Dietary Fiber Content of Pear and Kiwi Pomaces

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Pear and kiwi pomaces, edible byproducts from single-pass metallic membrane ultrafiltration of pear and kiwi purees, were studied for composition and utilization as sources of sugar and dietary fiber in food technology. This paper describes the total (TDF), soluble (SDF), and insoluble (IDF) dietary fiber content of pear and kiwi pomaces determined according to the AOAC gravimetric method. In addition, fiber values were determined by measuring the levels of the composite sugars by colorimetric and GLC methods and Klason lignin. On a dry weight basis, the TDF content of pear pomace was 43.9%, while that of kiwi pomace was 25.8%. In both pomaces, the SDF was pectic in origin and contributed approximately 7% dry weight, while IDF measured 36.3% in pear and 18.7% in kiwi. Lignin content, estimated gravimetrically, was 5.2% and 3.2% dry weight for pear and kiwi pomaces, respectively. Protopectins and high methoxyl pectins were the main type of pectic substances for IDF and SDF, respectively, in both pomaces.

Keywords: *Dietary fiber; pear; kiwi; pomaces; neutral sugars; uronic acids; Klason lignin*

INTRODUCTION

The availability of high quality foods with dietary fiber (DF) contents is of key importance for obtaining changes in fiber intakes according to general dietary recommendations for adults in Western societies. Dietary fiber has important therapeutic implications for certain conditions, such as diabetes and hyperlipidemia (Anderson et al., 1984), and may have preventive implications for others, such as hypertension, coronary disease, and intestinal disorders (Anderson, 1983; Jenkins et al., 1986).

Since each dietary fiber component exerts a different physiological effect, it is important to obtain data on both the total dietary fiber content and its profile (Costa et al., 1989; Hoagland, 1989). According to Asp (1990), the physiological effects of dietary fiber polysaccharides are related not only to the properties of the fiber polysaccharides but also to structural features of the plant cell wall.

Recently, new high fiber food products and ingredients have been developed by some food industries. Usually, cereals are the basis for these products. Presently, cereals contribute 35–60% to the present total DF intake in northern European countries, while the corresponding percentage from fruits is only 7–15% (Bingham, 1987). In view of the different properties and compositions of cereal fibers as compared with fruit and vegetable fibers, it would be interesting to find new sources from fruits for high DF products.

Pear and kiwi pomaces are the primary byproducts of the pear and kiwi juice industries. A conventional pear and kiwi juice process will remove about 80–85% of the fresh weight of the fruits. The increasing disposal of these wastes is rapidly becoming more difficult to solve. The use of these pomaces as an animal feed has been a conventional approach. Pear and kiwi pomaces may also be used for extraction of pectin such as apple, citrus pomaces (Jain et al., 1984), and other hydrocolloids (Walter et al., 1986) and to fertilize damaged soils (Stapleton, 1982). Recently some authors have demonstrated that fruit pomace, which has a high moisture and sugar content, can be fermented to citric acid or alcohol (Hang, 1987). Fruit fiber has also been incorporated into bakery products (Deuel, 1986).

The chemical constitution of the pomace is important in the determination of its potential for byproduct utilization. In view of the importance of fiber in food, there is much interest in the soluble and insoluble DF content of plant foods. To meet this requirement, various groups in Europe and the United States have developed methods for DF analysis. Although the AOAC procedure of Prosky et al. (1988) can be used for obtaining DF content of plant foods (essentially) by a gravimetric method, the actual fiber content of the residues based on the carbohydrate analysis has seldom been quantified. In this paper, we report the DF content of pear and kiwi pomaces obtained according to the AOAC procedure, and we have subsequently determined the Klason lignin and nonstarch polysaccharide content of the residues to assess the suitability of the fiber-rich pear and kiwi waste material as alternative sources of dietary fiber. This work has also allowed comparison of different methods of fiber analysis.

