Maracuja-do-mato (*Passiflora cincinnata* Mast.) jelly developed with pequi (*Caryocar brasiliense* Camb.) peel pectin and commercial pectin: a comparative study
ABSTRACT

The pequi peel corresponds to approximately 80% of the fruit’s weight and is often discarded. However, it is possible to extract pectin from this co-product. In this sense, the purpose of this study was to promote the extraction of pectin from the peel of the pequi using citric acid, evaluating its yield and degree of esterification, as well as comparing it with the commercial pectin in the formulation of maracuja-do-mato jelly. A yield of 29.9% was obtained in the extraction of the gelling agent, which was characterized as low-esterification pectin (36.3%). The maracuja-do-mato jelly developed from pectin extracted from the peel of the pequi was accepted by the tasters, reaching average grades above 7.0 for four of the five attributes evaluated, however, it differed statistically from the jelly produced with commercial pectin in appearance, color, and taste. Thus, pequi peel can be considered a viable alternative for pectin extraction.

**Keywords:** Alternative pectin, Extraction, Fruit jelly, Sensorial analysis.
INTRODUCTION

Pequi (*Caryocar brasiliense* Camb.) is a Brazilian fruit native from the Cerrado region with economic relevance for the local producers. The state of Minas Gerais is the largest producer, corresponding to about 73% of the total production (LEÃO et al., 2018). Pequi fruit is composed of peels (exocarp and external mesocarp) that represent around 80% of its total mass, and the 20% remained (internal mesocarp and almond) correspond to the edible parts. Mainly the edible portions of pequi fruits are used in many food preparations, but its peels are commonly discarded (SIQUEIRA et al., 2012; TORRES et al., 2018). Pequi peel has high levels of dietary fibers, carbohydrates, minerals, as well as pectic polysaccharides, showing its technological potential. But its use is still little investigated (LEÃO et al., 2018; SIQUEIRA et al., 2012).

Pectins compose the cell wall of plants and have an important function in cell-to-cell adhesion (GÜZEL; AKPINAR, 2019; MARIĆ et al., 2018). The main component of pectin is the homogalacturonan, a linear polymer of \(\alpha-1,4\)-linked-D-galacturonic acid with distinct degrees of methyl esterification. This degree of esterification directly influences the functional proprieties of pectin, especially its gel-forming propriety. Besides being a gelling agent, pectin is a food ingredient with other functions such as emulsifier, stabilizer, fat replacer, and thicker, being used in the production of jams, jellies, preserves, marmalades, ice creams, among others (ABBOUD et al., 2020; LEÃO et al., 2018; MARIĆ et al., 2018). Also, health-promoting proprieties of pectins have been described in the literature, such as their activities in the microbiota modulation, positive effects in the intestine, a decrease of cholesterol level, prevention of cardiovascular diseases, among others (GÜZEL; AKPINAR, 2019; MARIĆ et al., 2018; MOURA et al., 2020).

The extraction of pectins from the plant source involves the use of suitable methods that allow the maximum extraction yield with the maximum quality. These processes promote the hydrolysis of insoluble into soluble pectins and its solubilization from the vegetable tissues and are influenced by many factors such as temperature, pH, type and concentration of the acid agent, time of extraction, extraction technique used, among others (LEÃO et al., 2018; MARIĆ et al., 2018).

Despite pectin is found in a large number of vegetables, the main sources used in the food industry are apple and citrus wastes. But new vegetable sources, such as passion fruit, melon, and pomegranate peels, are being studied and show very promising results (ABBOUD et al., 2020; GÜZEL; AKPINAR, 2019; MARIĆ et al., 2018; MOURA et al., 2020). The search for new sources of pectins can stimulate the use of other plant wastes, decreasing their impact in the environment; diversify the type of pectins available, showing distinct chemical properties, yielding, and applications; decrease the production cost, among others (ABBOUD...
et al., 2020; GÜZEL; AKPINAR, 2019). In this context, the pequi peel, which represents a large portion of this fruit and is discarded, can be a potential source of pectin.

