Ramful, D., Tarnus, E., Aruoma, O. I., Bourdan, E., & Bahorun, T. (2011). Polyphenol composition, vitamina C content and antioxidant capacity of Mauritian citrus fruit pulps. *Food Research International*, 44(7), 2088-2099. http://dx.doi.org/10.1016/j.foodres.2011.03.056.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Advances in Free Radical Biology & Medicine*, 26(9-10), 1231-1237. PMid:10381194. http://dx.doi.org/10.1016/S0891-5849(98)00315-3.

Santos, C. M., Abreu, C. M. P., Freire, J. M., & Corrêa, A. D. (2013). Antioxidant activity of fruits of four peach cultivars. *Revista Brasileira de Fruticultura*, 35(2), 339-344. http://dx.doi.org/10.1590/S0100-29452013000200002.

Singleton, V. L., Orthofer, R., & Lamuela-Raventos, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in Enzymology*, 299(1), 152-178. http://dx.doi.org/10.1016/S0076-6879(99)99017-1.

Souza, V. R., Pereira, P. A. P., Pinheiro, A. C. M., Lima, L. C. O., & Pio, R. (2014a). Analysis of the subtropical blackberry cultivar potential in jelly processing. *Journal of Food Science*, 79(9), 1776-1781. PMid:25154800. http://dx.doi.org/10.1111/1750-3841.12565.

Souza, V. R., Pereira, P. A. P., Pinheiro, A. C. M., Nunes, C. A., Pio, R., & Queiroz, F. (2014b). Evaluation of the Jelly Processing Potential of Raspberries Adapted in Brazil. *Journal of Food Science*, 79(3), S407-S412. PMid:24467459. http://dx.doi.org/10.1111/1750-3841.12354.

Souza, V. R., Pereira, P. A. P., Queiroz, F., Borges, S. V., & Carneiro, J. D. S. (2012). Determination of bioactive compounds, antioxidant activity and chemical composition of Cerrado Brazilian fruits. *Food Chemistry*, 134(1), 381-386. http://dx.doi.org/10.1016/j.foodchem.2012.02.191.

Souza, V. R., Pereira, P. A. P., Teixeira, T. R., Silva, T. L. T., Pio, R., & Queiroz, F. (2015). Influence of processing on the antioxidant capacity and bioactive compounds in jellies from different blackberry cultivars. *International Journal of Food Science & Technology*, 50(7), 1658-1665. http://dx.doi.org/10.1111/ijfs.12819.

Stone, H. S., & Sidel, J. L. (1993). *Sensory evaluation practices*. San Diego: Academic Press.

Strohecker, R., & Henning, H. M. (1967). *Analisis de vitaminas: metodos comprobados*. Madrid: Paz Montalvo.

Tavarini, S., Degl'innoceti, E., Remorini, D., Massai, R., & Guidi, L. (2008). Preliminary characterization of peach cultivars for their antioxidant capacity. *International Journal of Food Science & Technology*, 43(5), 810-815. http://dx.doi.org/10.1111/j.1365-2621.2007.01520.x.

Vasco, C., Ruales, J., & Kamal-Eldin, A. (2008). Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. *Food Chemistry*, 111(4), 816-823. http://dx.doi.org/10.1016/j.foodchem.2008.04.054.

Wakeling, I., & Macfie, H. J. H. (1995). Designing consumer trials balanced for first and higher orders of carry-over effect when only a subset of k samples from t may be tested. *Food Quality and Preference*, 6(4), 299-308. http://dx.doi.org/10.1016/0950-3293(95)00032-1.

Xu, X. M., Guan, Y. Z., Shan, S. M., Luo, J. G., & Kong, L. (2016). Withaphysalin-type withanolides from Physalis minima. *Phytochemistry Letters*, 15(1), 1-6. http://dx.doi.org/10.1016/j.phytol.2015.11.005.

Zapata, J. L., Saldarriaga, A., Londono, M., & Diaz, C. (2002). *Manejo del cultivo de la uchuva en Colombia* (42 p. Boletín Técnico). Rio Negro Antioquia: Centro de Investigacíon La Selva.