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Summary

Brazil is one of the world's largest producers and consumers of yellow passion fruit and the wastes from this juice processing industry are still subvalued. The rinds, which comprise much of this waste, could be used as an alternative raw material for extracting pectin. The purpose of this work was to characterize the yellow passion fruit's rinds as well as the extracted pectin. The pericarp was separated into three fractions and characterized. The specific analysis of pectin content (soft conditions of extraction) included yield, viscosity, degree of esterification, phenolic compounds and high performance size exclusion chromatography (HPSEC) profile. The most abundant component of pericarp was total dietary fibre (65%) and the exocarp fraction showed appreciable xylose content (123 $mg \cdot g^{-1}$). The highest content of pectin isolates (13.6%) of high esterification (79%) with highest viscosity (3.41 $dl \cdot g^{-1}$) was found in the mesocarp fraction, the lowest retention to the phenolic content of isolated pectin (15%) compared to the prepared flour prior to pectin extraction, and the HPSEC profile suggests the presence of a single population of polymers with high molar mass. This paper confirms the potential of Brazilian yellow passion fruit rinds as a raw material for the industrial pectin extraction.

Keywords

passion fruit; waste; physicochemical characterization; pectin analysis; industrial extraction

The significant growth in the food and agricultural industries generates an increase in waste production. For example, the fruit juice industry produces a large amount of waste, which may cause potential problems at final disposal and is usually used as a component of animal feed [1]. However, the dietary fibre content of such waste makes it possible to develop new natural ingredients for the food industry [2].

Brazil is the world's largest producer of passion fruit. Brazil is both the world's largest grower and consumer of fresh and processed passion fruit, accounting for 50–60% of the total world production. Brazil was importing passion fruit juice concentrate in order to satisfy increasing local demand [3]. According to Brazilian Institute of Geography and Statistics, the fruit production between 2001 and 2005 was approximately 480 Mt per year and in 2008 was 648 Mt [4]. Since large quantities (tons) of by-products are generated during processing, it is of economic, scientific and technological interest to find use for them [5].

There are nine categories of fruit/vegetable types, and the passion fruit is classified as an amorphous fruit, with little firm flesh structure under the skin, putting it in the same category as naranjilla, guava and soursop [6]. Similarly to citrus fruit, the pericarp (rind or peel) of passion fruit is divided into the exocarp (or flavedo) and mesocarp (or albedo). The inner boundary around the seeds is the endocarp [7]. Pericarp and seeds are separated during passion fruit processing in

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Tab. 1. Approximate analysis of passion fruit rinds.

Analysis	Peel without exocarp [8]	Peel with exocarp [9]	Peel without exocarp [9]	Rind flour [10]
Protein [g kg^{-1}]	40.5 ± 6.1	51.5 ± 2.3	55.9 ± 1.8	76.3 ± 1.4
Fat [g kg^{-1}]	< 0.1	5.7 ± 0.5	4.7 ± 0.3	6.0 ± 0.7
Dietary total fibre [g kg^{-1}]	572.5*	648.0 ± 19.9	516.6 ± 0.7	641.1 ± 0.6
Ash [g kg^{-1}]	75.2 ± 0.2	33.6 ± 2.4	28.8 ± 3.0	61.7 ± 0.3
Pectin extracted [g kg^{-1}]	n. d.	n. d.	156–401**	n. d.
Saccharides [g kg^{-1}]	212.8 ± 4.4	261.2 ± 20.5	516.6 ± 0.7	788.6***
Moisture [%]	99.3 ± 1.2	46.0 ± 6.0	43.1 ± 1.5	67.4 ± 0.6

The values are expressed as mean ± standard deviation.
n. d. – not determined, * – sum of soluble fibre and insoluble fibre, ** – diverse conditions of extraction with nitric acid by optimization of the process, *** – by difference include dietary fibre.

order to extract the juice. The approximate composition of passion fruit rind and albedo as found in the literature are shown in Tab. 1.

