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Manufacturing of Formosa papaya (*Carica papaya* L.) jam containing different concentrations of dehydrated papaya seed flour

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Abstract

Brazil is one of the largest world producers of papaya, resulting in a high production of processing residues such as peels and seeds that are discarded as waste in the environment. The present work aimed to formulate a papaya jam with the addition of papaya seed flour. Four treatments were developed: control (0% flour); T1 (0.5% flour); T2 (1.0% flour); and T3 (1.5% flour), with three replicates. The jams were evaluated for proximate composition, pH, water activity, titratable total acidity, total soluble solids, texture profile, colour, antioxidant activity, microbial counts and sensorial evaluation. The results indicated that the higher the content of the papaya seed flour, the higher the crude fiber in the jams, as papaya seeds have expressive amounts of crude fiber and protein. In the microbial count, no growth of moulds and yeasts was observed in the jams made from papaya seed flour, demonstrating the fungicidal action of the seeds. The sensory attributes scored between the hedonic terms 6 (slightly liked) and 7 (moderately liked) for the control and the formulations containing different percentages of seed flour. Papaya seed flour may be a suitable alternative for the manufacture of jams, leading to a reduction of the processing residues in the fruit industries, thus directly contributing to the environment; reducing the discard and contaminations of soil and water resources.

Introduction

Papaya (*Carica papaya* L.) originated in America and is cultivated throughout the tropical regions (FAO, 2016a) with a world production of 13.05 million tons in 2016, with India, Brazil, Indonesia, Nigeria and Mexico as main producers. Brazil is the second world largest producer, with 10.72% of world production (FAO, 2016b). According to the Brazilian Institute of Geography and Statistics (IBGE, 2016), the fruit is cultivated in most Brazilian states, with the states of Bahia and Espirito Santo standing out, accounting together for 71% of Brazilian production. In 2016, the state of Espirito Santo produced 311,150 tons of the varieties Hawaii and Formosa, in approximately 6,118 hectares, with an average yield of 50.86 t/ha/year, which was the highest in the country (IBGE, 2016).

Papaya is consumed both natural and processed in the form of jams, sweets, and pulp, leading to the production of significant quantities of seeds, which are eliminated during selection thereby contributing to large waste generation (Venturini *et al*., 2012). During papaya processing, peel and seeds, which constitute about 50% of the fruit, are removed and discarded, leading to environmental problems. The reuse of waste from fruit processing is an alternative to reduce losses, and tends to contribute to the development of the Brazilian agroindustry, besides being of enormous importance for the environment, once large volumes of residues have been inappropriately discarded (Uchôa *et al*., 2008). Thus, the transformation of these residues into flours may be a suitable alternative for use in the food industry as product enrichment.

Seed, stem, and peel-rich flours have been used in the manufacture of bakery products, pasta and jams, increasing the supply of products with high fiber content, vitamins, minerals and flavonoids (Guimarães *et al*., 2010). The papaya seeds also

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possess important nutrients for the proper functioning of humans. Papaya seeds contain about 26% lipids, 25% proteins, and 29% fibres, being a good nutritional source, besides exhibiting antioxidant activities (Jorge and Malacrida, 2008). Another functional characteristic of papaya seeds is the water retention capacity, which is very desirable in the meat industry as an additional ingredient to enrich some meat products (Porte *et al*., 2011).

Azevedo and Compagnol (2014) in evaluating the influence of the addition of papaya seed flour on the quality of the technological and sensorial aspects of hamburgers, observed that the papaya seed flour caused an improvement in the technological quality of the hamburgers since it increased both the yield of cooking for moisture retention and reduced shrinkage of the hamburgers. In addition, the sensory quality of the hamburgers was not depreciated until the level of addition of 2% of papaya seed flour. Piovesan (2012) observed that the addition of 1.5% of the hydroethanolic extract of papaya seeds in chicken sausages was effective in reducing lipid oxidation, representing a superior antioxidant capacity to the control (without addition of extract).

The objective of the present work was therefore to develop and characterise papaya jam formulations containing different concentrations of papaya seed flour.

Materials and methods

Processing of papaya seed flour

The Formosa papaya at maturation stage 5 (fruit with 76-100% of the surface of the yellow bark) was used to obtain the seeds and the seed meal. Three seed samples were used. The Formosa variety was purchased from the market of Uberaba. The fruits were transported to the Processing Plant of Instituto Federal do Triângulo Mineiro (IFTM) - Campus Uberaba. The peeled fruits were washed, immersed in sodium hypochlorite solution (100 ppm) for 10 min, and then rinsed under running water. The peels were manually removed with a knife, the fruits were cut, and the seeds were removed. The seeds were washed under tap water to remove sugars to prevent caramelisation, and oven dried at 65°C for 24 h. Following drying, the dehydrated seeds were milled, sieved, and stored in plastic containers for further use.

