Characterization, processing potential and drivers for preference of pepper cultivars in the production of sweet or spicy jellies

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Abstract Due to the importance of studying alternatives to reduce pepper post-harvest loss and verify the processing potential of the several cultivars/varieties available, the objective of this study was to characterize common peppers in Brazil, and to evaluate their potential for further processing into jelly form. More specifically, the most-consumed species and varieties in Brazil were investigated, that is: Habanero, Cheiro do Norte, Biquinho, Malagueta, Cayenne, Paprika and Dedo de Moça. Additionally, the drivers of liking for pepper jelly were sought so as to understand the desirable characteristics of this product. The different peppers were initially assessed by the following physical and physicochemical analyses: length, diameter, unit mass, total soluble solids, total titratable acidity, pH, color, total phenolic content, antioxidant activity, and vitamin C levels. Jellies made with different pepper types were also analyzed for total titratable acidity, pH, color,

and texture profile, and a sensory study was conducted to elucidate the drivers of liking. As expected, different pepper types varied in physical and physicochemical properties, and the resulting jellies also differed in terms of physical, physicochemical, textural and sensory characteristics. In general, less pungent peppers (Biquinho, Paprika and Cheiro do Norte) were the most suitable for processing to produce jellies with more desirable attributes for consumers: reddish color, characteristic flavor and aroma of a pepper, sweet taste, and low pungency.

Keywords *Capsicum* ssp · Pepper types · Jelly · Consumer profile

Introduction

Production of peppers in Brazil is concentrated mostly in the Southeast, Central-West and South regions. Such cultivation, considered as a secondary activity in the country, has undergone significant transformation, and assumed great socioeconomic importance (Ribeiro et al. 2008). Peppers have been prominent in the national and international scene, mainly because of the exotic flavor of their fruits, their functional characteristics, and the diversity in the form of their consumption. Peppers can not only be eaten raw, but can also be processed and used in several products in the food industry.

Peppers belong to the genus *Capsicum*, and include approximately 30 species, in which the domesticated ones are particularly important: *C. annum*, *C. chinense*, *C. frutescens*, *C. baccatum* and *C. pubescens*. The cultivation of these species is widespread because of their rich nutritional content and capsaicinoids, which are responsible for their pungency (Hoffman et al. 1983; Sanatombik and Sharma

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2008). Habanero, Cheiro do Norte, Biquinho, Malagueta, Cayenne, Paprika and Dedo de Moça (Ribeiro et al. 2008) stand out as pepper types whose fruits are well-defined and diversified, and which are also rich in compounds that are beneficial to human health (Lunn 2007) and with potential as food material. According to Scoville's pungency scale, Habanero is the most pungent among these peppers, followed by Malagueta, Cayenne, and Dedo de Moça. The peppers Cheiro do Norte, Paprika and Biquinho present the least pungency.

Studies involving the different pepper cultivars focus on determining their productivity characteristics, resistance to pests, susceptibility to mechanical injuries, physiological features, and physicochemical attributes (Costa et al. 2015). However, there are no reports of studies that evaluated the nutritional characteristics of different pepper types. Furthermore, as peppers are perishable, it is important to study alternatives to reduce post-harvest loss, verify the processing potential of these different cultivars/varieties, as well as to raise the profile of consumption of the various products that can be obtained from peppers. According to Finger and Casali (2006), the rapid degradation and loss of product quality limits the commercialization of peppers in the fresh fruit market. Thus, processing in the form of sauces, jams and jellies is a means to increase shelf life, value, and the marketing period of the product.

According to Brazilian legislation (CNNPA no. 12, 1978), fruit jelly is a product prepared with fruit pulp and fruit juice that can present whole fruits or pieces in various forms, such ingredients being mixed with sugars, with or without added water, pectin, acids and further ingredients allowed by such standards. Such mixtures will be suitably processed to a suitable semi-solid consistency and finally packaged in a manner to ensure its preservation. The legislation allows the addition of acidulantes (such as citric acid) and pectin to compensate for any deficiencies in the original pectin content or fruit acidity. Specifically, pepper jelly does not yet have a clear regulation, although it is informally referred as jelly due to the standard ingredients and typical jelly texture characteristics. Depending on the characteristics of the pepper, such as pungency, the jelly can be made with an aqueous extract of the pepper, with a low pepper concentration. The pepper has the function of conferring the characteristic flavor of peppers and mainly the pungency in the jellies due to their capsaicinoids content. In jelly preparation, just the pepper pulp can be used, or pulp with the seeds, depending on the characteristics desired. The combination of the sweet taste from the sucrose and the spice from the pepper is what makes pepper jelly such an exotic product.