Pectic substances are heterogeneous complex polysaccharides, consisting mainly of α-D-galactopyranosyluronic acid residues, organized on a linear backbone with associated neutral monosaccharides in the lateral chains [11]. Pectin is a high value functional food ingredient widely used as a stabilizer and gelling agent in the food industry. The properties of pectin have been known for nearly 200 years, but there has been recent progress in the understanding of the complex fine structure of pectic polymers [12]. In Europe, apple pomace generated during juice production has been used as a source of pectin and other insoluble products such as sweeteners, edible fibres, ethanol, or fuel production over several decades [13]. Studies have reported on the extraction of pectin using different extraction conditions from conventional sources like sugar beet, citrus and apple [14–17], but also from alternative raw materials [18–24]. The pericarp of *Passiflora edulis* was found to be of satisfactory quality as a pectin source, as demonstrated in experimental studies of jelly production [25]. Passion fruit pericarp appears to be good raw material for pectin production under different conditions of extraction, which influence the yield and quality of the final product [8, 26–31]. Most of these works, however, are aimed at passion fruit rind pectin from Ivory Coast [26, 28–30]. There is an evolution of analysis concerning the extraction, nature and application of pectin from passion fruit in that country. The rind pectic substances were fractionated with water, ammonium oxalate and dilute acid solutions to obtain a naturally low-methoxyl pectin [26]. The cell wall material, obtained from yellow passion fruit rinds, is a potential insoluble fibre source [28] and the non-starchy polysaccharides were the predominant components [29]. Acid type and concentration used for pectin extraction affected the molecular characteristics of pectin [30]. These works showed that the yellow passion fruit rind is as an alternative industrial pectin source to apple pomace or citrus peel.

The raw material used for the production of pectin on an industrial scale in Brazil is citrus pomace, in the only pectin producer in Latin America, the largest supplier in the world, having costumers in about 100 countries [32]. The main industrial processing to obtain pectin is done in mild acid and heat conditions that were applied to pectin extraction from Brazilian raw material. The goal of this study was the characterization of the physicochemical composition of the pericarp and its fractions as well as the extracted pectin to establish a regional extraction protocol and to identify alternatives for the final use of these agricultural wastes and food industry by-products.

MATERIALS AND METHODS

The pectin production and analysis were carried out in laboratories of three Universities and one Institute of Research (Universidade Tecnológica Federal do Paraná – UTFPR and Universidade Estadual de Ponta Grossa – UEPG, Ponta Grossa, Brazil; Universidade Federal do Paraná – UFPR, Curitiba, Brazil and Institute National de la Recherche Agronomique – INRA, Avignon, France). The fruits of *Passiflora edulis flavicarpa* were obtained from commercial producers in Brazil, during the 2006 harvest (2006–2007 marketing year), and were mature and undamaged.

Raw material

About 30 kg of yellow passion fruit was selected; green or senescent fruits were discarded to have a homogenous raw material. The fruit was washed in water and pulp was manually removed. The pericarp was separated into three fractions: exocarp, mesocarp and endocarp. A part of the pericarp (about 30%) was not fractionated, but was used for analytical comparison instead. The thermal inactivation (denaturation) of enzymes was done by heating in boiling water (97 °C) for 3 min, followed by cooling in an ice bath. The fresh material was put in cheese-cloth bags, centrifuged in centrifuge Arno model Classic (Arno, São Paulo, Brazil) with centrifugal force of 2560 × *g* to decant water, and dried at 60 °C in a ventilated oven for approximately 18 h. Dried pericarp and pericarp fractions were then ground using a hammer mill. For the purpose of molecular profile and characteristics comparison, pectin extraction was carried out in an industrial sample of rind flour of *Passiflora edulis*, a gift from the flour waste production industry of União da Vitória (Paraná, Brazil). The flour of passion fruit wastes was finely ground and passed through a 250 μm size screen sieve. The dried flour was packaged and stored at room temperature.

Physical analysis

Several randomly chosen fresh fruits were first weighed whole. The fruit pulp was then removed and the weight of each fraction (exocarp, mesocarp, endocarp and seeds) was determined to establish relative percentage of each component.