Jam production

Papaya was selected at the time of purchase by colour and size. Four treatments were developed: control (0% flour); T1 (0.5% flour); T2 (1.0% flour); and T3 (1.5% flour) referring to the dehydrated seed in relation to the amount of papaya pulp. These percentages were defined in pre-tests (Table 1). The fruits were washed under running tap water and sanitised in sodium hypochlorite solution (100 ppm) for 10 min. The injured parts were removed, the fruits were cut in half to remove the seeds and then cut into small pieces for better grinding. The papaya pulp was placed in an aluminium pan with ¾ of sugar and cooked on an industrial stove. When the mixture reached 55°Brix, pectin (low degree of methoxylation) and the remaining sugar was added. At 61°Brix, water-diluted citric acid, and the dehydrated seed flour were added. Cooking was stopped at 63°Brix (the ºBrix reading was measured using a portable digital refractometer), and the product was packed at 90°C in pre-sanitised 200 g glass containers which were sealed and inverted downward for 3 min. Cooling was done in a container with water at 60ºC, followed by circulation of cold water. The jams were produced as shown in Figure 1. Treatments and replicates were identified, and the products were stored in a dry and ventilated place. According to the Brazilian legislation, all formulations were classified as extra jam, since they contained 50% of pulp.

Physico-chemical characterisation

The proximate composition of the jams containing dehydrated papaya seed flour was determined following the methods recommended by AOAC (2005), except for crude fiber, which was determined following the method of AOAC (1997). Moisture content was determined by oven drying at 105 ± 2°C; nitrogen content by the Kjeldahl method, and the protein content was estimated by multiplying the nitrogen content by 6.25; lipid content was

Table 1. Formulations of papaya jams containing different concentrations of papaya seed flour.

Raw material	Control	Formulation 1	Formulation 2	Formulation 3
Papaya pulp	1000 g	1000 g	1000 g	1000 g
Crystal sugar	500 g	500 g	500 g	500 g
Citric pectin	10 g	10 g	10 g	10 g
Citric acid	5 g	5 g	5 g	5 g
Dehydrated papaya seed*	-	5 g (0.5%)	10 g (1%)	15 g (1.5%)

*Percentage referring to the dehydrated seed in relation to the amount of papaya pulp.

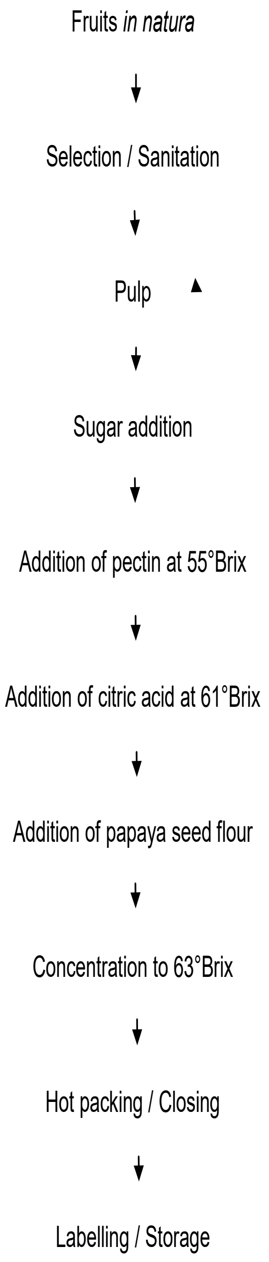

Figure 1. Jam manufacturing process.

determined by the Soxhlet method using petroleum ether; ash content by incineration in a muffle at 550°C; dietary fibres by the enzymatic-gravimetric method; and carbohydrates by difference. All analyses were performed in triplicate.

The jam pH was measured using a pH meter, model DM 22 (Brand Digimed, São Paulo, Brazil), with glass electrode. The water activity (a_w) was determined using a water activity meter (AQUA LAB / 4TE). The total titratable acidity (TTA) was determined by titration with NaOH solution (0.1 M) and phenolphthalein indicator until the colour changed from white to light pinkish, following the method described by Instituto Adolfo Lutz (2008). The total soluble solids (°Brix) content of the jams was measured using a portable digital refractometer AR-200 (Brand Tecnal, Piracicaba, São Paulo, Brazil), with a refractive index at 25°C.

Texture profile analysis

The texture analysis was performed in the Laboratory of Bromatology of the IFTM-Campus I Uberaba. Measurements were performed at 20°C using the TA.XTplus Texture Analyser (Stable Micro Systems, Godalming). Three readings of each treatment were made by direct readings (200 g sample), using a flat-ended aluminium probe 36 mm diameter (P/36R). Data collection and the construction of the TPA curves were performed by the program Texture Expert, version 1.11 (Stable Micro Systems Ltd.). The parameters of elasticity, cohesiveness, adhesiveness, and chewiness were determined. Elasticity is defined as the height that the food recovers during the time that elapses between the end of the first peak and the start of the second peak (b/a). Cohesiveness is the ratio between the second and first peak areas (A2/A1). Adhesiveness is the area of negative force between the two compression cycles (A3). Chewiness is a unique parameter that incorporates firmness, cohesion and elasticity

Instrumental colour

The colour was determined by direct readings using the Minolta CR-400 colorimeter (Konica Minolta Sensing Inc., Japan), with spectral reflectance included as calibration mode, illuminant D65, and an observation angle of 10º, operating in the CIE system (L^*, a^*, b^*). The values of L^* (luminosity/lightness), a^* (intensity of red colour) and b^* (intensity of yellow colour) were determined.

