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Passion fruit peel flour – Technological properties and application in food products

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A B S T R A C T

The peel of passion fruit is rich in fiber which has properties comparable to food additives. Thus, in this study, the technological properties of flour obtained from yellow passion fruit peel were determined and compared to those of five commercial additives. Two flour samples were prepared from passion fruit shells through a modified process in order to evaluate their potential use as a stabilizing agent, emulsifier, thickener and gelling agent. These characteristics were then compared to those of low and high methoxyl pectins, xanthan gum, guar gum and carrageenan. The flour samples obtained have significant stabilizing capacity, as they were able to hinder particle settling when applied to nectars. Another positive feature observed was the emulsifying potential, showing similar results to additives commonly used in mayonnaise, such as xanthan and guar gums. The flour samples also showed good properties as a thickening and gelling agent in ice cream toppings and structured fruit. The results demonstrate that flour produced from passion fruit peel can be used to replace the commercial hydrocolloids studied since, besides being obtained through simple procedures and associated with low cost, the flour samples showed similar technical characteristics with regard to their stabilizing, emulsifying, thickening and gelling power.

1. Introduction

The passion fruit vine belongs to the family Passifloraceae and genus *Passiflora*. It is a native plant of tropical America and is cultivated in regions with a tropical or subtropical climate (Kishore, Pathak, Shuklar, & Bhar, 2011).

Passion fruit industrialization is generally aimed at juice and nectar production. In this process, 54,000 tons of by-products, such as seeds and peel, are generated per year in Brazil. Albedo (or pith), the main peel component, is rich in fiber and pectin, and can be used as an ingredient in the preparation of functional foods. Furthermore, it can be added to products that require an increase in viscosity (López-Vargas, Fernández-López, Pérez-Álvarez, & Viuda-Martos, 2013).

Fiber has some properties comparable to food additives which act as thickening or gelling agents and stabilizers of emulsions and foams. In addition, it is a fat mimetic. Moreover, it has swelling capacity and can increase water retention, properties which are essential for the preparation of creams, sweets and frozen desserts, among other food products (Ayala-Zavalaa et al., 2011; http://www.sciencedirect.com/science/article/pii/S0963996913000823 Martinez et al., 2012). Elleuch et al. (2011) reported that, in addition to the previously mentioned characteristics, fiber can modify the textural properties, prevent syneresis and improve the shelf-life of foods such as sweets, soups and dairy and bakery products.

The main reason for the widespread use of hydrocolloids in foods is their ability to alter the viscosity and texture of the products (Marcotte, Hoshahili, & Ramaswamy, 2001; Saha & Bhattacharya, 2010). Hydrocolloids, such as xanthan gum, carrageenan, guar gum and pectin, are generally used in foods due to

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their thickening, stabilizing, gelling and emulsifying properties, among others (Codex Alimentarius, 2015).

The literature reports several studies on passion fruit peel flour carried out to investigate, for instance, pectin extraction (Kliemann et al., 2009; Pinheiro et al., 2008; Seixas et al., 2014; Yapo & Koffi, 2006; Yapo, 2009), addition to functional beverages (Pineli et al., 2015) and the preparation of flexible films for food products (Nascimento, Calado, & Carvalho, 2012). However, the application of raw flour as a hydrocolloid agent is still little explored.

In this context, the aim of this study was to prepare food products using commercial additives and passion fruit peel flours, in order to evaluate the technological properties of the flour samples with regard to their thickening, stabilizing, emulsifying and gelling power.

2. Material and methods

2.1. Raw material

Passion fruit peel was used to prepare two flour samples. The first was obtained by maceration in water for 12 h, applying an adapted version of the methodology described by Oliveira, Nascimento, Borges, Ribeiro, and Ruback (2002), and is referred to herein as treated flour (TF). The second sample, not subjected to maceration, is referred to as untreated flour (UF).

In order to obtain the flour samples, the peel was cut into strips of approximately 1 cm. These were then dried in a dryer with forced air circulation at 50 °C until reaching constant weight (model Meloni - PE 30, Brazil). The dried strips were grinded in an industrial blender and sieved until flour samples with particles smaller than 150 μm were obtained.