The colour of the fruits was evaluated by looking at relative colour attributes measured by the CIELAB method, which measures luminosity (L^*) and chromatic coordinates (a^* and b^*) using Kodak Easy Share C743 Zoom Digital camera (Eastman Kodak, New York, New York, USA) to acquire the images, and Corel X4 (Corel, Ottawa, Canada) software to treat them [33].

Raw material analysis

Moisture content was determined by drying of the product until constant weight [34]. All the compositions are given on a moisture-free basis. Ash [35], fat [36], proteins [37] and total dietary fibre [38] were determined according to Association of Official Analytical Chemists (AOAC) – official methods. Total polyphenol content was estimated by the modified Folin-Ciocalteu method [39]. Flour of the raw material aliquots (1 g) was diluted in 50 ml of a solution 1 : 4/ v/v of water: ethanol 78.5%. The suspension was incubated at –18 °C for 24 h, then was centrifuged at 10 000 × *g* for 20 min and the supernatant was collected to be used as sample.

In pectin isolates, the sample was obtained by 100 mg of raw material dilution in 1 ml of distilled water. The Folin-Ciocalteu method employed in this study to measure total phenolic compounds consisted of adding 0.1 ml of the supernatant to 8.4 ml of distilled water and 0.5 ml of the Folin-Ciocalteu reagent. After 3 min, 1 ml of aqueous saturated sodium carbonate was added. The resulting solution was left to settle for 60 min. Absorbance of the supernatant was measured at 720 nm in a spectrophotometer (UV-VIS Q798UV-DB, Quimis Aparelhos Científicos, Diadema, Brazil). Absorption measurements were reported as catechin. The percentage of the isolated pectin in the phenolic content was calculated as the ratio between the phenolic content of the isolated pectin and the phenolic content in the prepared flour prior to pectin extraction (in %).

Contents of available carbohydrates were calculated by subtracting all previously mentioned components from the total (100 – ash – fat – protein – total dietary fibre). The energy values of pericarp were calculated by using general energy conversion factors recommended for this substance [40]: protein and available carbohydrate – 17 kJ·g^{-1}, dietary fat – 17 kJ·g^{-1} and dietary fibre – 8 kJ·g^{-1}.

The galacturonic acid (GalA) was determined by a meta-hydroxyl-diphenyl assay in 0.5 ml of sample [41] obtained by 8–12 mg of raw material dilution in 250 μl of 72% sulfuric acid under intense stirring (each 15 min at 20 °C). Then, the volume was adjusted to 3 ml with water (MilliQ system, Millipore, Billerica, Massachusetts, USA) and the acid hydrolysis of the material was carried out for 3 h at 100 °C (Saeman hydrolysis). Neutral saccharides were measured as alditol acetates after hydrolysis in 1 ml of 2 mol·l^{-1} sulfuric acid (3 h, 100 °C) with inositol as an internal standard [42]. They were injected to a GC-FID HP 5890 Series II (Agilent, Palo Alto, California, USA) with a capillary column of 30 m × 0.25 mm i.d. coated with DB225 MS, having a 0.25 μm film thickness (J&W Scientific, Agilent). The separation was carried out isothermically at 215 °C [43].

Pectin isolation

The extraction of pectins from the flour of passion fruit wastes was carried out according to the methods described by FERTONANI et al. [14] with slight modifications. Approximately 4 g of dried raw material was mixed with diluted nitric acid to a final concentration of 0.05 mol·l^{-1}. The suspension was shaken for 20 min at 80 °C. The resulting