Total antioxidant activity (DPPH)

Antioxidant activity was determined by the DPPH assay, as reported by Brand-Williams *et al.* (1995) with some adaptations. This methodology is based on the antioxidant ability to donate hydrogen ~~ato~~ms or electrons to the radical DPPH (2,2-diphenyl-1-picrilhydrozil) with consequent colour changes from purple to yellow. Briefly, 5 g of sample were used to obtain the extract. Next, 4 mL of 50% methanol were added and allowed to stand for 60 min at room temperature, and then 4 mL of 70% acetone were added and allowed to stand for 30 min. The extraction was performed in the absence of light, covering the beakers with aluminum foil. The mixture was centrifuged in the 206 Execelsa BABY I for 15 min, the supernatant was transferred to a 10 mL volumetric flask, and the volume was made up with distilled water.

For the DPPH solution, 2.4 mg of DPPH was dissolved in methanol in a 100 mL volumetric flask, protected from light. Then, 3 mL of extract and 1 mL of DPPH solution were placed in tubes coated with aluminum foil and homogenised. After 30 min, readings were performed in a spectrophotometer at 515 nm (Spectrophotometer GEHAKA UV-380G São Paulo). The percentage of DPPH radical scavenging was calculated using the equation as follows:

$$\% \text{ Inhibition of DPPH radical} = [(\text{Abs}_{\text{DPPH}} - \text{Abs}_{\text{sample}}) / \text{Abs}_{\text{DPPH}}] \times 100$$

where Abs_{DPPH} = absorbance of DPPH methanol solution; $\text{Abs}_{\text{sample}}$ = absorbance of the sample after 30 min of reaction with the DPPH solution.

Microbiological assessment

The enumeration of moulds and yeasts was carried out as established by RDC 272 of January 2, 2005 (ANVISA, 2005), and the results were analysed according to the limits allowed by the RDC 12 (ANVISA, 2001). The microbial counts were performed following the method described by Silva *et al*. (2010). Aliquots of 25 g were homogenised with 225 mL of 0.1% peptone water and serially diluted in decimal scale (100, 10^1, and 10^2). Samples were incubated at 22 ± 1°C for 7 d, and then microbial counts were performed with the help of manual colony counter.

Sensory evaluation

Sensory acceptance and purchase intention tests were performed using a 9-point structured hedonic scale. The scores consist of: (1) extremely disliked, (2) moderately disliked, (3) regularly disagreed, (4) slightly disagreed, (5) neither liked nor disliked, (6) slightly liked, (7) regularly liked, (8) moderately liked and (9) extremely liked. The attributes colour, aroma, flavour, texture, and overall acceptance were evaluated. The purchase intent test was performed using a 5-point scale anchored at both extremes ranging from certainly buy (5) and certainly would not buy (1). The sensory evaluation was performed with 62 untrained consumers aged from 18 and 60 years, recruited among students, staff, and professors of the Federal Triangulo Mineiro Institute, Campus I Uberaba (Meilgaard *et al*., 1999). Samples were served to consumers in a monadic way, as described by Macfie *et al*. (1989). The acceptability index was calculated by dividing the mean overall acceptance score by the maximum score of the hedonic scale.

Statistical analysis

A completely randomised design with four treatments and three replicates was used for the proximate composition, pH, water activity, texture profile, instrumental colour, and antioxidant activity. Formulations containing different concentrations of papaya seed flour (0.5, 1.0 and 1.5%) represented the treatments. A randomised block design was used for the sensory evaluation. The effects of the treatments were compared by the F-test, and the differences analysed by the Tukey's test at 5% probability. The analysis of variance and test of means were performed using the SISVAR software (Ferreira, 2000). Data of proximate composition, pH, water activity (a_w), total titratable acidity (TTA), total soluble solids (ºBrix), texture profile, instrumental colour and antioxidant activity were submitted to the Tukey's test at 5% probability to identify the differences.

Results and discussion

The results of the proximate composition of papaya jams containing papaya seed flour are shown in Table 2.

Significant differences were observed for moisture, protein, lipids, carbohydrates, ash, and crude fibre among treatments, that is, the addition of papaya seeds increased the contents of these variables in papaya jams, thus changing the chemical characteristics of the jams, with a probable improvement in the nutritional quality of the final product.

The moisture contents varied from 33.18% (control) to 43.70% (T1), with significant differences among the treatments (T1, T2, and T3) when compared to control. Treatments' moisture levels were above that recommended by RDC 272 (ANVISA, 2005) in jams of 38%. Similar results were found by Damiani *et al*. (2011) in mango jam containing fruit peel, in which the greater the substitution of pulp for peel, the higher the moisture content. They reported that the addition of seed or peel to jam formulations increased the moisture levels. Mota (2006) found similar values (42.84 to 46.44%) in jams made with different blackberry varieties.

The protein content varied from 0.49% (control) to 0.82% (T3), and the treatments T2 and T3 were statistically different from control. These results indicated that the higher the addition of papaya seed flour, the higher the protein levels, which is very important from the nutritional point of view. Damiani *et al*. (2011) studied mango candy containing fruit peel and observed higher protein contents with the increase in mango peel, and Storck (2013) also found

Table 2. Proximate composition, physicochemical characterisation and colour parameters L^*, a^*, and b^* of jams containing different concentrations of papaya seed flour.