2.2. Rheological analysis of hydrocolloids

The rheological parameters of the hydrocolloids under study (carrageenan – CAR (INS 407), guar gum – GUA (INS 412), xanthan gum – XAN (INS 415) (Sigma-Aldrich, USA) and low (LMP) and high (HMP) methoxyl pectins (INS 440) (CPKelco, USA)) and the passion fruit peel flours (UF and TF) were obtained in triplicate, at 25 °C, using a cone and plate rheometer (Thermo Scientific, model MARS III). An increase in the shear stress was obtained by increasing the rotation, through continuous variation of the cone angular velocity. Shear gradients from 0 to 700 s[1] were applied for 30 s, with a C60 cone-plate and 0.5 ml of sample. Thus, ascending and descending curves were obtained. The strain rate was determined using a computer program (RheoWin Data Manager, by Thermo) employing Eqs. (1) and (2):

$$\gamma = \omega/sin\theta \quad (1)$$

$$\tau = \frac{T}{\frac{2}{3}\pi r^3} \quad (2)$$

where γ = shear rate (1/s), T = shear stress (Pa), w = angular speed of the cone (rpm) and Π = cone angle.

The rheological behavior was determined using the power law rheological model ($K = t\gamma^n$) with the aid of Origin software (version 6.0).

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2.3. Product preparation, technological assessment and instrumental analysis

In order to determine the technological properties of the two flours (UF and TF), four different products were developed (nectar, structured fruit, passion fruit ice cream syrup and mayonnaise). Eight formulations were produced for each product with different types of additives and they were analyzed in triplicate. Five formulations contained commercial additives (hydrocolloids), that is, carrageenan (CAR), guar gum (GUA), xanthan gum (XAN) and low (LMP) and high (HMP) methoxyl pectins. The sixth formulation contained UF, the seventh contained TF and the eighth formulation was the control, without hydrocolloid addition, referred to herein as CTL.

2.3.1. Flour stabilizing power when added to passion fruit nectars

The passion fruit nectar was prepared with a concentration of 20% pulp and 80% distilled water. The addition of other ingredients was calculated on a 100% basis, with 11% soluble solids (°Brix) and 0.1% of each additive, according to the standard methods established for nectar (Brazil, 2003, 2013).

The stabilizing power of the additives was assessed applying an adapted version of the methodology described by Babbar, Aggarwal, and Oberoi (2015), by calculating the percentage of suspension (cloud) in the nectar. The cloud volume was measured every 30 min for the first 8 h and then every hour until stabilization. Samples were kept under refrigeration for seven days. Calculations were performed using Eq. (3):

$$\%Suspension = \left[\left(H_{jb} - H_c\right) \times 100\right] / H_{jb} \quad (3)$$

where H_{jb} = height of juice in the bottle and H_c = height of cloud.

2.3.2. Emulsifying power of flours added to mayonnaise and color analysis

Mayonnaise was prepared using oil, eggs and salt, plus 0.05% citric acid and 0.1% of each additive, according to standard methods established in Brazilian regulations (Brazil, 2007). The emulsifying power of each formulation was evaluated considering the texture profile, using a CT3 10K texturometer (Brookfield, USA) with a TA15/1000 tapered tip. Analysis was conducted at room temperature with 10 g samples, which were placed in porcelain capsules and analyzed in triplicate. For the evaluation, a TPA-type parameter was determined applying a load of 4 g, velocity of 2 mm/s and target value of 4.0 mm. The parameters determined were hardness, adhesion strength, adhesiveness, cohesiveness and gumminess.

Color analysis was also conducted using a MiniScan EZ digital colorimeter (Hunterlab, USA) and CIE Lab L*, a * and b * system, where L* denotes lightness and ranges from 0 (black) to 100 (white), and a* and b* denote opposite dimensions, ranging from green (−) to red (+) and from blue (−) to yellow (+), respectively.

2.3.3. Thickening power and water activity assessment of flours added to passion fruit syrup

Passion fruit syrup for ice cream topping was prepared with 10% pulp and 90% water (100% mixture) and 30% sugar, 0.05% citric acid and 0.1% of additives under study were added to the syrup. The mixture was concentrated at a temperature of 180 °C, until reaching 60°Brix.