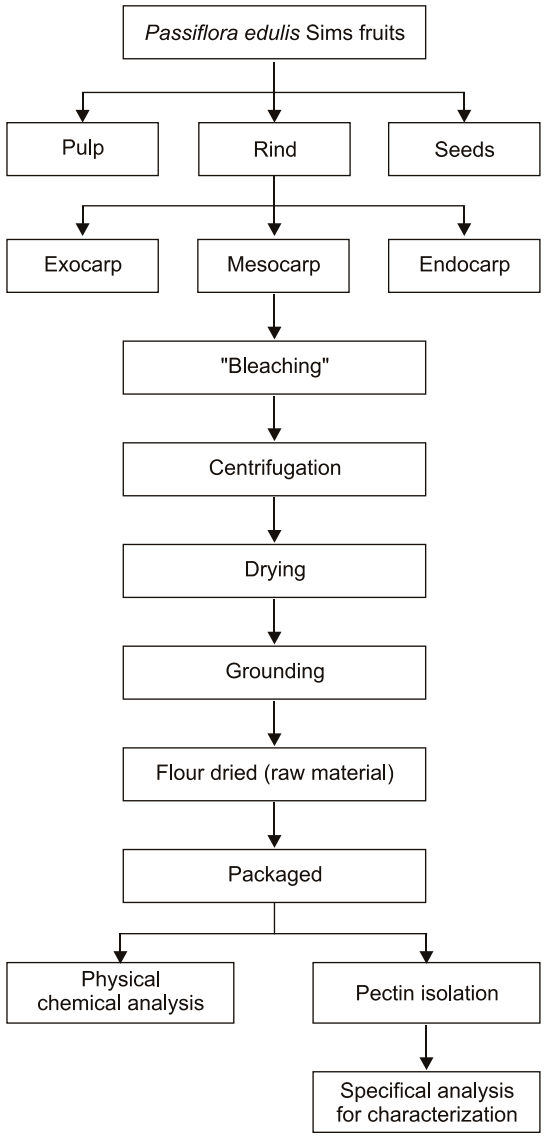

Fig. 1. A scheme of the experiment for the determination of physicochemical composition of the yellow passion fruit rind and characterization of respective pectic substances.

slurries were allowed to cool to refrigerator temperature (4 °C), poured in 2 volumes of 96% ethanol and left at the same temperature for 30 min. The precipitate was washed with 96% ethanol overnight, dried by solvent exchange with acetone, air-dried in a ventilated oven at 45 °C for 24 h, and weighed. Fig. 1 provides a scheme of the processing of yellow passion fruit and its characterization, as well as that of the pectin extracted in this study.

Analyses of pectin isolates

The degree of esterification (DE) was determined by a modified titrimetric procedure [44]. Colloidal dispersions of pectin isolates were prepared by dissolving dried pectins in an aqueous buffer salt solution ($1\,g \cdot l^{-1}$ in freshly prepared 0.09 $mol \cdot l^{-1}$ NaCl, 0.01 $mol \cdot l^{-1}$ NaF, 0.001 $mol \cdot l^{-1}$ Na_2EDTA, pH 6.5). A cellulose acetate membrane (Millipore) with a 0.45 μm cut-off was used to filter the pectin material [26]. Pectin colloidal dispersions were pipetted into a Schott capillary viscosimeter (glass capillary No. 100 Type 51310 Cannon-Fenske, Cannon Instrument, State College, Pennsylvania, USA) equipped with a CT-52 thermostat (Schoot Instruments, Wayzata, Minnesota, USA) operating at (25 ± 1) °C. The flow times were recorded three times with a stopwatch. A table provided by the viscometer manufacturer was used to calculate the reduced viscosity.

High performance size-exclusion chromatography (HPSEC) was carried out with pectin isolates using multidetection equipment with a Waters 2410 differential refractometer (RI) (Waters, Milford, Massachusetts, USA) and an on-line adapted Wyatt Technology Dawn F multi-angle laser light scattering (MALLS) detector (Wyatt Technology, Santa Barbara, California, USA). Four Waters Ultrahydrogel 2000/500/250/120 columns (Waters) were connected in series and coupled to the multidetection equipment. A $0.1\,mol \cdot l^{-1}$ $NaNO_2$ solution containing NaN_3 ($0.5\,g \cdot l^{-1}$) was used as eluent. The samples were previously filtered through a cellulose acetate membrane (0.22 µm; Millipore) and injected at $1.5\,mg \cdot ml^{-1}$. HPSEC data were collected and analysed by a Wyatt Technology ASTRA program (Wyatt Technology).

Statistical analysis

The pectins were isolated from the dried flour at least five times, until the amount of data sufficient for analyses was obtained. Three replicates were taken for each analysis of dried flour and isolated pectin, and the results were expressed as mean ± standard deviation. Analysis of variance (ANOVA) was performed at the $p = 0.05$ significance level to study the variation among samples. The Tukey test was used to determine differences between individual plant materials.