Parameters	Control	T1	T2	T3
Moisture (%)	33.18 ± 6.94^{b}	43.70 ± 3.57^{a}	43.55 ± 3.42^{a}	40.10 ± 0.03^{a}
Protein (%)	0.49 ± 0.12^{c}	0.52 ± 0.08^{c}	0.61 ± 0.00^{b}	0.82 ± 0.22^{a}
Lipids (%)	0.17 ± 0.02^{c}	0.21 ± 0.11^{ab}	0.20 ± 0.00 ^{b}	0.22 ± 0.02^{a}
Total carbohydrates (%)	61.84 ± 5.97^{a}	49.76 ± 6.11^{b}	49.57 ± 6.30^{bc}	38.21 ± 17.66^{c}
Ash (%)	0.40 ± 0.02^{a}	0.27 ± 0.10^{b}	0.41 ± 0.03^{a}	0.42 ± 0.04^{a}
Crude fibre (%)	0.20 ± 0.35^{d}	0.35 ± 0.16^{c}	0.82 ± 0.27^{b}	0.85 ± 0.29^{a}
pH	3.56 ± 0.19^{c}	3.85 ± 0.01^{a}	3.81 ± 0.06^{b}	3.78 ± 0.04^{b}
TA (%)	0.031 ± 0.01^{a}	0.032 ± 0.01^{a}	0.034 ± 0.01^{a}	0.036 ± 0.01^{a}
TSS (ºBrix)	56.70 ± 4.53 ^{a}	50.90 ± 1.27^{bc}	49.46 ± 2.70^{c}	51.60 ± 0.57^{b}
aw	0.85 ± 0.01^{a}	0.86 ± 0.01^{a}	0.85 ± 0.01^{a}	0.85 ± 0.01^{a}
L^*	37.50 ± 5.38^{a}	28.37 ± 3.75^{b}	28.39 ± 3.39^{b}	34.23 ± 2.11^{c}
a^*	0.44 ± 0.25^{a}	0.30 ± 0.11^{ab}	0.15 ± 0.04^{b}	0.12 ± 0.07^{c}
b^*	1.30 ± 0.08^{a}	1.19 ± 0.03^{a}	1.06 ± 0.16^{a}	1.30 ± 0.08^{a}

Data are means ± standard deviation. Means with the same small letter superscripts in the same row are significantly ($p > 0.05$) different by the Tukey's test. Control = no addition of papaya seed flour; T1 = addition of 0.5% papaya seed flour; T2 = addition of 1% papaya seed flour; and T3 = addition of 1.5% papaya seed flour in relation to the amount of papaya pulp in the formulation.

higher protein values (1.7%) in jam formulations containing papaya peel. Therefore, fruit residues should be added in food formulations, as they have important nutrients which will contribute to increase the nutritional value of the final product.

The lipid contents ranged from 0.17% (control) to 0.22% (T3). The treatments T1, T2, and T3 statistically differed from control, with an increase in the lipid content of the jams with the addition of papaya seed flour. Júnior *et al*. (2013) found higher fat levels in guava jam with okara with increasing okara concentration. This result is desirable since papaya seeds contain oleic acid levels similar to olive oil, which is considered essential for human health.

The carbohydrate contents ranged from 38.21% (T1) to 61.84% (control), and the treatments T1, T2, and T3 were significantly different from control, with a significant reduction with an increase in papaya seed flour. This reduction may be due to gel formation with shorter cooking time. In addition, the treatments T1, T2, and T3 had higher moisture contents as a function of pectin present in seeds. Thus, lower carbohydrate levels were observed for these treatments when compared to control. Damiani *et al*. (2011) found carbohydrate levels up to 76.15% in candy containing mango peel, which was higher than those found in the present work. The addition of mango peel also reduced the carbohydrate content, indicating that the addition of peel and seeds can contribute to the production of low-sugar and low-calorie jams, which are suitable for diabetic patients.

The ash contents ranged from 0.27% (T1) to 0.42% (control), and only the treatment T1 was statistically different from control. Storck *et al*. (2013) found 1.70% and 1.67% ash in papaya seeds and papaya peel, which was higher than the values found in the present work, thus evidencing the high mineral contents of these fractions. No changes (0.09%) were observed in ash content of jaboticaba jams containing fruit peel, as a function of higher peel concentrations (Dessimoni-Pinto *et al*., 2011).

Significant differences were observed for crude fibre for all treatments, ranging from 0.20% (control) to 0.81% (T3). It was observed that the higher the concentration of papaya seed flour, the higher the crude fibre content of the jams. Therefore, significant amounts of crude fibre in the papaya seed flour affected positively in the fibre content of the jams. Amaral *et al*. (2012) found 0.35% crude fibre in jams made from passion fruit pulp, and 0.69% in jam containing passion fruit peel, showing that the addition of peel or seed increased the crude fibre of the product, with greater benefits to the consumers.

As shown in Table 2, no significant differences were observed in water activity (a_w) and titratable acidity (TTA) among the treatments T1, T2, and T3 and control. In contrast, significant differences ($p > 0.05$) were observed among the treatments T1, T2, and T3, when compared to control for both total soluble solids (ºBrix) and pH.

The pH values ranged from 3.56 (control) to 3.81 (T1) and the pH of the treatments T1, T2, and T3 were statistically higher than control. Lower pH values (3.07 to 3.53) were found by Viana *et al*.

(2012) in *araçá-boi* jam when compared to that of the present work. All treatments were in accordance with the current legislation of below 4.5 (ANVISA, 2005).