The preparation of jellies using sweet and/or spicy peppers is one of the most recent forms of adding value to

the product. In this context, the objective of this study was to characterize and evaluate the processing potential in the form of jelly of different pepper types, specifically the most-consumed species and varieties in Brazil. In addition, identification of the pepper jelly 'drivers of liking' was sought to understand the desirable characteristics of this product.

Materials and methods

Pepper samples

Seven types of peppers were used for this study: Habanero (*Capsicum chinense*), Cheiro do Norte (*Capsicum chinense*), Biquinho (*Capsicum chinense*), Malagueta (*Capsicum frutescens*), Cayenne (*Capsicum annuum*), Paprika (*Capsicum annuum*) and Dedo de Moça (*Capsicum baccatum* var. *pendulum*).

The peppers were harvested in the morning, at physiological maturity, which was determined by color and size. After manual selection to remove peppers with some visual damage, the fruits were sanitized in chlorinated (0.5%) clean water, and immediately frozen in a freezer at -18°C until analysis and processing (around 7 days).

Jelly preparation

After thawing at room temperature and withdrawing the seeds, the peppers were triturated with water in an industrial blender and then filtered to obtain a clear extract. The proportions of pepper and water were determined, considering the pungency of each pepper, and through pre-tests. These pre-tests consisted of a focus group (15 consumers) for each pepper type, in which samples of jellies prepared with pepper extract at different concentrations were offered to the tasters, who were asked to evaluate the pungency, classifying it as weak, ideal, or strong. Sucrose, high methoxylation pectin (Danisco, SP, Brazil), and citric acid were also used, in addition to the peppers to enhance the jellies.

The proportions of pepper and water to enhance the extracts of different peppers was: 1.5% pepper and 98.5% water for Habanero, 5% pepper and 95% water for Malagueta, 8% pepper and 92% water in Cayenne, 8% pepper and 92% water for Dedo de Moça, 70% pepper and 30% water for Cheiro do Norte, 55% pepper and 45% water for Paprika, and 70% of pepper and 30% water for Biquinho.

Percentages of the ingredients used in the jelly formulations (expressed regarding total weight) were: 60% pepper extract, 38.5% sugar, 1.0% pectin, and 0.5% citric acid. For the processing of jellies, the sugar and the pepper extracts were initially mixed and heated in an open pan

over a gas flame (Macanuda, SC, Brazil). After boiling, pectin, pre-mixed with a small amount of sugar to facilitate its homogenization, was added. At the end of the process, after the soluble solids reached 55°Brix, measured at $\pm 25\text{ }^{\circ}\text{C}$ on a portable model RT-82 refractometer, cooking was stopped, and the citric acid was added. After the jellies were ready, they were packaged while still hot in sterile 250 mL glass bottles. Then, thermo-inversion was carried out and the jellies were stored at room temperature. Jellies were analyzed 24 h after preparation.

Chemical analysis

To characterize the peppers, measurements of length, diameter, unit mass, total soluble solids (SS), total titratable acidity (TA), pH, and color (L^* , Chroma and Hue) were carried out on fresh fruits (after thawing at room temperature). The different pepper types were also evaluated for their content of phenolic compounds, antioxidant activity (DPPH, ABTS and β -carotene) and vitamin C concentration.

In the jellies prepared with the different pepper types, analyses of total TA, pH, color (L^* , Chroma and Hue), texture profile analysis, and sensorial characteristics were performed.

Three repetitions were performed for all physical and physicochemical analyses.

Physical and physicochemical analysis

A 150 mm digital caliper (Kingtools, São Paulo, SP, Brazil) was used to measure the length and diameter, and a semi-analytical balance (Shimadzu of Brazil, São Paulo, SP) to measure the mass of the fruits.

The TA, SS and pH values were determined according to the Adolfo Lutz Institute—IAL (2005). The color was determined according to the method described by Gennadios et al. (1996). The L^* , Chroma and $^{\circ}\text{Hue}$ values were determined by using a Minolta CR 400 colorimeter (Konica Minolta, São Paulo, Brazil) with standards and D65 CIELAB.