The thickening power was determined by viscosity analysis in a Ford viscosity cup (Omicron, Brazil) with a No. 4 orifice at 20 °C. Viscosity analysis involves determining the time the sample takes to drain. Calculations were performed through an equation provided by the manufacturer (equation Eq. (4)), using the Centistoke (cSt) measurement unit:

$$V = 3.85 \times (\Delta t - 4,49) \quad (4)$$

where V = speed and Δt = final time−initial time.

In addition, water activity (a_W) was measured in triplicate through direct readings, using a portable water activity meter (Aqualab, Decagon Device, Pollman,WA).

2.3.4. Gelling power of flours added to structured passion fruit and color analysis

Structured passion fruit was prepared with 65% passion fruit pulp (3.98 pH and 13.9°Brix) and 35% distilled water (100% mixture) and heated to 65 °C. When the desired temperature was reached, a hydrocolloid mixture containing 1% alginate, 2% gelatin and 3.5% of the additives under study was added. After homogenization, 35% sucrose, 10% glucose and 0.2% calcium phosphate were added, with stirring for 10 min. The mixture was placed in a petri dish with 50.0 mm diameter and 10.0 mm height and kept in a refrigerator (10 °C) for 24 h prior to analysis.

The parameters of the structured fruit texture were evaluated in a CT3 Texture Analyzer (Brookfield, USA) using a cylindrical probe with 36 mm diameter (P/36), 60 s retention time, 1 mm/s test speed and 5 g load force. The parameters measured were firmness, adhesion strength, adhesiveness and stress relaxation.

In addition, color analysis was performed using a MiniScan EZ digital colorimeter (Hunterlab, USA) and the color described using the CIELab system, as detailed in the previous section.

2.4. Statistical analysis

Results were submitted to analysis of variance (ANOVA) and compared applying the Tukey test at 5% error probability, with the aid of the SPSS (version 17.0) statistical package for Windows (SPSS, Chicago, USA).

3. Results and discussion

3.1. Rheological analysis of hydrocolloids

The rheological flow of the hydrocolloids was determined by evaluating the suspension in water. The rheological characteristics varied according to gum type, since the gel formation characteristics of the gums differ according to the solvent and temperature. All samples showed non-Newtonian behavior, i.e., there is a nonlinear relation between the shear stress and shear rate, resulting from structural changes caused by the shear gradient applied. This behavior may be due to the fact that gums have a highly-folded long chain in the relaxed state. After exposure to shear stress, unfolding occurs, which can lead to thixotropy, and the liquid part of the product is released (Carvalho et al., 2013). The observed plastic flow behavior is a desirable and appropriate property for bubblegum (jellybean) products, corroborating other results which indicated that the flours obtained from passion fruit peel are appropriate for this type of product.

The flow properties obtained from each of the rheograms were evaluated applying the k consistency index and n flow behavior index, which were calculated using the Oswald-de Waele Equation (Power Law) (Jones et al., 2009). The consistency index is determined through the mean viscosity based on points obtained from a flow curve and it varies according to the different gum interaction forces. The behavior index showed that the gums under study had n values lower than 1, which means that they can be classified as pseudoplastic (Fester, Slatter, & Alderman, 2012).

3.2. Product preparation, technological assessment and instrumental analysis

3.2.1. Stabilizing power of flours in passion fruit nectar and color analysis

The effect of the hydrocolloids on the cloud sedimentation characteristics of the passion fruit nectar can be observed in Fig. 1. Nectar samples containing different hydrocolloids reached decantation equilibrium in 18 h. It should be noted that the efficiency of each stabilizer was observed through the linear behavior of the curves. In this case, the flatter and the lower the gradient, the better the stabilizing effect provided by the additive.

The best results for the stabilizers studied were observed with carrageenan and guar gum, which led to clouds with volumes of 10% and 15%, respectively, followed by the TF and HMP pectin, with suspensions of 30% and 37%, respectively. The other stabilizers promoted nectar cloud formation with a similar behavior to that of the control sample (without stabilizer), that is, the cloud volume ranged from 50 to 57%. Xanthan gum was not effective in stabilizing the suspended solid particles in the nectar at the concentration used in this study (0.1%), showing a higher final decantation volume (65%).