The total titratable acidity (TTA), expressed in citric acid, varied between 0.031% (control) and 0.036% (T3), with no significant difference between the treatments T1, T2, T3, and control, thus the addition of papaya seed flour did not change TTA of the jams. Júnior *et al*. (2013) also found no significant difference in the acidity of guava jam with okara, with higher contents than those found in the present work, demonstrating no changes in titratable acidity with the addition of fruit residues to the formulations. High acidity values may favour fungal growth in foods.

The mean total soluble solids ranged from 49.46% (T2) to 56.7% (control), with higher levels ($p > 0.05$) in control when compared to the other treatments, thus the addition of papaya seed flour decreased soluble solids of the jams. In blackberry jams with different cultivars, the total soluble solids varied from 47.15°Brix to 57.03°Brix (Mota, 2006), which is close to the values found in the present work. According to Viana *et al*. (2012), the ideal total soluble solids content in jams is 67.5°Brix, since the gel becomes weaker in smaller values (64°Brix), while higher values (71°Brix) can lead to crystallisation. The Brazilian legislation recommends total soluble solid values ranging from 67 to 68ºBrix for all jams classified as extra, as is the case of the jams containing papaya seed flour in the present work (ANVISA, 2005). The reduction of TSS may be due to the addition of seed flour, which increased the insoluble solids and moisture levels probably due to the presence of soluble fibres.

No significant differences were observed in water activity among the formulations, with values ranging from 0.85 to 0.86 a_w which were within the recommended values by Brazilian legislation (<0.90 a_w) (ANVISA, 2005). According to Júnior *et al*. (2013), these results are similar to those found in mango jam with okara (0.85 to 0.86 a_w). However, jams produced with jaboticaba peel exhibited lower a_w levels when compared to the present work (Dessimoni-Pinto, 2011), demonstrating that the addition of seeds and peels to the formulations did not change the a_w values.

Table 2 shows the results of instrumental colour measurements. Significant differences were observed between treatments for the parameters L^* and a^*, with no significant difference for b^*. Lightness/luminosity (L^*) ranged from 28.37 to 37.50, with significant differences among the treatments T1, T2, T3, when compared to control, which exhibited greater L^* values. Campos *et al*. (2012) found L^* between 29.6 and 25.4 in mango jams containing fruit peel, which was lower than the findings of the present work. The lower lightness/luminosity of the treatments T1 and T2 may be due to the Maillard and caramelisation reactions that occurred during evaporation in the manufacturing process of jams, providing a perfect environment for the occurrence of non-enzymatic reactions (Fellows, 2000). The a^* values ranged from 0.12 to 0.44, and the treatments T2 and T3 differed significantly from control, with a slight tendency to red, and darkening of the jam containing papaya seed flour. The b^* values ranged from 1.06 to 1.30, with no significant differences between the treatments T1, T2, and T3 when compared to control. T2 presented a lower tendency to yellow than the other treatments. When compared to guava jam with okara (Júnior *et al*., 2013), higher b^* values were observed in the present work. However, Damiani *et al*. (2009) also found higher b^* values in mango jams made with the replacement of peel by fruit pulp, with lower carotenoids losses, tending to yellow colour in the final product.

Table 3. Texture profile and antioxidant activity (AA) after 30 days of storage of jams containing different concentrations of papaya seed flour.

Parameters	Control	T1	T2	T3
Adhesiveness	-743.67 ± 146.9^{a}	-578.95 ± 17.73^{ab}	- 560.21 ± 36.47^{b}	-503.92 ± 92.76^{b}
Cohesiveness	0.73 ± 0.02^{a}	0.80 ± 0.04^{a}	0.71 ± 0.04^{a}	0.76 ± 0.01^{a}
Elasticity	0.97 ± 0.02^{a}	0.96 ± 0.01^{a}	0.92 ± 0.03^{a}	0.93 ± 0.02^{a}
Chewiness	-0.087 ± 0.02^{a}	0.02 ± 0.04^{a}	-0.067 ± 0.04^{a}	-0.077 ± 0.01^{a}
AA	88.52 ± 5.38^{a}	92.52 ± 3.75^{a}	91.72 ± 3.39^{a}	90.87 ± 2.11^{a}

Data are means ± standard deviation. Means with the same small letter superscripts in the same row are significantly ($p > 0.05$) different by the Tukey's test. Control = no addition of papaya seed flour; T1 = addition of 0.5% papaya seed flour; T2 = addition of 1% papaya seed flour; and T3 = addition of 1.5% papaya seed flour in relation to the amount of papaya pulp in the formulation.

Table 3 shows the analysis of variance of the texture measurements, with significant differences at 5% level for adhesiveness. The texture of the jam is directly related to gel formation, which is dependent on pectin concentration, soluble solids, time and temperature. Different texture parameters including adhesiveness, cohesiveness, elasticity, and chewiness can be determined by the texture analyser (Durán *et al*., 2001). The adhesiveness ranged from -743.67 (control) to -503.92 (T3), with significant differences among the formulations, demonstrating that the addition of papaya seed flour reduced the adhesiveness of jams. Rahman and Al-Farsi (2005) have reported that the increase in moisture and water activity leads to a decrease in adhesiveness, as occurred in the present work. No significant differences were observed for cohesiveness, elasticity, and chewiness among the treatments with the addition of different concentrations of papaya seed flour. According to Pereira *et al.* (2010), chewiness is a secondary texture parameter, which is evaluated by the number of chews needed to leave the food in conditions to be swallowed, being very important for the consumers' acceptance of jams (Masmoudi *et al.*, 2008). In the present work, no changes were observed for chewiness with the addition of papaya seed flour, which might indicate a good acceptance of the jams.