Bioactive compounds and antioxidant activity

Preparation of phenolics and antioxidants extract The extractions were performed according to the method described by Larrauri et al. (1997). Briefly, 5 g of pepper samples was weighed and extracted with 20 mL of methanol/water (50:50, v/v) and, after centrifugation ($25,400\times g$ 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 phenolic content The total phenolic analysis was performed according to the Folin–Ciocalteu method (Singleton et al. 1999), with some modifications. The extract (0.5 mL) was mixed with 2.0 mL of distilled water, 0.25 mL of Folin–Ciocalteu reagent (10%), and 0.25 mL of saturated sodium carbonate solution. The absorbance was measured at 750 nm against a blank in a spectrophotometer. Aqueous solutions of gallic acid were used for calibration. The results are expressed in gallic acid equivalents (GAE)/100 g.

Antioxidant analysis The DPPH method, proposed by Brand-Williams et al. (1995), with a few modifications, was used to determine antioxidant activity. Briefly, pepper extracts (0.1 mL) were allowed to react with 3.9 mL of the DPPH radical solution for 30 min in the dark, performing readings at 517 nm, and observing the decrease in absorbance until stabilization. The results are expressed as EC 50 (g of sample/g of DPPH).

The procedure described by Re et al. (1999), with minor modifications, was followed to determine the antioxidant activity through the ABTS method. 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 ABTS radical cations. 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. Next, 30 μL of the sample or the reference substance were mixed with 3 mL of the ABTS radical solution. The absorbance reduction at 734 nm was measured after 6 min against a blank in a spectrophotometer. Trolox ethanolic solutions 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.).

Finally, the antioxidant capacity was determined according to the β -carotene method described by Marco (1968), with minor modifications. Initially, 50 mL of β -carotene diluted in chloroform (20 mg mL^{-1}), 40 μL of linoleic acid and 530 μL of Tween-40, and 1 mL of chloroform were mixed for β -carotene/linoleic acid system preparation. After evaporation of chloroform, oxygen-saturated water was added to the system until it had an absorbance of 0.6 at 470 nm. Then, 5 mL of this solution/system was mixed with 0.4 mL of each dilution of the extracts used for the experiment, or with 0.4 mL of the Trolox[®] standard for the control. The tubes were placed in a water bath at 40 $^{\circ}\text{C}$ and subsequent readings were performed after 2 min and 120 min at an absorbance of 470 nm with the use of a spectrophotometer. The results are expressed as % of protection.

Vitamin C The ascorbic acid content analysis was performed through the colorimetric method with 2,4-dinitrophenylhydrazine (2,4-DNPH), as described by Strohecker and Henning (1967). Samples were analyzed at an absorbance of 520 nm against a blank in a spectrophotometer. Results are expressed in mg of ascorbic acid/100 g of fresh weight.

Texture profile analysis

Texture profile analyses (TPA) were performed according to the conditions described by Souza et al. (2014): “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 by 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).

Sensory analysis

Sensory analysis was performed with 100 participants (35 men and 65 women) who were students and university employees aged between 18 and 40 years. The consumers were selected based on their regular consumption of pepper products to ensure that they were the target audience. In sensory evaluation, each taster analyzed seven pepper jelly formulations through the sensory acceptance test and the check-all-that-apply (CATA) test.

Participants received approximately 5 g of each jelly sample in disposable white plastic cups encoded with randomized three-digit figures, toast to eat with the jellies, and a disposable cup with water to clean the palate. The samples were served in a balanced and monadic manner, in a laboratory environment with adequate lighting, temperature set at 23 °C, and absence of interferers such as odors and noises. The sensory analysis was performed in one session, with a 30 min break after the fourth sample.

The testers evaluated the acceptance samples for attributes of appearance, aroma, taste, consistency and overall liking using a hedonic scale of 9 points (Stone and Sidel 1993). Afterward, they completed a CATA questionnaire with 22 randomized terms related to pepper jelly previously determined by a focus group (Adams et al. 2007). The terms were: Reddish color, Orange color, Yellowish color, Bright, Opaque, Transparent, Pepper aroma, Pungent aroma, Tomato aroma, Fruit aroma, Sweet aroma, Without Aroma, Firm, Gelatinous, Soft, Gummy, Breakthrough, Pepper taste, Acid Taste, Fruit Taste, Sweetened Taste, Pungent.

Briefly, the focus group was made with 15 consumers (6 men and 9 women) of pepper-based products ranging in age from 18 to 40 years. Samples of pepper jelly were offered to the participants and, with the help of a leader, the characteristics of the products were raised. The most cited terms were those selected for the CATA test.

Sensory analysis was performed according to the local Ethics Committee, approval no. 1605,638.