Additives in nectar often reduce sediment formation since they increase the product viscosity (Sinchaipanit, Kerr & Chamchan, 2013). The results reported herein show the action of different hydrocolloid types when added to nectars and indicate that the flours under study could provide a stabilizing option for juices (UF and TF), although the degree of decantation was higher compared to carrageenan and guar gum. TF showed greater stabilizing power than UF; however, the low cost and ease of obtainment of UF also needs to be considered.

Genovese and Lozano (2000) investigated several stabilizer concentrations in apple juice. However, in order to ensure good results in relation to xanthan gum, it was necessary to use a concentration of 0.4–0.5%, which does not adhere to the Brazilian resolution Resolução de Diretoria Colegiada No. 8, 03 June 06, 2013 (Brazil, 2013), which allows a maximum of 0.2% of this additive in nectars.

Sinchaipanit, kerrb, and chamchana (2013) assessed cloud stability in carrot juice comparing various hydrocolloids, including HMP pectin and guar gum, and observed that pectin was less effective in preventing sedimentation, with moderate decantation occurring within eight days. For guar gum the same effect was achieved only after 16 days. In addition, Babbar et al. (2015), assessed lychee juice stability using hydrocolloids, including pectin, and found that LMP pectin had no significant effect on the cloud stability.

3.2.2. Emulsifying power of flours in mayonnaise and color analysis

The textures of mayonnaise samples prepared with different additives are shown in Table 1.

Each hydrocolloid type has specific characteristics and these can also vary depending on the type of product to which they are applied. Based on the results obtained in this study, it can be observed that the action of several gums in different concentrations affects the interaction of the compounds and the product emulsification. Izidoro, Sierakowski, Waszczynskyj, Haminiuk, and Scheer (2007) reported that mayonnaise samples containing thickeners and stabilizers are more rheologically stable.

The mayonnaises samples did not differ in terms of adhesion strength. Regarding the hardness, the guar gum sample showed no significant difference compared to the xanthan gum sample, although these differed from the other hydrocolloids. Adhesion strength and hardness are important parameters because they are related to food chewing/swallowing (Szczesniak, 2002). In this