MATERIALS AND METHODS

Preparation of Samples for Analysis. Pear and kiwi pomace concentrates and pear and kiwi juices were obtained from single-pass, tubular metallic membrane ultrafiltration which was similar to that described by Thomas et al. (1986). Juice yields were 85%; no filtration aids were employed. Since the entire fruits were comminuted to a puree before filtration, the pomaces consisted of the entire insoluble portions of the fruits, including seeds, skins, and cores. Once the pomaces were obtained, they were immediately dried at 60 °C to constant weight, with yields of 30–35% of dry matter, and were ground in a Cyclone mill (Tecator, Inc., Boulder, CO). Finally, the dried residues were conveniently stored in a desiccator. In preparation for analysis, the above residues

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were extracted with 80% ethanol (1:100 w/v) with sonication to extract simple sugars. The extractive free residues were recovered and dried under vacuum with P_2O_5 at ≤40 °C for ≥4 h.

Dietary Fiber Analysis. The method was based on the enzymatic removal of starch and protein from the material and separation into soluble and insoluble fractions by filtration. The experimental procedure described by Prosky et al. (1988) was followed. Fiber Sigma kits with heat-stable amylase, protease, and amyloglucosidase (Sigma Chemical Co., St. Louis, MO) were used. One gram of sample was successively treated with a heat-stable α-amylase (100 °C, pH 6, 30 min), protease (60 °C, pH 7.5, 30 min), and amyloglucosidase (60 °C, pH 4.5, 30 min). The suspension was filtered and washed with distilled water, 95% ethanol, and acetone to give the insoluble residue material (IRM). From the filtrate after precipitation with alcohol was obtained the soluble polymeric material (SPM). These residues were corrected for (i) undigested protein, by determining the nitrogen content according to the Kjeldahl procedure and multiplying by a factor of 6.25, and (ii) minerals, by determining the ash content after incineration in a muffle furnace at 525 °C for 8 h.

Chemical Analysis. The IRM fractions were dispersed in 72% H_2SO_4 for 3 h at room temperature followed by dilution to 1 M and hydrolyzing for 2.5 h at 100 °C (Saeman hydrolysis). The insoluble material from hydrolysis was determined gravimetrically as Klason lignin, and suitable aliquots were taken from the hydrolysate to determine sugar and uronic acid content. The composition of insoluble dietary fiber (IDF) content was determined as the sum of total neutral sugars from 72% H_2SO_4 hydrolysis, uronic acid, and Klason lignin. Cellulose content was estimated from the difference in the value of glucose released by 72% and 1 M sulfuric acid hydrolysates.

The SPM fractions were hydrolyzed using 1 M H_2SO_4 for 2.5 h at 100 °C, and neutral sugars and uronic acids were determined. Soluble dietary fiber (SDF) was calculated as the sum of the above components. Total dietary fiber (TDF), by gravimetric and chemical procedures, was expressed as the sum of SDF and IDF fractions.

Neutral Sugars Composition. The IRM and SPM hydrolysates were analyzed for sugar composition by both colorimetric and GLC methods. The total neutral sugar content of the fractions was colorimetrically determined according to the Bittner and Manning (1967) automated method, using neocuproine as the coloring reagent in a Technicon Autoanalyser II.

In addition, the detailed neutral sugar composition of IRM and SPM fractions was determined by GLC. The liberated sugars were reduced with $NaBH_4$ and acetylated according to the method of Harris et al. (1988) using 2-deoxyglucose as an internal standard. Alditol acetates were quantified by gas chromatography on a Carlo Erba Vega gas chromatograph (Fisons Scientific Instruments, Leics, U.K.) after automatic injection by a Carlo Erba A 200 autoinjector. Alditol acetates were separated with baseline resolution on a Restek RT_x 225 WCOT column (15 m × 0.32 mm i.d.; 0.25 μm film) using an oven temperature program of 90 °C for 1 min, 45 °C/min to 150 °C, 150 °C for 1 min, 2 °C/min to 210 °C, and 210 °C for 1.5 min. The carrier gas was helium at a column head pressure of 60 kPa. Detection was by flame ionization. Data were collected and integrated on a Spectra-Physics SP4400 integrator; re-integration was handled by a Spectraphysics Winner data handling station. Corrections for losses and response factors for all sugars were also applied.

Uronic Acid Content. The uronic acid content was determined as described by Esteban et al. (1993). The automated method was performed by a colorimetric assay at 520 nm using *m*-hydroxydiphenyl as the coloring agent in a Technicon Autoanalyser II.

Klason Lignin. Klason lignin content was obtained from the weight of residue left after hydrolysis with 72% H_2SO_4 for 3 h at 20 °C, followed by dilution to 1 M acid and heating at 100 °C for 2.5 h. The insoluble residue was recovered quantitatively over a glass filter (Pyrex No. 2), washed thoroughly with water, and then dried for 18 h at 105 °C.