Statistical analysis

Statistical analysis was performed using Sensomaker version 1.9 (Pinheiro et al. 2013). Initially, analysis of variance and Tukey’s test at 5% of probability were performed for physical, physicochemical, total phenolic, antioxidant, and ascorbic acid characteristics of the different pepper types; these were also performed for the physicochemical, texture profile, and sensory analysis of the pepper jelly formulations to verify if there was a significant difference between peppers and their respective jellies.

For easier visualization, the data were also analyzed by principal component analysis (PCA) to correlate the physicochemical and nutritional characteristics with different pepper cultivars and the physicochemical properties, textural characteristics and CATA attributes (attributes frequency) with the different pepper jelly formulations. Data were arranged in a matrix of lines (samples) and columns (evaluated parameters); they were standardized (correlation matrix) and PCA was applied. To consider the individuality of the consumers, multivariate statistical analysis of PARAFAC—three-way internal preference mapping was performed with the acceptance data, improving the understanding and visualization of the sensory acceptance of the pepper jelly samples. According to the procedure described by Nunes et al. (2011), the data were organized into a three-way matrix from stacked matrices (consumer × samples) of the acceptance attributes.

Results and discussion

Pepper cultivars

The average values and Tukey’s test results for physical, physicochemical properties, bioactive compounds and antioxidant activity for the different pepper cultivars are shown in Table 1. PCA was elaborated to correlate the physicochemical properties, bioactive parameters and antioxidant capacity data with pepper cultivars (Fig. 1).

As regards the size and weight parameters of different types of pepper, through PCA (Fig. 1) and average values table (Table 1), it is possible to verify that Cayenne pepper

Table 1 Physical, physicochemical and nutritional properties of the different pepper types

Peppers	AL (mm)	AD (mm)	UW (g)	SS (°Brix)	TA
Habanero	48.99 ^{bc}	31.77 ^a	9.71 ^{ab}	7.00 ^b	0.29 ^b
Malagueta	47.65 ^{bc}	8.02 ^d	1.28 ^e	6.67 ^{bc}	0.27 ^b
Cayenne	75.11 ^a	11.66 ^{cd}	2.87 ^{cde}	9.00 ^a	0.30 ^b
Dedo de Moça	64.72 ^{ab}	14.14 ^{cd}	3.89 ^{cd}	6.67 ^{bc}	0.37 ^a
Cheiro do Norte	59.98 ^{ab}	22.52 ^b	4.84 ^{bc}	5.67 ^{cd}	0.20 ^c
Paprika	56.05 ^{ab}	27.81 ^{ab}	10.26 ^a	5.33 ^d	0.26 ^b
Biquinho	27.42 ^c	15.05 ^c	1.98 ^{de}	5.00 ^d	0.32 ^{ab}
Peppers	pH	L*	Chroma	°Hue	
Habanero	5.02 ^b	33.67 ^{ab}	42.41 ^a	37.73 ^{ab}	
Malagueta	5.00 ^b	32.15 ^{ab}	40.00 ^{abc}	38.75 ^{ab}	
Cayenne	5.05 ^b	30.88 ^b	37.02 ^{de}	36.71 ^b	
Dedo de Moça	4.85 ^b	30.38 ^b	34.95 ^e	35.62 ^b	
Cheiro do Norte	5.54 ^a	42.40 ^a	37.74 ^{cd}	56.56 ^a	
Paprika	4.72 ^b	32.46 ^{ab}	42.01 ^{ab}	39.99 ^{ab}	
Biquinho	4.88 ^b	34.71 ^{ab}	39.79 ^{bc}	34.84 ^b	
Peppers	Total phenolics	DPPH	ABTS	β-Carotene	Ascorbic acid
Habanero	147.65 ^c	10,970.80 ^a	29.02 ^a	57.03 ^a	33.04 ^d
Malagueta	149.41 ^c	8828.60 ^a	19.32 ^{ab}	58.15 ^a	28.70 ^d
Cayenne	189.63 ^a	53,534.60 ^a	5.57 ^c	66.65 ^a	178.81 ^a
Dedo de Moça	170.51 ^b	6991.80 ^a	10.69 ^{bc}	61.80 ^a	22.89 ^d
Cheiro do Norte	102.59 ^e	41,435.10 ^a	10.08 ^{bc}	55.65 ^a	99.09 ^c
Paprika	121.26 ^d	46,884.90 ^a	12.99 ^{bc}	54.57 ^a	93.70 ^c
Biquinho	150.72 ^c	12,163.91 ^a	16.09 ^{bc}	61.34 ^a	146.50 ^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