Therefore, this study aimed to (i) extract pectin from the pequi (*Caryocar brasiliense* Camb.) peel (external mesocarp) flour and characterize it in terms of yield and degree of esterification, as well as (ii) comparing this pectin with the commercial citrus pectin through the production of maracuja-do-mato (*Passiflora cincinnata* Mast.) jelly.

**MATERIAL AND METHODS**

**Samples**

Pequizeiro (*Caryocar brasiliense* Camb.) fruits and maracuja-do-mato (*Passiflora cincinnata* Mast.) frozen pulp were acquired from the local market of Salinas, in the state of Minas Gerais, Brazil.

**Pequi peel flour**

Pequi fruits were washed with potable water and selected according to their size uniformity, color, firmness, and absence of any damage. Pequi peel flour was obtained according to the procedure recommended by Soares-Júnior et al. (2009), with some modifications. The select fruits were manually peeled. The external mesocarp portion, which will be called in this studied as peels, was separated and bleached in boiling water for 6 min. In the sequence, the peels were dehydrated in an oven with forced air circulation (Q317M, QUIMIS, Brazil) at 60 °C for 36 h. After cooled, the dehydrated peels were ground in a processor (Multichef FP15, Arno, Brazil) and stored in polyethylene bags in the dark.

**Pectin extraction**

Pectin extraction from the pequi peel flour was carried out according to Munhoz et al. (2010), with some modifications. Pequi peel flour (8 g) was dissolved in 400 mL of 8% citric acid solution. The extraction was conducted in a water bath at 74 °C for 60 min.

After extraction, the samples were cooled at 4 °C for 2 h and filtrated in nylon fabric. In the filtrate, containing pectin, was added 95% ethanol solution in the proportion of 1:2 (filtrate: ethanol). The precipitated pectin was recovered by filtration and dried in an oven at 55 °C until constant weight. The yield of pectin was quantified as follows (Equation 1).

\[
\text{Yield(\%)} = \frac{\text{Pectin extracted and dried (g)}}{\text{Peel flour (g in dry weight)}} \times 100
\]
Pectin quantification

The quantification of pectins was performed by titrimetry according to Munhoz et al. (2010). Pectins (0.25 g) were dissolved with ethanol (2 mL) and deionized water (25 mL) for 30 min in a magnetic stirrer.

The free carboxylic groups of anhydrogalacturonic acids were neutralized with 0.1 N NaOH solution. For esterified carboxylic groups determination, carboxylic groups were first submitted to saponification with 10 mL of 0.25 N NaOH solution for 30 min at room temperature and then neutralized with 10 mL of 0.25 N HCl solution. After that, the solution was neutralized with 0.1 N NaOH solution.

The determination of the amount of milliEquivalent (mEq) of free (mEq1) and esterified carboxylic groups (mEq2) was calculated according to the Equation 2 and used to determine the degree of esterification (Equation 3).

\[
m\text{Eq(milliEquivalent)} = N\times \text{NaOH volume spent (L)}
\]

\[
\text{Degree of esterification} = \frac{m\text{Eq2}}{m\text{Eq1} + m\text{Eq2}}
\]

Development of jelly formulations

The production of maracuja-do-mato jellies was performed in the Experimental Unit for Processing Fruits and Vegetables according to the methodology described by Soler (1991). Two formulations were used for the development of the jelly: (F1) jelly with commercial citrus pectin; and (F2) jelly with pectin extracted from the pequi peel. All practices were carried out following Good Manufacturing Practices.

The maracuja-do-mato pulp was diluted in potable water in the proportion of 1:1 (1 mL of water / 1 g of pulp). The pH of the pulp was determined using a pH meter (Q-400 AS, QUIMIS, Brazil) and the acidity correction to up to 3.2 with bicarbonate of sodium was carried out based on acidification calculations.