RESULTS AND DISCUSSION

The yellow colour of 90% of the fruit gave values of $L^* = 60.3 \pm 0.5967$, $a^* = 1.3 \pm 1.5275$ and $b^* = 51.0 \pm 7.5498$. The fresh weight of the whole fresh passion fruits and their fractions was determined to calculate the estimated percentage of waste produced during industrial produc-

tion. The size and the weight of the fruit, physical characteristics inherent to the species or cultivars, were estimated, although this attributes present utility for consumer market only, without a significant importance for the industrial production [45]. The relatively high standard deviation calculated indirectly indicated a high heterogeneity of fractions, although there was apparent homogeneity in the fruits' colour. The elimination of the pulp that adhered to the endocarp led to a 3% loss of weight. This fact may explain why, compared to other studies, we saw the lowest percentage of seeds. The seeds dry matter content in this work was 9%. A higher content of exocarp in fresh fruit was obtained in another study [46]. It can be due to the kind of instrument used to strip the pericarp (yellow peel). In this work, the pericarp was approximately 47% of the fresh fruit weight (exocarp = 15%, mesocarp = 27% and endocarp = 6%), similar to those observed by other authors, between 50.3% and 56.4% [5, 25, 46]. The seeds content was 13%, resulting in average waste of 60%. This is lower than the percentage waste generated from passion fruit in another study, which was about 75% [47]. The characterization of waste generated by passion fruit processing industry is the key to increase the value of its products, considering that discarded portion is relatively high, around 50%.

The results obtained by the approximate analysis of the fractions and the whole pericarp in the present study are shown in Tab. 2.

The endocarp fraction showed the highest ash content, as well as the highest protein content (13.1%). Ash values indicate a high mineral content, another possible variable for future studies.

The comparative percentage of pectin isolates under the same conditions of extraction indicated that the highest yield was found in the mesocarp, similar to citrus fruit, where the pectins are in the inner part of the peel, or albedo.

The dietary total fibre remained above 50% in all studies. This high value emphasized the possibility of the rinds' use in development of a functional natural ingredient, and this product could therefore be indicated as partial substitute in

Tab. 2. Approximate composition of passion fruit pericarp and fractions.

Analysis	Exocarp	Mesocarp	Endocarp	Pericarp
Protein [%]	4.3 ± 0.2^{a}	3.1 ± 0.2^{c}	13.1 ± 0.1^{b}	3.7 ± 0.2^{d}
Fat [%]	0.5 ± 0.1^{a}	0.6 ± 0.2^{c}	1.3 ± 0.3^{b}	0.7 ± 0.1^{c}
Ash [%]	6.6 ± 0.3^{a}	7.1 ± 0.6^{c}	9.3 ± 0.4^{b}	7.4 ± 0.1^{c}
Available saccharides [%]*	27.5	23.0	28.5	23.1
Dietary total fibre [%]	61.0 ± 4.0	66.1 ± 0.6	48.0 ± 1.5	65.0 ± 3.2
Moisture [%]	4.5 ± 0.1^{a}	6.1 ± 0.6^{b}	6.0 ± 0.4^{b}	4.3 ± 0.6^{a}
Energy values [kJ·g^{-1}]	11	11	11	10

The values are expressed as mean ± standard deviation. Average values within a column designated with different letters are significantly different at $p = 0.05$ (Tukey test). * – by difference.

Tab. 3. Monosaccharide composition of polysaccharides obtained from the passion fruit pericarp.