Average length (AL); average diameter (AD); unit weight (UW); soluble solids (SS); total acidity (TA—g citric acid/100 g f.w.); total phenolics (mg GAEs/100 g f.w.); antioxidant capacity—DPPH (EC₅₀—g of sample/g of DPPH); antioxidant capacity—ABTS (μM trolox/g of sample); antioxidant capacity—β-carotene (% of protection); Ascorbic acid (mg/100 g f.w.). DPPH: 2-diphenyl-1-picrylhydrazyl radical scavenging activity; GAE: gallic acid equivalent

presented the largest dimensions, with 75.11 mm of length; the Habanero stood out with an average diameter of 31.77 mm; and as for the unit mass, Paprika presented more significant mass, reaching 10.26 g. The peppers presented great variability in relation to their shape, size and weight. In general, the average length varied from 27.42 mm (Biquinho) to 75.11 mm (Cayenne), mean diameter from 8.02 (Malagueta) to 31.77 (Habanero), and the unit mass from 1.28 (Malagueta) to 10.26 grams (Paprika). This high variability is expected because of the different peppers types and varieties involved.

In relation to the physicochemical characteristics, it was observed that the content of soluble solids ranged from 5.0 (Biquinho) to 9.0°Brix (Cayenne), TA ranged from 0.26 (Paprika) to 0.37 (Dedo de Moça) g of citric acid/100 g and pH varied from 4.72 (Paprika) to 5.54 (Cheiro do Norte) (Table 1). According to the Table 1 and Fig 1, of average

values Cayenne pepper has the highest SSs value (9.00 °Brix) and, consequently, the highest ratio (SS/TA) (30.00). Biquinho pepper showed the highest TA 0.37 g of citric acid/100, and the Cheiro do Norte pepper had the highest pH/low acidity (5.54). Generally, these parameters are used to predict the best use of fruit (consumed fresh, or processed). For pepper, however, this type of assimilation probably does not make sense due to the particularity of this product. Pepper that has the highest SS content and ratio is not necessarily the sweetest, depending on the content of capsaicinoids, for example.

L* ranged from 30.38 (Dedo de Moça) to 42.40 (Cheiro do Norte), Chroma from 34.95 (Dedo de Moça) to 42.41 and Hue from 34.84 (Biquinho) to 56.56 (Cheiro do Norte) (Table 1). In general, it is possible to infer from the Chroma, a parameter that measures the color tone, that all the peppers have an orange coloration (varying from red to

Fig. 1 Principal component analysis (PCA) for the samples of different pepper types, and physical/physicochemical properties. Average length (AL), average diameter (AD), unit weight (UW), soluble solids (SS), total acidity (TA), solids/acidity (ratio), Chroma (C*), Ascorbic Acid (AA), Total Phenolic (TP)

yellow). The pigmentation of peppers is due to a complex mixture of carotene, xanthophylls and other substances. The levels of these pigments are influenced mainly by the cultivars, the climatic conditions, the degree of fruit ripening and post-harvest aging (Matsufuji et al. 2007; Hervert-Hernández et al. 2010; Topuz et al. 2011; Pinto et al. 2013).

According to the Table 1 and Fig. 1, Cheiro do Norte pepper is lighter and has the highest color intensity, as indicated by higher value of L^* and Hue (42.40 and 56.56, respectively). Habanero pepper stood out from the others because it presented the highest value of Chroma, showing a more yellowish coloration than the others.

It is possible to observe that the Cayenne pepper had the highest total phenolic content (189.63 mg GAE/100 g), antioxidant activity by the β -carotene method (66.65% protection), and stands out for having a higher content of vitamin C (178.81 mg/100 g). The Habanero pepper was distinguished by presenting the highest antioxidant activity by the ABTS method (29.02 μ M of trolox/fruit gram).

Following the classification proposed by Vasco et al. (2008), the pepper fruits are divided into three categories, according to the content of phenolic compounds: low (< 100 mg 100 g^{-1}), medium (100–500 mg 100 g^{-1}), and high phenol content (> 500 mg GAE 100 g^{-1}). According to this classification, all pepper types can be classified as having a medium concentration of phenols.

According to Ramful et al. (2011), fruits are classified into three categories depending on ascorbic acid content: low (< 30 mg 100 g^{-1}), medium (30–50 mg 100 g^{-1}) and

high content (> 50 mg 100 g^{-1}) of vitamin C. According to this classification scheme, most of the analyzed peppers are classified with a high content of ascorbic acid. Cayenne and Biquinho peppers showed high levels of ascorbic acid (178.81 and 146.50 mg/100 g respectively); these values are higher than those found in other studies (Pinto et al. 2013). The concentration of ascorbic acid, as well as total phenolics and antioxidant activity of the pepper, is influenced by the species, variety, cultivar, and maturation stage of the fruit, among other factors (Wahyuni et al. 2011).