Table 1. Gravimetric Composition of Insoluble Residue Material (IRM), Soluble Polymeric Material (SPM), and Total Polymeric Material (TPM) of Pear and Kiwi Pomaces and Corrected Values for Dietary Fiber Expressed as Percent of Dry Matter

	gravimetric residue	protein	ash	fiber[a]
pear pomace				
IRM	38.1 ± 0.1	1.6 ± 0.1	0.2 ± 0.0	36.3 ± 1.4 (IDF)
SPM	15.0 ± 1.0	2.2 ± 0.1	5.2 ± 0.9	7.6 ± 1.3 (SDF)
TPM	53.1	3.8	5.4	43.9 (TDF)
kiwi pomace				
IRM	23.4 ± 0.8	3.5 ± 0.1	1.2 ± 0.1	18.7 ± 1.3 (IDF)
SPM	14.0 ± 1.3	1.9 ± 0.1	5.0 ± 0.7	7.1 ± 1.1 (SDF)
TPM	37.4	5.4	6.2	25.8 (TDF)

[a] Fiber content by difference.

Fractionation of Pectic Substances. The pectic substances were solubilized from the IRM and SPM preparations by sequential extraction with cold water, cold ammonium oxalate, and cold alkali, as described by Robertson (1979). The first two steps are supposed to solubilize high methoxy and low methoxy pectic polysaccharides, respectively, and the alkali is supposed to solubilize the residual protopectin. The residue (1 g of IRM or SPM) was dispersed in 5 mL of distilled water and then treated with 35 mL of distilled water and the solution stirred vigorously for 10 min by bubbling air through it. The suspension was centrifuged at 1000*g* for 15 min and the supernatant decanted into a 50 mL volumetric flask. Sodium hydroxide (1 N, 1.25 mL) was added and the water extract made up to volume, mixed, and allowed to stand for 15 min before the colorimetric procedure was begun. The residue in the centrifuge tube was treated with 40 mL of 0.75% ammonium oxalate and the procedure repeated as for extraction with water. The residue remaining after two oxalate extractions was dispersed in 50 mL of 1 N sodium hydroxide and, after mixing for 15 min with occasional shaking, was filtered through Whatman No. 1 paper. Suitable aliquots were taken from all three extracts for the determination of uronic acid according to the colorimetric method.

RESULTS AND DISCUSSION

The results of these investigations consist of the mean of assays perfomed on five different samples. The soluble sugar contents of the pear and kiwi pomaces were 49.5% and 57.7%, respectively, on a dry weight basis, and these sugars were removed during the preparation of IRM and SPM. Table 1 shows the composition of the IRM and SPM preparations from pear and kiwi pomaces, the protein and ash contents, and the corrected values for insoluble dietary fiber (IDF), soluble dietary fiber (SDF), and total dietary fiber (TDF). The soluble fiber contents of both pomaces are comparable and are approximately 7%, but the IDF content of the pear pomace (36.3%) is almost twice that of the kiwi pomace (18.7%) and this is reflected in the much higher content of TDF in pear. The marked difference in the IDF content can be inferred to be due to the presence of significant amounts of stone cells (sclereids) in the pear pomace.

The ash content of the SPM is very much higher than that of the IRM, and this is probably due to the presence of coprecipitated salts (e.g. phosphates) in the SPM. There is little doubt that a proportion of the buffer phosphates would coprecipitate with the SPM on treatment of the filtrate with alcohol (Ravindran and Palmer, 1990).

Table 2 shows the Klason lignin, neutral sugar, and uronic acid contents of the IRM and SPM samples from the pomaces and the corresponding DF values. It should be noted that the total neutral sugar content was

Table 2. Chemical Composition of Insoluble Residue Material (IRM), Soluble Polymeric Material (SPM), and Total Polymeric Material (TPM) of Pear and Kiwi Pomaces and Values for Dietary Fiber by Colorimetric Sugar Analysis Expressed as Percent of Dry Matter