Monosaccharide	Exocarp [mg·g^{-1}]	Mesocarp [mg·g^{-1}]	Endocarp [mg·g^{-1}]
Rhamnose	3.7 ± 0.6	3.1 ± 0.4	5.7 ± 0.1
Fucose	2.3 ± 0.1	3.4 ± 0.4	1.4*
Arabinose	23.4 ± 1.8	15.2 ± 2.6	6.6 ± 0.2
Xylose	133.4 ± 7.4	31.8 ± 3.2	15.9 ± 0.5
Mannose	18.1 ± 1.7	32.3 ± 2.7	20.4 ± 1.0
Galactose	23.4 ± 1.9	27.6 ± 4.1	10.8 ± 0.3
Glucose	229.9 ± 18.7	296.5 ± 15.0	238.7 ± 5.6
Cellulosic glucose**	136.0 ± 12.3	116.0 ± 66	180.2 ± 10.5
Anhydrouronic acid	120.4 ± 6.1	210.0 ± 14.4	142.0 ± 3.0
Total monosaccharides	555.2 ± 29.7	620.3 ± 42.2	441.5 ± 10.5

The values are expressed as mean ± standard deviation.
* – standard deviation is less than 0.1, ** – obtained by difference; Saeman hydrolysis-soft hydrolysis.

the diet for body weight reduction. The average energy value of flour passion fruit pericarp was 10 $kJ \cdot g^{-1}$, i.e. lower than usual flours, such as wheat flour and rice supplement flour – 15 $kJ \cdot g^{-1}$ [48] and other dietary fibre such as whole wheat flour – 14 $kJ \cdot g^{-1}$ or potato flour – 12 $kJ \cdot g^{-1}$ [49], but it has a completely different composition. However, for this application the drying process of the industrial wastes must be carried out very carefully, with moisture maintained at a level lower than 10% to avoid fermentation and other modifications such as blackening or burning of the product [50]. The moisture of the pericarp was adjusted for storage, since the ideal moisture content range for residue storage is around 5.3% (wet basis) [51].

The monosaccharide composition of the pericarp and fractions is shown in Tab. 3.

Colorimetric data showed the presence of 210 $mg \cdot g^{-1}$ of uronic acids in mesocarp. By GLC analysis, the exocarp fraction showed appreciable xylose content (133 $mg \cdot g^{-1}$) and arabinose (23 $mg \cdot g^{-1}$). The highest content of cellulosic glucose was found in the endocarp fraction, the internal peel around seeds. The mesocarp fraction showed the highest contents of manose, galactose, galacturonic acid and non-cellulosic glucose, probably formed by starch hydrolysis.

The phenolic compounds of raw material and specific analyses and pectin isolates associated with each fraction (raw material) are shown in Tab. 4.

The DE of the exocarp and endocarp are not important because a lower yield of pectin extraction was obtained from these fractions and their amount in plant of juice processing is relatively small. The pectin extracted from the mesocarp and pericarp had high DE and these data were not significantly different (ANOVA and Tukey test). The DE values were similar to those found by others authors [9, 31, 52]. However, the DE values in pectin from Ivory Coast passion fruit rind [26] were lower, probably due to the diversity of extraction conditions and the raw material (varieties and storage before and after processing).

The highest viscosities were seen in pectin from the mesocarp. The values were similar to 2.54 $dl \cdot g^{-1}$ for a sample of passion fruit pectin extracted with citric acid [9]. The starch was not detected in our pectin samples by Lugol solution, a fast qualitative test, used as an indicator for the presence of starch. Then, this viscosity was only due to pectin and other co-extracted non-starch polysaccharides.

The exocarp fraction was not useful for pectin extraction because it had a low yield and contained almost all phenolic compounds from the raw material. The pectin extracted from the mesocarp showed the lowest concentration of phenolic compounds as compared to that extracted from of the whole rind (pericarp). Presence of phenolic compounds associated with pectins may have many causes: in the *Chenopodiaceae,* feruloyl or coumaroyl acids are ester-linked to pectin's arabinans and galactans [53]; unidentified phenolics have often been reported as cross-linked to the cell walls of cauliflower, asparagus stems and olive seed hulls [54]; finally, some phenolics initially present in the cells may be extracted in the same conditions as pectins and thereafter become associated to pectins [55, 56]. In a previous study [57], such phenolic compounds could be retained by a resin, yielding paler pectins but with lower DE. A further filtration is applied in citric pectin plant producer in Brazil to result in a paler product because the colour of the pectin isolate is an issue of product quality with regard to consumer [58].