Through the characterization of different peppers, it is possible to verify that there is great variability in size, shape, color, physicochemical and nutritional characteristics, which probably reflect peppers or pepper products with great sensorial variability. It is noteworthy that the peppers' nutritional value in the fresh form is not reflected in products such as jelly, because of the low concentrations of pepper used, and the severe thermal processing. For these reasons, analysis of bioactive compounds and antioxidant activity in the resulting jelly was not performed.

Pepper jellies

Physicochemical and textural characterization

Through the analysis of variance, a significant difference was verified among the jellies obtained from different pepper cultivars for physicochemical and texture properties ($p \leq 0.05$). Average values of the physicochemical and textural properties of different formulations are shown in Table 2. PCA was elaborated to correlate the physicochemical properties and texture parameters data with the pepper jellies (Fig. 2).

The pH values ranged from 3.05 to 3.78 (Habanero and Biquinho, respectively) and titratable TA from 0.65 to 0.87 g of citric acid/100 g (Dedo-de-Moça, and Biquinho, respectively) (Table 2). It was observed that the jellies made from Biquinho and Cheiro do Norte peppers showed the highest pH values (3.78 and 3.64, respectively), and the jelly from Biquinho pepper had the highest TA (0.87 g of citric acid/100 g) (Table 2 and Fig. 2).

Regarding the color of jellies, the L^* color parameter ranged from 20.51 (Malagueta) to 35.10 (Cheiro do Norte), Chroma from 3.12 (Habanero) to 31.35 (Biquinho) and Hue from 36.48 (Biquinho) to 82.33 (Habanero) (Table 2). According to the table of average values (Table 2) and PCA (Fig. 2), the jelly made from Cheiro do Norte and Dedo de Moça peppers presented the highest values for the L^* parameter (35.10 and 30.75, respectively), characterized by being lighter than the other jellies. The jelly from Biquinho pepper was characterized by higher color intensity, due to the higher value of Chroma (31.35), and the

Table 2 Physical, physicochemical, textural and sensory properties of the different pepper jellies

Pepper jelly	pH	TA	L*	Chroma	°Hue	
Habanero	3.05 ^e	0.70 ^b	22.71 ^f	3.12 ^g	82.33 ^a	
Malagueta	3.08 ^e	0.69 ^b	20.51 ^g	13.64 ^e	65.55 ^c	
Cayenne	3.18 ^d	0.70 ^b	23.61 ^e	13.19 ^f	55.79 ^e	
Dedo de Moça	3.18 ^d	0.65 ^b	30.75 ^b	17.06 ^d	61.20 ^d	
Cheiro do Norte	3.64 ^b	0.68 ^b	35.10 ^a	21.27 ^c	70.94 ^b	
Paprika	3.48 ^c	0.74 ^b	27.74 ^d	23.92 ^b	43.51 ^f	
Biquinho	3.78 ^a	0.87 ^a	29.10 ^c	31.35 ^a	36.48 ^g	
Pepper jelly	Hard	Adhe	Spr	Cohe	Gum	Chew
Habanero	0.05 ^d	0.09 ^c	1.07 ^a	0.76 ^a	0.04 ^c	0.04 ^c
Malagueta	0.06 ^d	0.26 ^c	0.96 ^b	0.53 ^b	0.03 ^c	0.03 ^c
Cayenne	0.09 ^d	0.35 ^c	0.97 ^{ab}	0.50 ^{ab}	0.04 ^c	0.04 ^c
Dedo de Moça	0.41 ^{ab}	1.59 ^a	0.97 ^{ab}	0.42 ^c	0.17 ^{ab}	0.17 ^b
Cheiro do Norte	0.49 ^a	1.27 ^{ab}	0.99 ^{ab}	0.45 ^{ab}	0.22 ^a	0.22 ^a
Paprika	0.28 ^{bc}	1.68 ^a	0.98 ^{ab}	0.54 ^b	0.15 ^b	0.15 ^b
Biquinho	0.27 ^c	0.95 ^b	0.95 ^b	0.46 ^{ab}	0.13 ^b	0.12 ^b
Jelly pepper	Appearance	Aroma	Consistency	Taste	Overall liking	
Habanero	3.86 ^c	5.25 ^b	4.69 ^c	5.61 ^{bc}	5.19 ^d	
Malagueta	6.21 ^b	5.49 ^{ab}	5.94 ^b	5.40 ^c	5.67 ^{cd}	
Cayenne	6.22 ^b	5.68 ^{ab}	5.84 ^b	5.21 ^c	5.56 ^{cd}	
Dedo de Moça	6.06 ^b	5.44 ^{ab}	6.05 ^b	4.79 ^c	5.13 ^d	
Cheiro do Norte	6.01 ^b	5.49 ^{ab}	6.27 ^{ab}	6.36 ^{ab}	6.29 ^{cd}	
Páprica	7.25 ^a	6.08 ^{ab}	6.67 ^{ab}	6.79 ^a	6.87 ^{ab}	
Biquinho	7.75 ^a	6.16 ^a	6.94 ^a	6.93 ^a	7.11 ^a	