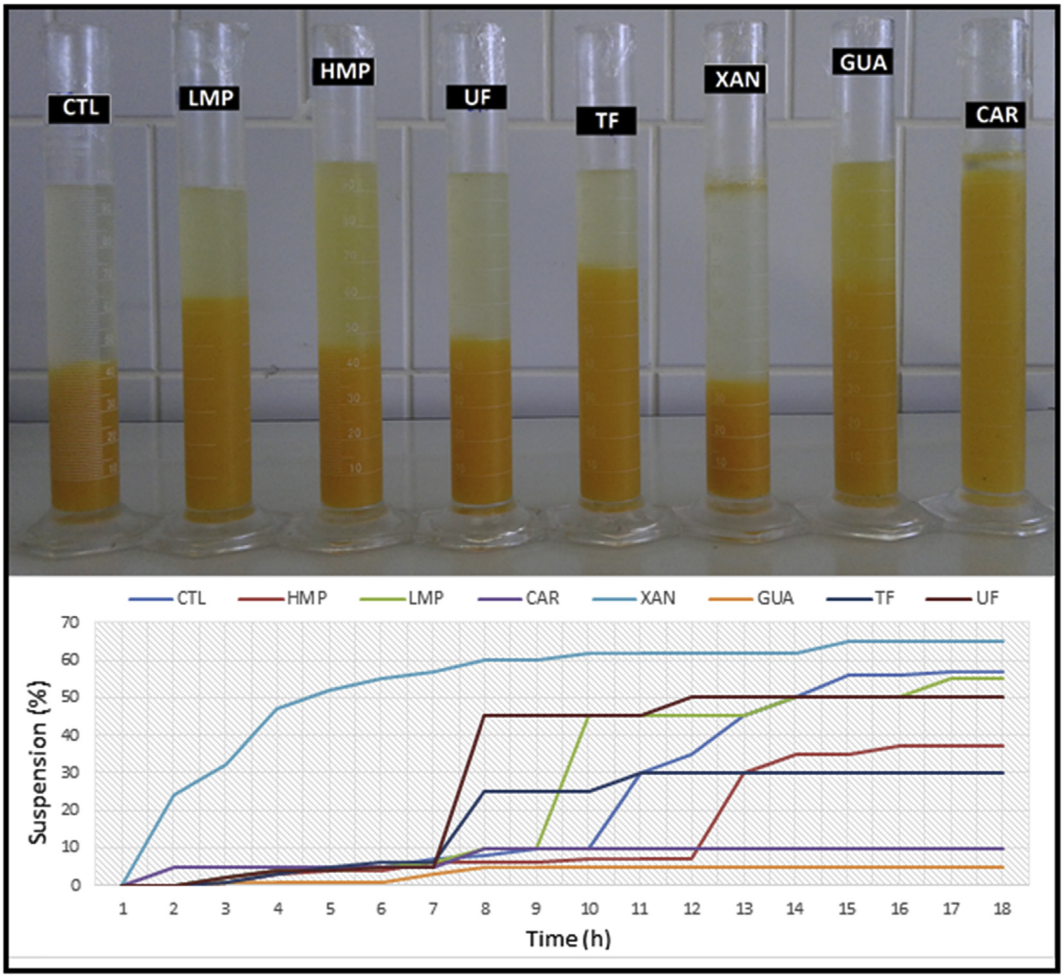

Fig. 1. Settling behavior of solids suspended in passion fruit nectar with different additives. HMP = high methoxyl pectins, LMP = low methoxyl pectins, CAR = carrageenan, GUA = guar gum, XAN = xanthan gum, UF = untreated flour, TF = treated flour, CTL = control samples.

respect, the performance of UF and TF was similar to that of other additives.

It was observed that the presence of hydrocolloids in mayonnaise formulations primarily affected the product "cohesiveness", and for some samples this parameter was 50% higher compared to the control sample. Regarding the gumminess, the sample containing carrageenan did not differ from the formulations with HMP, LMP, guar gum, UF and TF. Amin, Elbeltagy, Mustafa, and Khalil (2014) observed higher cohesiveness and gumminess in mayonnaise samples to which guar and xanthan gums were added, due to increased viscosity in emulsion.

In the case of the thickeners studied, guar and xanthan gums showed the best values for the product type in question. However, for UF and TF the gumminess was similar to that provided by guar gum. This finding is important because guar gum has the characteristic of forming dispersions by increasing the viscosity, acting as stabilizer in emulsions (Mudgil, Barak, & Khatkar, 2014). Thus, the flours could also be used for this function.

Mayonnaise samples prepared with guar gum also had higher adhesion strength compared with the UF, TF and control (CTL) samples, with values of 0.73; 0.63; 0.60 and 0.50 mJ, respectively.

Based on the results obtained, the flours used in this study can

Table 1
Mean values of texture parameters for mayonnaise samples with different additives.

Samples	Adhesion strength (g)	Hardness (mm)	Cohesiveness	Gumminess (g)	Adhesiveness(mJ)
HMP	3.33 ± 0.58^{a}	3.81 ± 0.00^{a}	2.37 ± 0.53^{abc}	25.00 ± 1.00^{ab}	0.23 ± 0.58^{d}
LMP	4.00 ± 0.00^{a}	3.86 ± 0.11^{a}	1.79 ± 0.50^{abc}	19.00 ± 1.00^{ab}	0.40 ± 0.10^{bcd}
CAR	5.00 ± 1.00^{a}	3.70 ± 0.52^{a}	3.09 ± 0.95^{a}	14.67 ± 4.51^{a}	0.33 ± 0.58^{cd}
GUA	5.00 ± 1.00^{a}	2.87 ± 0.42^{b}	2.81 ± 0.34^{ab}	19.33 ± 8.50^{ab}	0.73 ± 0.58^{a}
XAN	4.67 ± 0.58^{a}	3.47 ± 0.10^{ab}	1.62 ± 0.45^{bc}	12.33 ± 0.57^{b}	$0.40 \pm 0.1b^{cd}$
UF	5.33 ± 0.58^{a}	3.61 ± 0.20^{a}	1.23 ± 0.23^{c}	19.33 ± 4.51^{ab}	0.63 ± 0.58^{ab}
TF	5.33 ± 0.58^{a}	3.74 ± 0.11^{a}	2.30 ± 0.37^{abc}	19.50 ± 5.00^{ab}	0.60 ± 0.20^{abc}
CTL	3.67 ± 1.10^{a}	3.81 ± 0.00^{a}	1.00 ± 0.10^{c}	7.67 ± 1.53^{b}	0.50 ± 1.00^{abcd}