A pre-dissolution of both pectin types (pequi peel and commercial) was carried out before their addition into the concentrator. But initially, a dry mixture of one part of pectin and four parts of sugar was performed, requiring 1 g of pectin to 100 g of sucrose. This mixture was slowly added to the boiling maracuja-do-mato pulp under mechanical stirring until the formation of a homogeneous solution, without the presence of lumps. Then, sucrose was added in a 1:1 ratio (1 g of sugar / 1 g of pulp).

Sanitized glass bottles were filled with the jelly at a temperature of about 90 °C and then immediately closed and inverted for about 3 minutes to promote the heat treatment of the inside of the lids. The jellies were then kept at room temperature and under dark.
Physicochemical analyses

The pH and total soluble solids were determined according to AOAC (2019).

Sensorial analysis

For the acceptance and purchase intention sensory tests of maracuja-do-mato jellies, the samples were coded with a three-digit number, using the experimental model of randomized blocks. The tests were applied in individual booths, using white light, and the samples were served in properly identified disposable cups. The tests were applied to 50 untrained panelists with a minimum age of 14 years and familiarized with the testing procedures. It is worth mentioning that they had at their disposal a glass of water for cleaning the taste buds (MININ, 2018).

The attributes of appearance, color, texture, aroma, flavor, and overall impression were evaluated in the acceptance test using a 9-point structured hedonic scale ranging from “1 – disliked extremely” to “9 – like extremely”. To identify the purchase intention, a 5-point structured hedonic scale from “1 – certainly would not buy” to “5 – certainly would buy” was used, according to Meilgaard, Civille e Carr (1998). The obtained data were analyzed using analysis of variance (ANOVA) followed by Tukey test ($p \leq 0.05$) for means comparison using Excel software version 2010.

RESULTS AND DISCUSSION

Characterization of pectin from pequi peel flour

Extraction yield of pectin

The acid extraction of pectin from pequi peel flour resulted in a yield of 29.9%. This data agrees with those reported by Siqueira et al. (2012), in which a range from 15.9 to 47.5% of yield was obtained in the extraction of pectin from pequi peel flour when similar extraction conditions were employed (60 – 84 min/ 74 – 92 °C/ 2 – 8% citric acid). Similar yield values (up to 20.8%) were also found for pectins extracted from pequi peel flours under microwave heating (52 – 108 °C/ 317 – 883 W/ 3 – 9 min) (LEÃO et al., 2018). Therefore, the yield of pectin obtained from pequi peel flour can be considered satisfactory and agrees with the values found for other fruits such as guava pulp+peel (up to 13.2%) and passion fruit peel (20%) (ABBoud et al., 2020; MUNHOZ; SANJINEZ-ARGANDONÁ; SOARES-JÚNIOR, 2010).

During the conventional extraction of pectin, the efficiency of this process is mainly influenced by the concentration of the acid solution, time of extraction, and temperature of
extraction (ABBOUD et al., 2020; LEÃO et al., 2018; SIQUEIRA et al., 2012). The use of the acid solution, resulting in pH ranging from 1 to 3, favors the hydrolysis of insoluble into soluble pectins, increasing the yield of pectin. Also, it can reduce the molecular weight of pectins, facilitating their solubilization from the vegetable tissues and reducing their precipitation, which facilitates its release from the tissues (LEÃO et al., 2018). The increase in the temperature and time of extraction also commonly increases the yield of pectins extracted because they facilitate the release reactions of the soluble polymers in the acidic medium (SIQUEIRA et al., 2012). However, the use of strong acids and/or high temperature and time of extraction can also promote the degradation of these polymers causing alterations in their structure, besides strong acids may produce hazardous contaminants. Therefore, an equilibrium among all the variables ensures a satisfactory yield of pectin with the desirable quality (ABBOUD et al., 2020; SIQUEIRA et al., 2012).

**Degree of esterification of pectin**

The degree of esterification is an important criterion used in the pectin classification. It measures the amount of methylated galacturonic acid groups in relation to the total galacturonic acid groups, classifying pectins as high-methoxyl (degree of esterification > 50%) or low-methoxyl (degree of esterification < 50%). This information indicates its functional proprieties since the degree of esterification of pectin directly affects the characteristics of pectin gel formation (ABBOUD et al., 2020; GÜZEL; AKPINAR, 2019; LEÃO et al., 2018).