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

Total acidity (TA—g citric acid/100 g f.w); hardness (Hard); adhesiveness (Adhe—N/s); springiness (Sprin); cohesiveness (Cohe); gumminess (Gum—N) and chewiness (Chew)

jelly from Habanero pepper was characterized as being more yellowish than the others, due to the higher value of Hue (82.33).

In relation to texture, through PCA (Fig. 2) and the table of average values (Table 2), it can be seen that the type of pepper has great influence on the textural characteristics of the obtained jelly. The jellies obtained from Dedo de Moça and Cheiro do Norte peppers showed higher hardness (0.41 and 0.49, respectively), gumminess (0.17 and 0.22 N, respectively) and chewiness (0.17 and 0.22, respectively). As the hardness measures the force required to achieve a certain deflection, gumminess measures the

Fig. 2 Principal component analysis (PCA) for the samples of different pepper jellies and their physicochemical and texture properties. Total acidity (TA), hardness (Hard), adhesiveness (Adhe N/s), springiness (Spr), cohesiveness (Cohe), gumminess (Gum N) and chewiness (Chew)

force required to masticate a semi-solid food, and chewiness is the amount of power needed to simulate chewing a semi-solid sample in a constant state of swallowing (Friedman et al. 1963; Bourne 1968; Van Vliet 1991). The jellies obtained from Dedo de Moça and Cheiro do Norte peppers were characterized as being more gummy, rigid and firm.

The jellies obtained from Dedo de Moça and Cheiro do Norte peppers, along with the jelly obtained with Paprika, were also characterized as being more adhesive (from 1.27 to 1.68 N/s). Adhesiveness measures the amount of force required to overcome the attractive forces between the food surface and the surface in contact with it.

Finally, the jelly from Habanero pepper showed the highest springiness (1.07) and cohesiveness (0.76). Springiness measures the speed at which the deformed material is returned to its original condition after the removal of the deforming force, and cohesiveness is the extent to which the material can be stretched before irreversibly breaking (Bourne 1968; Van Vliet 1991). Thus, the jelly obtained from the Habanero pepper was characterized as being the more elastic and cohesive one.

Texture is a multi-parameter attribute, described by a large number of mechanical characteristics which give rise to a profiling method of texture description (TPA) applicable to both sensory (Brandt et al. 1963) and instrumental measurements (Bourne 1978). Textural properties can have an enormous influence on consumer preference, however; which characteristics are liked or disliked depends primarily on physiological factors which are common to all

people, and on cultural factors which may vary between cultures (Szczesniak 2002). In general, the key liked texture characteristics are crispy, crunchy, tender, juicy and firm, and generally disliked textural features include characteristics that make the product difficult to control and manipulate in the mouth: tough, lumpy, slimy (Szczesniak and Kahn 1971).

Several factors may explain the change in texture among the jellies prepared from different pepper types. Product gelling has a significant influence on the amount of naturally occurring sugar, pH, and the amount of pectin present in each type of fruit (Souza et al. 2014).

Sensory evaluation

Through analysis of variance, a significant difference was verified among the jellies obtained from different peppers for all sensory parameters evaluated ($p \leq 0.05$). The average scores and Tukey's test results for the sensory characteristics evaluated in pepper jelly formulations are shown in Table 2. Figure 3 shows the three-way internal preference map that represents the distribution of consumers, samples and consumer sensory attributes.