Means followed by the same letters in the same column do not differ according to the Tukey test at 5% probability. HMP = high methoxyl pectins, LMP = low methoxyl pectins, CAR = carrageenan, GUA = guar gum, XAN = xanthan gum, UF = untreated flour, TF = treated flour, CTL = control sample.

Table 2
Mean values of color parameters for mayonnaise samples with different additives.

Samples	L*	a*	b*
HMP	73.88 ± 0.20^{bc}	−2.95 ± 0.00^{a}	15.31 ± 0.30^{a}
LMP	72.39 ± 0.27^{d}	−2.82 ± 0.03^{ab}	14.97 ± 0.53^{ab}
CAR	73.57 ± 0.11^{ab}	−2.53 ± 0.04^{cd}	11.78 ± 0.25^{e}
GUA	73.31 ± 0.56^{abc}	−2.17 ± 0.07^{e}	12.50 ± 0.07^{cd}
XAN	72.39 ± 0.38^{d}	−2.54 ± 0.22^{cd}	12.17 ± 0.02^{cde}
UF	73.84 ± 0.09^{a}	−2.34 ± 0.04^{bc}	11.85 ± 0.07^{de}
TF	73.69 ± 0.03^{ab}	−2.62 ± 0.00^{bc}	12.57 ± 0.40^{c}
CTL	72.88 ± 0.55^{cd}	−2.69 ± 0.28^{abc}	14.33 ± 0.56^{b}

Means followed by the same letters in the same column do not differ according to the Tukey test at 5% probability. HMP = high methoxyl pectins, LMP = low methoxyl pectins, CAR = carrageenan, GUA = guar gum, XAN = xanthan gum, UF = untreated flour, TF = treated flour, CTL = control sample.

Table 3
Mean values of color parameters for samples with different additives.

Thickening	Viscosity (CSt)	a_w
HMP	42.35 ± 1.17^{f}	0.764 ± 0.00^{b}
LMP	55.52 ± 1.29^{d}	0.761 ± 0.00^{b}
CAR	43.43 ± 0.95^{f}	0.748 ± 0.00^{c}
GUA	75.42 ± 0.91^{c}	0.700 ± 0.00^{d}
XAN	337.84 ± 1.01^{a}	0.728 ± 0.00^{d}
UF	74.46 ± 3.40^{c}	0.746 ± 0.00^{c}
TF	143.99 ± 3.49^{b}	0.730 ± 0.00^{d}
CTL	50.13 ± 0.23^{e}	0.791 ± 0.00^{a}

Means followed by the same letters in the same column do not differ according to the Tukey test at 5% probability. HMP = high methoxyl pectins, LMP = low methoxyl pectins, CAR = carrageenan, GUA = guar gum, XAN = xanthan gum, UF = untreated flour, TF = treated flour, CTL = control sample.

be considered to show similar behavior to guar and xanthan gums in mayonnaise processing. Thus, they could represent a suitable option to replace commercial emulsifiers.

Table 2 shows the mean values for the color parameters L*, a* and b* for the mayonnaise samples prepared with different additives. All samples showed high lightness (L* >72) with a yellow tone (+b*) and green pigment traces (-a*). The lightness (L*) of the UF sample did not differ significantly from that of TF, guar gum and carrageenan. Amin et al. (2014) evaluated the color of mayonnaise samples prepared from a mixture of soybean oil, xanthan gum and guar gum, and observed lightness values ranging from 70.06 to 84.09.