The international specifications indicate that the pectin can be a white, yellowish, light greyish or light brownish powder [59]. Future studies must characterize these components and evaluate their

Tab. 4. Phenolic compounds from passion fruit pericarp and quality parameters of the extracted pectin (80 °C, 20 min, 0.05 $mol \cdot l^{-1}$ nitric acid).

Analysis	Fraction			
	Exocarp	Mesocarp	Endocarp	Pericarp
Pectin extracted [$g \cdot kg^{-1}$]	53 ± 6^{a}	130 ± 14^{b}	58 ± 8^{a}	11 ± 16^{b}
Degree of esterification [%]	70.0 ± 1.7^{a}	79.0 ± 0.8^{b}	59.1 ± 0.1^{c}	79.6 ± 0.8^{b}
Reduced viscosity [$dl \cdot g^{-1}$]	2.2^{*a}	3.4^{*b}	n.d.	2.1^{*a}
Phenolic compounds of rinds [$g \cdot kg^{-1}$]	1.7 ± 0.2^{a}	1.3 ± 0.1^{a}	1.3 ± 0.1^{a}	1.5 ± 0.2^{a}
Phenolic compounds of pectin isolates [$g \cdot kg^{-1}$]	1.7^{*a}	0.2^{*b}	0.3^{*c}	0.3^{*c}
Phenolic retention [%]	99.7	15.3	23.0	21.0

The values are expressed as mean ± standard deviation. * – standard deviation is less than 0.1. n.d. – not determined. Averages within a column designated with different letters are significantly different at $p = 0.05$ (Tukey test).