The pectins extracted from the pequi peel flour in the present study were of low degree of esterification, corresponding to a degree of esterification of 36.3%. This data agrees with those found by Siqueira et al. (2012), in which a range from 13.2 to 46.2% of degree of esterification was found in the pectin extracted from pequi peel flour in similar extraction conditions (60 – 84 min/ 74 – 92 °C/ 2 – 8% citric acid). However, in another study, the degree of esterification of pequi peel flours was higher than 50% using microwave heating extraction (52 – 108 °C/ 317 – 883 W/ 3 – 9 min) (LEÃO et al., 2018).

The differences observed in the degree of esterification of pectins extracted from pequi peel flour directly reflects the extraction conditions applied as well as the composition of each sample. It is expected that more severe extraction conditions, such as the high concentration of acids, high temperature, and high times of extraction used isolated or in combination, will result in the increased of pectin yield, but also increase the degree of degradation of the pectin. This can cause possible de-esterification, transforming pectin with a high degree of methylation into pectin with a low degree of methylation, among other undesirable compounds (MOURA et al., 2020; SIQUEIRA et al., 2012). These effects were clearly observed in the study conducted by Siqueira et al. (2012) in pequi peel flour, in which the experiments that
resulted in the lowest pectin yields were those that showed the highest degree of esterification. Therefore, the extraction conditions used will determine the type of pectin extracted (ABBOUD et al., 2020; SIQUEIRA et al., 2012).

Other factors that impact in the degree of esterification of pectins are related to the fruit, including the fruit species, the part of the fruit used, as well as the intrinsic composition of each sample that can vary for the same species and part of fruit due to the influence of different edaphoclimatic conditions. The effect of the part of fruit used can be observed in the study of Leão et al. (2018) with pequi peel flour produced from the whole peel (exocarp+mesocarp) and from mesocarp portion, in which higher yield of pectin and a lower degree of esterification was found in the whole peel compared to the mesocarp portion. The influence of fruit species in the yield of pectin and degree of esterification was showed in the study of Güzel e Akpınar (2019), in which pectin yield ranged from 6.1 to 13.3% and the degree of esterification ranged from 56.7 to 84.7% according to the fruits species (kiwifruit, melon, apple, pomegranate, and orange).

Low-methoxyl pectins, as the obtained in this study from the pequi peel flour, can form stable gels in the absence of sugars and a wide range of pH (2 – 6), but the presence of bivalents ions, such as calcium, is required (ABBOUD et al., 2020; SIQUEIRA et al., 2012). Therefore, this type of pectin becomes highly interesting in the elaboration of light products, especially jellies (SIQUEIRA et al., 2012), besides regular products.

**Physicochemical characteristics of maracuja-do-mato jellies**

Total soluble solids and pH are important parameters related to the characteristics of the jelly and affect its shelf life (LEMOS et al., 2019; VIEIRA et al., 2017).

In the maracuja-do-mato jellies, the final pH values were 3.2 and 3.3 for the formulation with pequi peel pectin and commercial pectin, respectively. These values agree with the study conducted by Viana et al. (2012) with papaya jam and different concentrations of araça-boi, in which the pH values ranged from 3.1 and 3.5. The jellies pH around 3.4 is suggested to be adequate since pH values below 3.0 can favor the syneresis occurrence (JACKIX, 1988). Besides that, this pH range found in jellies characterizes the product as acid, which contributes to the prevention of *Clostridium botulinum* growth, an important pathogenic bacterium (VIANA et al., 2012).

According to the Brazilian National Health Surveillance Agency, the content of total soluble solids in jellies must be between 62 and 65 °Brix (BRASIL, 1978). In the present study, the average value was 65 °Brix, which ensures the correct characterization of the product. Similar total soluble solids were found in other jellies such as mango (69 °Brix) (LAGO-VANZELA et al., 2011) and acai mixed with cocoa honey (65.2 °Brix) (MELO NETO
et al., 2013). The small differences in the total soluble solids among jellies can be attributed to the characteristics inherent to the raw materials.