According to the PARAFAC (Fig. 3) and the table of average values (Table 2), the jellies elaborated with Biquinho, followed by Paprika and Cheiro do Norte peppers were the most accepted samples for all sensorial attributes evaluated. The jellies elaborated with other peppers were the least accepted samples, with emphasis on

Fig. 3 Three-way internal preference map for appearance, aroma, color, taste, consistency and overall liking (OL) obtained for the pepper jellies. Consumers are represented by vectors, samples by squares and acceptance attributes by circles

Fig. 4 Principal component analysis (PCA) for the attributes of pepper jellies. 1. Reddish color, 2. Orange color, 3. Yellowish color, 4. Bright, 5. Opaque, 6. Transparent, 7. Pepper aroma, 8. Pungent aroma, 9. Tomato aroma, 10. Fruit aroma, 11. Sweet aroma, 12. Without Aroma, 13. Firm, 14. Gelatinous, 15. Soft, 16. Gummy, 17. Breakthrough, 18. Pepper taste, 19. Fruit Taste, 20. Acid Taste, 21. Sweetened Taste, 21. Pungent

Habanero, which was differentiated from the samples of jellies with the lowest scores for all sensorial attributes. The jellies generally showed good sensory acceptance, with average grades situated between the hedonic terms “neither liked/nor disliked” and “liked very much”, except for Habanero. For the jellies of the most-accepted peppers (Biquinho, Paprika, and Cheiro do Norte), the average scores were higher, ranging from the hedonic terms “liked it slightly” and “liked it very much”.

From the physicochemical characteristics of the PARAFAC (Fig. 3) and the table of average values for the sensory and physicochemical parameters of jellies (Table 2), it is not clear which parameters contributed to greater or less acceptance of the different jelly formulations. In general, it can be verified that the most accepted jellies (Biquinho, Paprika and Cheiro do Norte) were characterized by higher pH and higher Chroma values. The jelly elaborated with Habanero pepper, which was less accepted, was characterized by its greater springiness and cohesiveness. It is believed that the characteristics that influence the acceptability of jelly are related to the composition of the pepper that will be reflected in its flavor and pungency. Thus, the following is the result of the CATA test to better understand the differences in sensory acceptability of different jelly samples.

For the survey of the pepper jelly drivers of liking, the frequency of responses for each descriptor term was analyzed through PCA (Fig. 4).

According to the PCA obtained from the frequency of responses for each formulation (Fig. 4), it can be verified that the most sensorially accepted jellies, elaborated with the Biquinho and Paprika peppers, were characterized by the following: reddish color, pepper aroma, tomato aroma, firm, pepper flavor and fruit flavor. The jelly made from the Cheiro do Norte pepper, which was also among the most accepted jellies, had the following characteristics: opaque, pungent aroma, gummy and sweet taste. These characteristics, presented in the jellies that obtained greater acceptance, are the drivers of liking of pepper jelly. Therefore, the consumer expects a pepper jelly to have a reddish color, a characteristic pepper aroma and flavor, sweet taste, pungent aroma and to be firm/gummy.

Regarding the jellies elaborated with the Cayenne, Malagueta and Dedo de Moça peppers, which showed less sensory acceptance, these were characterized by the following: orange color, gelatinous, soft, brittle and pungent. Finally, the less-accepted jelly, elaborated with Habanero pepper, was described as a yellowish color, transparent, sweet aroma, fruit aroma, without aroma, and acid taste (Fig. 4). These characteristics reflect the attributes that negatively contribute to the acceptance of the jelly, and reinforce the previously discussed drivers of liking.

In general, the peppers that were used at a lower concentration (Habanero—1.5%, Malagueta—5% and Cayenne—8%) because of their high pungency are not suitable or indicated for the preparation of jellies. This is because the product does not reflect consumer preferences. The jelly lacks the characteristic coloring of pepper (yellow or orange), transparent coloration, with no characteristic flavor, and aroma of pepper and pungent. The peppers of lesser pungency, which were used in much higher concentrations (Paprika—55%, Biquinho—70% and Cheiro do Norte—70%), are the most suitable for preparation of jellies. The jellies elaborated with these peppers have characteristics that are desirable by the consumer, such as reddish color, characteristic flavor and aroma of pepper, sweet taste, and not very strong pungency, among others.

Conclusion

The different types of pepper (Habanero, Malagueta, Cayenne, Dedo de Moça, Cheiro do Norte, Paprika, and Biquinho) presented significant variability in, physicochemical, and nutritional properties which was reflected in jellies with different physical, physicochemical, textural, and sensorial characteristics. In general, the jellies elaborated with the less pungent peppers (Biquinho, Paprika and Cheiro do Norte) were the best suited for processing to jellies with most desirable characteristics consumers

acceptability attributes: reddish color, characteristic flavor and aroma, sweet taste, and acceptable pungency.

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