The results of antioxidant activity are presented in Table 3, with no significant differences ($p > 0.05$) among the treatments after 30 days of production. Higher values of antioxidant activity was observed with increasing concentrations of papaya seed flour. Foods with high antioxidant activity bring several health benefits to consumers, such as the prevention of cardiovascular diseases, degenerative diseases, cancer cell growth, diabetes, Alzheimer's and others. Corrêia (2015) studied guava jams stored for 45 days and found that the formulation containing grape juice concentrate presented higher DPPH when compared to the formulation containing only guava pulp. However, lower antioxidant activity was observed with the increase in shelf life period. Piljac-Žegarac *et al.* (2009) studied the antioxidant capacity of dark fruit juices during 29 days of refrigerated storage, and found similar results of the present work, with no significant changes between treatments within 30 days of storage.

Table 4. Microbial counts (log CFU/g) of jams containing different concentrations of papaya seed flour.

	Control	T1	T2	T3
10^{-1}	2×10^2	<10	Absent	Absent
10^{-2}	2×10^3	<10	Absent	Absent
10^{-3}	<10	Absent	Absent	Absent

Control = no addition of papaya seed flour; T1 = addition of 0.5% papaya seed flour; T2 = addition of 1% papaya seed flour; and T3 = addition of 1.5% papaya seed flour in relation to the amount of papaya pulp in the formulation.

Table 4 shows the results of microbiological analyses of papaya jams made with different concentrations of dehydrated seeds. All samples presented counts within the standards recommended by the current legislation, with a maximum of 104 CFU/g for moulds and yeasts (ANVISA, 2001), making them suitable for human consumption. In addition, a significant difference in moulds and yeasts counts was observed among the treatments when compared to control. No fungal growth was observed for the jams containing seeds, indicating the fungicidal function of the seeds. The results also indicate good manufacturing practices, such as adequate sanitation of fruits and equipment, besides the absence of chemical preservatives.

Table 5. Sensory acceptance scores of jams containing different concentrations of papaya seed flour.

Parameters	Control	T1	T2	T3
Colour	8.03 ± 0.80^a	7.06 ± 0.16^b	6.96 ± 0.26^b	6.85 ± 0.38^b
Aroma	7.42 ± 0.63^a	6.24 ± 0.55^b	6.64 ± 0.14^b	6.83 ± 0.05^{ab}
Flavour	7.50 ± 0.10^a	6.93 ± 0.47^a	7.27 ± 0.13^a	7.92 ± 0.52^a
Texture	6.69 ± 0.05^a	6.98 ± 0.21^{ab}	7.29 ± 0.19^{ab}	6.79 ± 0.40^b
Overall acceptance	7.70 ± 0.38^a	7.27 ± 0.05^{ab}	7.26 ± 0.07^{ab}	7.03 ± 0.29^b

Data are means ± standard deviation. Means with the same small letter superscripts in the same row are significantly ($p > 0.05$) different by the Tukey's test. Control = no addition of papaya seed flour; T1 = addition of 0.5% papaya seed flour; T2 = addition of 1% papaya seed flour; and T3 = addition of 1.5% papaya seed flour in relation to the amount of papaya pulp in the formulation.

The results of the sensory evaluation are presented in Table 5. The formulations with addition of papaya seed flour had positive results for aroma, flavour, texture, and overall acceptance, with no significant differences when compared to control. With respect to texture and overall acceptance, T3 was significantly different from control, with no differences from the other treatments, while T1 and T2 did not differ from control. These results may be due to the higher concentrations of papaya seed flour in the formulations. For colour, control scored "liked very much" in the hedonic scale, differing from the other treatments, which scored "moderately liked ", probably due to the absence of seed flour in control. The papaya seed flour led to changes in colour of the formulations. Lower scores were found by Viana *et al.* (2012) in papaya jam with *araçá-boi*, with greater acceptance for the jams containing a higher concentration of papaya pulp. For aroma, control and T3 scored " moderately liked" which differed from T1 and T2 with " slightly liked ", with no significant differences among the samples. Silva *et al.* (2014) studied a candy made with yellow passion fruit peel and found that 92% of the judges rated "liked very much", indicating no changes in aroma of the candies with the addition of residues. For flavour, there was no difference ($p > 0.05$) among the treatments when compared to control, showing that the papaya seed flour did not change the palate, thereby yielding good acceptance scores (moderately liked). Silva and Ramos (2009) studied two types of Silver banana candy and found a higher flavour score for the formulation containing fruit peel, scoring " liked very much" when compared to the formulation made with fruit pulp. Higher acceptance scores were also observed in passion fruit peel jams (Amaral *et al.*, 2012) demonstrating that fruit residues can be used in food formulations, with no changes in flavour, besides improving the nutritional quality of the final product. Texture is an important parameter in the perception and acceptability of jams. Although the treatments T1 and T2 were not significantly different from control, T3 showed a significant difference probably due to the cooking time. However, lower scores ($p > 0.05$) were observed for T3, probably due to the higher amounts of seeds in this formulation.