**Sensorial analysis**

**Acceptance test**

In Table 1 are shown the average scores of sensorial attributes assessed by the acceptance test of maracuja-do-mato jellies.

**Table 1. Average scores of sensorial attributes assessed by the acceptance test of maracuja-do-mato jellies made with commercial pectin (F1) and pectin extracted from pequi peel (F2).**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>F1</th>
<th>F2</th>
<th>MSD²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>7.90±1.07a</td>
<td>7.46±1.34b</td>
<td>0.44</td>
</tr>
<tr>
<td>Aroma</td>
<td>7.24±1.81a</td>
<td>6.86±1.90a</td>
<td>0.44</td>
</tr>
<tr>
<td>Color</td>
<td>8.02±1.12a</td>
<td>7.56±1.36b</td>
<td>0.45</td>
</tr>
<tr>
<td>Flavor</td>
<td>7.86±1.20a</td>
<td>7.24±1.57a</td>
<td>0.53</td>
</tr>
<tr>
<td>Texture</td>
<td>7.62±1.14a</td>
<td>7.34±1.52a</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Means ± standard deviation followed by the same letter do not differ significantly by the Tukey test at the 5% level of significance. MSD² = Minimum Significant Difference.

Significant differences were found between F1 and F2 jellies for the attributes of appearance, color, and flavor (Table 1). Pectin was the only ingredient that varied between the formulations. Then, the pectin of pequi peel seems to darken the maracuja-do-mato jelly and, consequently, interferes negatively in the appearance and color attributes of the product. The influence of pectin of pequi peel in the color of jelly was previously reported by Siqueira et al. (2012), in which the dark coloring of light mango jelly was associated with the insoluble characteristic of this pectin, resulting in its incomplete dissolution and, consequently, causing dark marks in the product. In agreement with these data, Licodiedoff et al. (2010) also reported color alterations according to the type of pectin employed in the formulation of pineapple jam.

Despite this, the appearance and color characteristics of F2 jelly obtained good acceptance by the panelists, reaching average scores between 7 (liked regularly) and 8 (liked a lot). These results agree with those reported for the pulp of acerola juice jelly (7.36) about appearance (CAETANO et al., 2012), and for umbu-caja jellies (between 7 and 8) for appearance and color attributes (OLIVEIRA et al., 2013).

Concerning the flavor, the difference between the two jelly formulations, despite significant, corresponded to only 7.9%, and it is probably associated with the compounds, such as aromatics, carried out with the pectin from the pequi peel to the jelly. For both maracuja-do-mato jellies, the average scores were between 7 (liked regularly) and 8 (liked a lot).
Similar scores were reported for this attribute in passion fruit jelly with carrots (7.5) studied by Gomes et al. (2013), as well as in pulp and peel passion fruit jellies (7.62 and 7.94, respectively) reported by Amaral et al. (2012). Therefore, maracuja-do-mato jellies can also be considered well accepted concerning this attribute.

For the aroma attribute, there was no statistical difference between the two jellies, and scores between 7 (liked regularly) and 8 (liked a lot) were found for both formulations. In light mango jelly made with pectin of pequi peel, Siqueira et al. (2012) also found average scores for aroma between 7 and 8 for the product elaborated.

Regarding the texture, both maracuja-do-mato jellies showed good gel formation, obtaining scores between 7 (liked regularly) and 8 (liked a lot). These results agree with those found for the texture attribute in jambolana jelly (7.0) (LAGO, GOMES e SILVA, 2006) and different formulations of blackberry with acerola jellies (6 to 7) (SANTOS et al 2009). Therefore, texture and the other attributes, as well as the physicochemical characteristics and composition of the jellies, together have a great influence on the acceptability of a product by consumers.