The HMP, LMP and control sample (CTL) formulations showed higher traces of the green pigment (-a*) and yellowness (-b*). However, the lowest green trace was observed with the addition of guar, and the lowest yellow trace was observed for samples with carrageenan, xanthan and UF added. Lower values were found by Amin et al. (2014) both for a* (−1.38 to −1.71) and b* (8.1–11.17). Therefore, it is clear that the hydrocolloid added can affect the mayonnaise color, which can be attributed to the particular characteristics of each additive.

Table 5
Mean values of color parameters for structured passion fruit.

Samples	L*	a*	b*
HMP	37.22 ± 0.64^{c}	6.81 ± 0.33^{b}	27.06 ± 2.18^{c}
LMP	38.82 ± 0.85^{c}	4.84 ± 0.13^{b}	26.80 ± 1.15^{cd}
CAR	34.93 ± 2.80^{cd}	5.02 ± 0.14^{d}	21.94 ± 2.14^{de}
GUA	43.62 ± 3.89^{b}	6.80 ± 0.39 ^{b}	35.20 ± 4.74^{b}
XAN	70.99 ± 1.69^{a}	5.55 ± 0.10 ^{c}	43.49 ± 1.30^{a}
UF	32.32 ± 1.20^{d}	7.00 ± 0.21^{b}	19.02 ± 0.98^{ef}
TF	36.71 ± 0.52^{cd}	7.53 ± 0.15^{a}	24.57 ± 0.26^{cd}
CTL	27.81 ± 0.65^{e}	3.93 ± 0.11^{e}	15.28 ± 0.94^{f}

Means followed by the same letters in the same column do not differ according to the Tukey test at 5% probability. HMP = high methoxyl pectins, LMP = low methoxyl pectins, CAR = carrageenan, GUA = guar gum, XAN = xanthan gum, UF = untreated flour, TF = treated flour, CTL = control sample.

3.2.3. *Assessment of thickening power in passion fruit syrup*

In Table 3, the thickening power (viscosity) and water activity in passion fruit syrup for ice cream of the hydrocolloids under study can be observed. The syrup with the highest viscosity was that containing xanthan gum, followed by TF, guar and UF. This indicates that the potential of these flours as a thickening agent is significant, since they led to passion fruit syrup samples with higher viscosity when compared to other traditional commercial thickeners for this product, such as HMP and LMP pectins and carrageenan.

In the test syrup, the viscosity increased from 48% to 187%, respectively, when UF and TF were added, while high-methoxyl and low-methoxyl pectins and carrageenan addition provided little or no increase in the product viscosity. One reason for the results obtained for pectin may be the low concentration used (0.1%), since the manufacturer recommends from 0.3% to 1.0% for application in jams and jellies with soluble solid contents between 60 and 65%. In the case of carrageenan, the lack of a viscosity increase can be explained by the need for this additive to be associated with potassium or calcium ions in order to gel, besides this compound being unstable under acidic conditions. This hydrocolloid is more suitable for products such as puddings, ice creams, yogurts and others, due to its ability to form gels in low concentrations with milk, due to the presence of calcium (Saha & Bhattacharya, 2010).

However, Molina-Rubio, Cacas-Alencáster & Martínez-Padilla (2010) found that carrageenan was the best option out of the hydrocolloids studied by the authors, modifying the rheological properties of semi-liquid syrup for confectionery, which consisted of sucrose, high fructose corn syrup, gum, citric acid and water. The same authors reported that samples with carrageenan added showed higher values for all rheological properties studied, including viscosity. Vickers et al. (2015) assessed the thickening effect of 15 additives on a thin honey beverage, and noted that samples with calcium caseinate and high-methoxyl and low-methoxyl pectin were relatively more active in terms of viscosity.

Regarding the a_w, the control sample provided the highest value

Table 4
Means values of the texture parameters for structured passion fruit.