Overall acceptance corresponds to the consumer's overall view of the product. In the present work, this attribute scored " moderately liked ", with good consumers' acceptance, indicating that the use of fruit residues in the formulation of new products did not change the sensory characteristics, which was also observed in banana peel jam (Dias *et al.*, 2011). Furthermore, the addition of papaya seed flour led to the production of jams with good sensory acceptance for different parameters. Therefore, the addition of fruit residues in jams can bring health benefits, reducing the waste generation and the environmental impact in the fruit processing industries (Damiani *et al.*, 2008). According to Teixeira *et al.* (1987), to be accepted, a product should have a sensory acceptability index of around 70%, that is, scores above 6.3 in the 9-point hedonic scale, which was found in the present work for all attributes.

Conclusion

The papaya seed flour is a good option as a raw material in the composition of papaya jams. The present work demonstrated the potential for the use of residues from the industrialisation of papaya. Due to the good sensorial acceptance and the increase in the nutritional value, future studies with higher concentrations than the ones used in the present work are henceforth suggested in order to establish the maximum acceptable concentrations of addition of this residue, with the objective towards greater waste utilisation.

References

Amaral, D. A., Pereira, M. L. S., Ferreira, C. C. and Gregório, E. L. 2012. Sensory evaluation of jam made from passion fruit peel and pulp. HU Revista 38(3): 181-186.

Association of Official Analytical Chemists (AOAC). 1997. Official methods of analysis (16th ed). Washington: AOAC.

Association of Official Analytical Chemists (AOAC). 2005. Official methods of analysis (18th ed). Washington: AOAC.

Azevedo, L. A. and Campagnol, P. C. B. 2014. Papaya seed flour (*Carica papaya*) affects the technological and sensory quality of hamburgers. International Food Research Journal 21(6): 2141-2145.

Brand-Williams, W., Cuvelier, M. E. and Berset, C. 1995. Use of free radical method to evaluate antioxidant activity. LWT - Food Science and Technology 28(1): 25-30.

Brazilian Health Regulatory Agency (ANVISA). 2001. Resolution RDC n. 12 of January 2, 2001 - Technical Regulation on Microbiological Standards for Foods. Retrieved from ANVISA website: http://portal.anvisa.gov.br/documents/33880/2568070/RDC_12_2001.pdf/15ffddf6-3767-4527-bfac-740a0400829b

Brazilian Health Regulatory Agency (ANVISA). 2005. Resolution RDC, n. 272 of 22 September 2005. Technical regulation for vegetable products, fruit products, and edible mushrooms. Retrieved from ANVISA website: http://portal.anvisa.gov.br/legislacao#/visualizar/27633

Brazilian Institute of Geography and Statistics (IBGE). 2016. Produção agrícola municipal: Culturas temporárias e permanentes. Retrieved from IBGE website: https://biblioteca.ibge.gov.br/visualizacao/periodicos/66/pam_2016_v43_br.pdf

Campos, H. G. 2012. Physicochemical characterization of mango jam enriched with residues from pulp processing. Porto Alegre, Brazil: Federal University of Rio Grande do Sul.

Corrêia, A. F. K. 2015. Variables related to the processing of mini tomatoes dehydrated by adiabatic convective drying and freeze-drying. Brazil: University of São Paulo, PhD Thesis.

Damiani, C., de Almeida, A. C. S., Ferreira, J., Asquieri, E. R., Vilas Boas, E. V. B. and Silva, F. A. 2011. Sweets formulated with mango skin. Pesquisa Agropecuária Tropical 41(3): 360-369.

Damiani, C., Vilas Boas, E. V. B., Junior, M. S. S., Caliari, M., Paula, M. L. and Asquieri, E. R. 2009. Chemical evaluation of mango (*Mangifera indica* L.) jams formulated with different levels of peels in substitution to pulp. Ciência e Agrotecnologia 31(1): 177-184.

Damiani, C., Vilas Boas, E. V. B., Soares Junior, M. S., Caliari, M., Paula, M. L., Pereira, D. E. P. and Silva, A. G. M. 2008. Análise física, sensorial e microbiológica de geléias de manga formuladas com diferentes níveis de cascas em substituição à polpa. Ciência Rural 38(5): 1418-1423.

Dessimoni-Pinto, N. A., Moreira, W. A., Cardoso, L. M. and Pantoja, L. A. 2011. Jaboticaba peel for jelly preparation: an alternative technology. Ciência e Tecnologia de Alimentos 31(4): 864-869.

Dias, C. S., Borges, S. V., Queiroz, F. and Pereira, P. A. P. 2011. Effect of temperature on the physical, physicochemical, and chemical changes during storage of jam made from banana (Musa spp. cv. prata) peel. Revista Instituto Adolfo Lutz 70(1): 28-34.

Durán, L., Fiszman, S. M. and Barber, C. B. 2001. Empirical mechanical properties. In Alvarado, J. D. and Aguilera, J. M. (Eds). Methods to measure the physical properties in food industries, p. 22-43. Zaragoza, Spain: Acríbia.

Fellows, P. 2000. Food processing technology: principles and practice (2nd ed). Boca Raton: CRC Press.

Ferreira, D. F. 2000. Statistical analysis through SISVAR for Windows version 4.0. In Annual Reunion of the Brazilian Region International Biometry Society, p. 255-258. São Carlos: UFSCar.