In this context, the Acceptability Index (A.I.) is considered an important indicator of the acceptance of a product, in terms of its sensorial properties. Thus, A.I. values of at least 70% are considered necessary to a product be considered with good acceptance (TEIXEIRA; MEINERT; BARBETTA, 1987). In Table 2 are shown the A.I. of the sensorial attributes and overall impression of the two maracuja-do-mato jellies.

Table 2. Acceptability index (%) of maracuja-do-mato jellies made with commercial pectin (F1) and pectin extracted from pequi peel (F2).

<table>
<thead>
<tr>
<th>Attribute</th>
<th>F1 (%)</th>
<th>F2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>87.8</td>
<td>82.9</td>
</tr>
<tr>
<td>Aroma</td>
<td>80.4</td>
<td>76.2</td>
</tr>
<tr>
<td>Color</td>
<td>89.1</td>
<td>84.0</td>
</tr>
<tr>
<td>Flavor</td>
<td>87.3</td>
<td>80.4</td>
</tr>
<tr>
<td>Texture</td>
<td>84.7</td>
<td>81.6</td>
</tr>
<tr>
<td>Overall impression</td>
<td>87.8</td>
<td>83.3</td>
</tr>
</tbody>
</table>

As shown in Table 2, all the sensorial attributes of maracuja-do-mato jellies presented A.I. values higher than 70%, in which only the aroma for the F2 jelly showed A.I. below 80%. Therefore, these results allow us to suggest the possibility of commercial insertion of maracuja-do-mato jelly produced with pectin from the pequi peel. In agreement with the results found in the present study, A.I. varying from 74.1 to 86.6% were verified in peppermint jelly produced with pectin from the pequi peel (LIMA et al., 2017), while A.I. varying between 80 and 97% were found in jellies of guava with passion fruit (ZOTARELLI; ZANATTA; CLEMENTE, 2008). In both studies, the developed jellies were also well accepted.
Following the same tendency observed for the specific sensorial attributes evaluated, the A.I. for the overall impression for both jellies were below 80%, indicating good acceptance of both maracuja-do-mato jellies by the panelists. In the overall impression, no panelists gave the scores 1 (dislike extremely), 2 (dislike a lot), or 3 (dislike regularly) for any of the maracuja-do-mato jellies. Also, score 9 (like extremely) was attributed by 32 and 30% of the panelists for the F2 and F1 jelly, respectively. In pepper with pineapple jellies, the percentage of score 9 was only 24% (ARAÚJO et al., 2012). Therefore, these results reinforce the good acceptance of the maracuja-do-mato jelly produced with pectin from pequi peel.

**Purchase intention test**

The sensorial analysis is an important and effective means to better understand the consumer’s opinion and its intention to buy concerning a new product. In this sense, assess the purchase intention of a product by panelists brings important information about this issue (MINIM, 2018).

According to the purchase intention test, the highest frequency of scores attributed by the panelists for the F2 jelly was 4 (probably would buy) and 5 (certainly would buy). It means that 61.2%, considering the sum of these two categories, have a strong intention to buy the formulation from sample F2. Similar results were reported for Japanese quince jelly (66%) (PEREIRA et al., 2011) and araça-boi jellies (74%), also indicating the high intention of panelists to buy the products (VIANA et al., 2012). Besides that, it is also important to highlight that no panelists gave the scores 1 (certainly would not by) or 2 (probably would not by) for the F2 jelly, while 2% of the panelists attributed the score 1 for the F1 jelly.

**CONCLUSION**

In this study, the yield (29.9%) as well as the degree of esterification of the pectin (36.3%) obtained from the pequi peel were satisfactory in the established extraction conditions (8% citric acid, 74 °C, and 60 min). Regarding the sensorial analysis, maracuja-do-mato jelly with pequi peel pectin has great consumption potential, since all sensory quality attributes evaluated presented acceptability indexes above 70%, which is considered a good indicator of acceptance in the consumer market. Thus, the extraction of pectin from the pequi peel is a way of using this co-product, being an alternative to avoid environmental pollution resulting from disposal in an inappropriate place.
REFERÊNCIAS