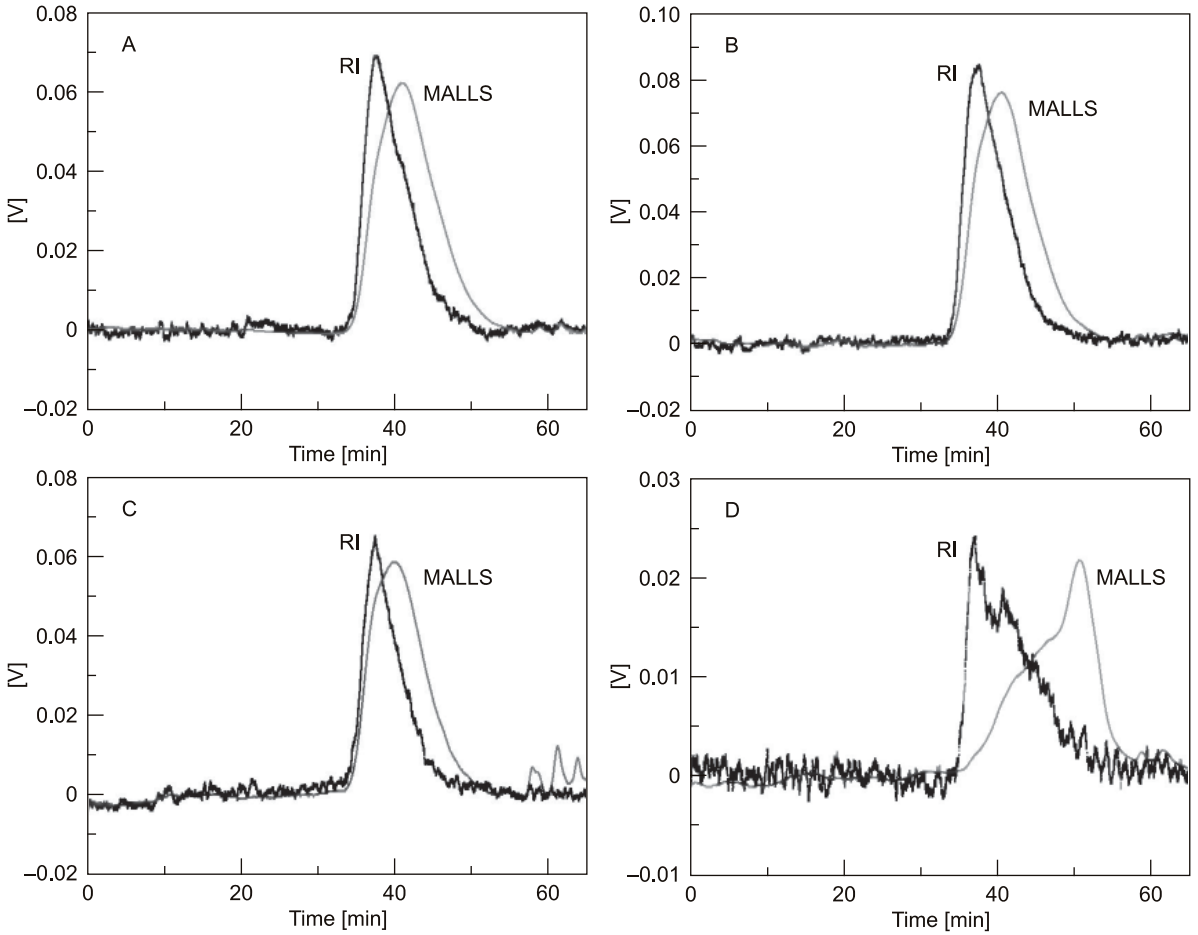

Fig. 2. Chromatographic profile (Four Waters Ultrahydrogel 2000/500/250/120) columns in series of samples of passion fruit pectin extracted by 50 mol·l^{-1} nitric acid, 20 min, 80 °C at 1.5 mg·ml^{-1}.

Raw materials: A – pericarp, B – exocarp, C – mesocarp, D – pericarp industrial sample.

antioxidant capacity, but probably it not detracts from the possible usage of the pectin.

Analysis of the pectin isolate samples by HPSEC using MALLS and RI detectors resulted in the profiles presented in Fig. 2. The presence of only one peak by light scattering overlapping with an RI peak for pectins obtained from the pericarp, exocarp and mesocarp of the fruits suggests the presence of a single population of polymers with high molar masses. These results are similar to those obtained for pectin isolated from passion fruit peel using citric acid [31]. However, the pectin extracted with nitric acid under severe conditions [9] showed a much differentiated profile, confirming the observation that extraction conditions influence the quality of the extracted pectin. The chromatographic profile for the pectin isolated from the industrial raw material showed a polymodal distribution by both detectors (MALLS and RI), indicating the occurrence of a population of polymers with different molar masses. The highest intensity detected by RI did not coincide with the MALLS signal, indicating that the material with high molar mass in this sample was present in low concentrations. The pectin breakdown from processed passion fruit could be due to either the production of enzymes produced by fungi or to the endogenous active enzymes (before drying and without denaturation), if the raw material was stored improperly [60].

The amount of this by-product per year in Brazil could reach 300 000 metric tons, with the potential to produce 2 000 metric tons of pectin. In order to obtain pectin with the highest degree of purity and viscosity, the mesocarp fraction must be utilized. However, if we use industrial extraction, the separation process includes additional steps, increasing both the cost and duration of the process.

CONCLUSIONS

Dietary total fibre was the major component in fractions of passion fruit pericarp (48–66%). The results found in this study for the percentage of passion fruit solid waste residues (average of 60%) emphasized the urgent necessity of waste management, promoting its minimization, and increasing the economic and environmental value of these by-products. The mesocarp contained the lowest phenolic compound concentration. The average amount of total neutral monosaccharides in this fraction was 555 $mg \cdot g^{-1}$ and the main monosaccharides were rhamnose, fucose, arabinose, xylose, mannose, galactose and glucose, with averages of 4, 2, 23, 133, 18, 23 and 230 $mg \cdot g^{-1}$, respectively. The galacturonic acid content was 120 $mg \cdot g^{-1}$.

Pectin was extracted at 80 °C for 20 min with diluted nitric acid to a final concentration of 0.05 $mol \cdot l^{-1}$ (solute/solvent 1 : 50 w/v) from passion fruit pectin fractions rind. Pectin with the highest reduced viscosity (3.4 $dl \cdot g^{-1}$) and with a high molecular mass was extracted from mesocarp fraction, with viscosity suitable for application as stabilizer and thickener. The extraction yield was 130 $g.kg^{-1}$ of a pectin with high methoxylation (DE = 79%). The gelling properties of mesocarp pectin will be reported in a future publication.

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