Food and Agriculture Organization (FAO). 2016a. Papaya Production. Retrieved from FAO website: http://faostat.fao.org/

Food and Agriculture Organization (FAO). 2016b. Statistics Division. Retrieved from FAO website: http://faostat3.fao.org/home/

Guimarães, R. R., Freitas, M. C. F. and Silva, V. L. M. 2010. Simple cakes elaborated with flour of watermelon inner skin (*Citrullus vulgaris*, Sobral): chemical, physical, and sensory evaluation Ciência e Tecnologia de Alimentos 30(2): 354-363.

Instituto Adolfo Lutz (IAL). 2008. Analytical Standards of the Adolfo Lutz Institute: Physicochemical Methods for Food Analysis. São Paulo: IAL.

Jorge, N. and Malacrida, C. R. 2008. Papaya Seed Extract (*Carica papaya* L.) as a source of natural antioxidants. Revista Alimentos e Nutrição 19(3): 337-340.

Júnior, B. R. C. L., Oliveira, P. M., Castro, R. L. E., Lamas, J. M. N. and Martins, E. M. F. 2013. Development and characterization of creamy guava candy containing okara flour. Vértices 15(2): 25-37.

Macfie, H., Bratchell, N., Greenhoff, K. and Vais, L. V. 1989. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. Journal of Sensory Studies 4(2): 129-148.

Masmoudi, M., Besber, S., Chaabouni, M., Robert, C., Paquot, M., Blecker, C. and Attia, H. 2008. Optimization of pectin extraction from lemon by-product with acidified date juice response surface methodology. Carbohydrate Polymers 74(2):185-192.

Meilgaard, M., Civille, G. V. and Carr, B. T. 1999. Sensory Evaluation Techniques (3nd ed). Boca Raton: CRC Press.

Mota, R. V. 2006. Physicochemical characterization of blackberry jelly. Ciência e Tecnologia de Alimentos 26(3): 539-543.

Pereira, P. A. P., Souza, V. R., Ferreira, L. O., Queiroz, F., Borges, S. V. and Carneiro, J. D. S. 2010. Texture profile analysis (TPA) of traditional, light, and diet sweet guava formulations. In XIX UFLA Post-Graduation Congress. Brazil: Federal University of Lavras.

Piljac-Zegarac, J., Valek, L., Martinez, S. and Belscak, A. 2009. Fluctuations in the phenolic content and antioxidant capacity of dark fruit juices in refrigerated storage. Food Chemistry 113(2):394-400.

Piovesan, N. 2012. Papaya seeds (*Carica papaya* L.) and marcela (*Achyrocline satureioides*) natural extracts and their antioxidant and anti-microbial capacities in chicken sausage. Brazil: Universidade Federal de Santa Maria, MSc Dissertation.

Porte, A., Silva, E. F., Almeida, V. D. S., Silva, T. X. and Porte, L. H. M. 2011. Functional technological properties of papaya (*Carica papaya*) and pumpkin (Cucurbita sp.) seed flour. Revista Brasileira de Produtos Agroindustriais 13(1): 91-96.

Rahman, M. S. and Al-Farsi, S. A. 2005. Instrumental texture profile analysis (TPA) of date flesh as a function of moisture content. Journal of Food Engineering 66(4): 505-11.

Silva, E. B., Santos, E. R., Rosa, J., Cardoso, F. T., Souza, G. G., Nogueira, R. and Nascimento, K. O. 2014. Whole food utilization: Physicochemical and sensory evaluation of a sweet made from yellow passion fruit (*Passiflora edulis* f. *flavicarpa*) peel. Revista Augustus 19(38): 44-60.

Silva, M. B. L. and Ramos, A. M. 2009. Chemical composition, texture and sensorial acceptance of sweets made from banana pulp and whole banana. Revista Ceres 56(5): 551-554.

Silva, N., Taniwaki, M. H., Junqueira, V. C. A., Silveira, N. F. A., Nascimento, M. S. and Gomes, R. A. R. 2010. Manual of Methods of Microbiological Analysis of Food and Water (4th ed). São Paulo: Livraria Varela Editora.

Storck, C. R., Nunes, G. L., Oliveira, B. B. and Basso, C. 2013. Leaves, stalk, peel and seeds of vegetables: Nutritional composition, utilization and sensory analysis in food preparations. Ciência Rural 43(3): 537-543.

Teixeira, E., Meinert, E. M. and Barbetta, P. A. 1987. Análise Sensorial de Alimentos, Série Didática. Florianópolis: UFSC Press.

Uchôa, A. M. A., Costa, J. M. C., Maia, G. A., Silva, E. M. C., Carvalho, A. F. F. U. and Meira, T. R. 2008. Physicochemical characterization, and crude and dietary fiber of powdered mixes made from tropical fruit by-products. Segurança Alimentar e Nutricional 15(2): 58-65.

Venturini, T., Benchuinal, L. R., Bertual, D. A., Rosa, M. B. and Meilli, L. 2012. Drying and extraction of papaya (*Carica papaya* L.) seeds. Gestão, Educação e Tecnologia Ambiental 5(5): 950-959.

Viana, E. S., Jesus, J. L., Reis, R. C., Fonseca, M. D. F. and Sacramento, C. K. 2012. Physicochemical and sensory characterization of papaya jam containing *araçá-boi*. Revista Brasileira Fruticultura 34(4): 1154-1164.