Samples	Adhesiveness (mJ)	Adhesion strength (g)	Firmness (g)	Stress relaxation (s)
HMP	1.4 ± 0.25^{a}	90.5 ± 1.05^{a}	3296 ± 2.00^{a}	4.63 ± 1.23^{cd}
LMP	0.5 ± 0.4^{ab}	10.5 ± 3.50^{c}	1629 ± 1.38^{b}	4.00 ± 0.5^{d}
CAR	1.1 ± 0.06^{ab}	39.3 ± 1.90b^{c}	424 ± 1.06^{c}	4.27 ± 0.46^{d}
GUA	0.3 ± 0.02^{b}	12.5 ± 3.50^{c}	669 ± 1.39^{c}	8.37 ± 1.11^{ab}
XAN	0.5 ± 0.46^{ab}	28.7 ± 1.48^{bc}	337 ± 2.32^{c}	11.43 ± 1.78^{a}
UF	0.6 ± 0.3^{ab}	14.5 ± 2.50^{c}	1221 ± 2.54b^{c}	6.30 ± 0.92^{bc}
TF	0.4 ± 0.1^{b}	75 ± 4.50^{ab}	2769 ± 0.82^{a}	5.85 ± 0.15^{bc}
CTL	1.1 ± 0.56^{ab}	41.3 ± 4.8^{ab}	386 ± 0.49^{c}	7.57 ± 1.62^{bc}

Means followed by the same letters in the same column do not differ according to the Tukey test at 5% probability. HMP = high methoxyl pectins, LMP = low methoxyl pectins, CAR = carrageenan, GUA = guar gum, XAN = xanthan gum, UF = untreated flour, TF = treated flour, CTL = control sample.

(0.97), showing a significant difference from the other samples, due to the absence of hydrocolloids. Mixtures with guar, xanthan and TF provided lower values due to the interaction with the water available to act in the gel formation. Saha and Bhattacharya (2010) confirmed this phenomenon, reporting that hydrocolloids may disperse in water and act as thickeners or change the viscosity, which is a known characteristic of these compounds.

3.2.4. Assessment of gelling power

Table 4 shows the mean values for the texture of structured passion fruit prepared with different additives. All variables determined for this product showed significant differences. However, the parameter with the lowest variation between samples was adhesiveness, which is related to the tensile force required to separate food from the compression plate (Szczesniak, 2002).

Structured fruits generally feature textures similar to that of jellybeans. Structured passion fruit prepared with HMP pectin and TF showed higher firmness when compared to the control sample (no additives), which was very fluid and did not show the jellybean characteristic. Firmness is important for this type of product since it allows more time in the mouth, according to sensorial analysis.

Azoubel, Araújo, Oliveira, and Amorim (2011), who studied the firmness of passion fruit (*Passiflora cincinnata* Mast), observed that gelatin had a strong influence on the characteristics of this parameter, since there was an increase in firmness with higher gum concentration. Other fruits have been used in studies on structure development, in which various types of hydrocolloids and concentrations were tested. Lins, Cavalcanti, Azoubel, Melo, and Maciel (2014) studied structured yellow mombin fruit and reported similar behaviors to that observed in this research. Grizotto, Bruns, Aguirre, and Menezes (2007) assessed structured pineapple and noted that the firmness increased with increasing additive (alginate and pectin) concentrations. The different behaviors observed for the structured fruit texture can be explained by the gel properties, which vary according to types of hydrocolloid and product as well as the conditions of the process (Saha & Bhattacharya, 2010). The sucrose and hydrocolloid concentrations along with the temperature are also important variables which affect the rheological state of the hydrocolloid gel (Marcotte et al., 2001).

The color results (L*, a* and b*) for the structured passion fruit samples are shown in Table 5, where it can be observed that the structured control showed lower values than the other samples. Thus, the addition of hydrocolloids to the structured passion fruit during preparation influences the final color of the product. In fact, both the hydrocolloid type and concentration can affect the product color (Azoubel et al., 2011).

Of the samples containing hydrocolloids that with xanthan gum showed the lightest color, which was visually perceived during the product preparation, while the structured fruit samples containing UF were similar to those with TF and carrageenan. Regarding the a* and b* values, despite the statistical difference between formulations, it is clear that all structured passion fruits had color characteristics in the yellow region (+b*), with traces of red (+a*).

4. Conclusions

Based on the results obtain in this study, passion fruit peel flours, treated and untreated, can be used to replace the commercial hydrocolloids considered herein. These flours can be obtained through simple and low cost procedures and had similar technological characteristics regarding stabilizing, emulsifying, thickening and gelling power. Furthermore, it was noted that the treated passion fruit peel flour had higher stabilizer, thickening and gelling power when compared to untreated flour.

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