	Klason lignin	sugars	uronic acids	fiber[a]
pear pomace				
IRM	5.2 ± 0.3	19.8 ± 0.4	2.6 ± 0.3	27.6 ± 1.6 (IDF)
SPM		2.1 ± 0.1	5.2 ± 0.2	7.3 ± 0.3 (SDF)
TPM	5.2	21.9	7.8	34.9 (TDF)
kiwi pomace				
IRM	3.2 ± 0.2	8.3 ± 0.2	1.5 ± 0.1	13.0 ± 0.8 (IDF)
SPM		1.7 ± 0.0	5.4 ± 0.2	7.1 ± 0.2 (SDF)
TPM	3.2	10	6.9	20.1 (TDF)

[a] Fiber content as sum of components.

obtained by colorimetric assay using glucose as the standard, which would underestimate the pentoses, particularly xylose. The Klason lignin content of the IRM from pear pomace (5.2%) was much higher than that of kiwi pomace (3.2%) and could be attributed to the presence of much lignin and stone cells in the former. However, Klason lignin may give an overestimate of the true lignin content because it will also include other components such as residual tannins, residual phenolics, and their condensation products (Theander and Aman, 1979; Rebolé et al., 1989).

The neutral sugar and uronic acid components of pear pomace IRM are higher than those obtained from kiwi. Furthermore, the ratio of neutral sugars to uronic acids is greater in pear pomace (7.6) compared with kiwi (5.5). This would indicate a lower proportion of pectic substances in the former. The SPM of both pear and kiwi pomaces exhibited much lower neutral sugar/uronic acid ratios (0.4 and 0.3, respectively) as compared with IRM. From this, the main constituents can be inferred to be the pectic polysaccharides.

Interestingly, the soluble fiber values of both pear (7.3%) and kiwi pomace (7.1%), obtained by chemical analysis, are highly comparable with the corresponding values obtained by "gravimetric" method (Table 1). This could be due to the high uronic acid content and relatively low levels of pentoses of the SPM since xylose is underestimated when glucose is used as the standard in the colorimetric assays. However, the insoluble fiber values of both pear (27.6%) and kiwi pomaces (13.0%) obtained by chemical analysis are much lower than the corresponding gravimetric values. This is probably due to (i) the higher levels of pentoses (particularly xylose) in the IRM and (ii) relatively lower levels of uronic acid and (iii) acid-soluble lignin which were not accounted for. These results show clearly that care must be exercised in the interpretation of the results of DF analysis when the values for neutral sugars are obtained by colorimetric methods.

The sugar compositions of the IRM and SPM from pear and kiwi pomaces are shown in Table 3. In the case of pear pomace, carbohydrate accounted for 28.3% of the dry weight of the IRM and 7.4% of the dry weight of the SPM, so that the value for TPM is 35.6%. The main sugars in the SPM in increasing order are rhamnose, glucose, xylose, galactose, arabinose, and uronic acid. Most (if not all) of these sugars are of pectic origin. In the case of the IRM, the value for IDF is appreciably more than that obtained by the colorimetric method. All of the sugars with the exception of glucose are quantitatively released by both 1 M H_2SO_4 and Saeman hydrolysis conditions. The carbohydrate content was rich in xylose and glucose which, together, composed approximately 80% of the total carbohydrate. Although most of the xylose can be inferred to arise from the stone cells of the pulp, most of the other sugars (including the glucose released by 1 M H_2SO_4 hydrolysis) would have arisen from the pectic polysaccharides or hemicelluloses, such as xyloglucans. The fact that the bulk of the glucose (93%) can only be released by Saeman hydrolysis shows that it is derived from cellulose. A significant proportion of this cellulose would be associated with the stone cells (sclereids), although some would have arisen from the parenchyma cell walls (Martín-Cabrejas, 1993). A point to note here is that the stone cells of the pulp, which are rich in glucuronoxylans, cellulose, and lignin, are the major contributors to the DF content of the pulp. Although other plant foods such as runner bean pods and asparagus stems (Selvendran and King, 1989; Waldron and Selvendran, 1992) have the potential to lignify after a certain stage of growth, these vegetables, unlike pear fruit, are not palatable after vascularization and supporting tissues have lignified because they become very tough. In the case of pear fruit, the stone cells are not "fibrous", unlike the parchment fiber of mature runner bean pods. However, these sclereids can make a significant contribution to the fiber content of the pomace. The lignified sclereids are not readily degraded by colonic bacteria, and the possible nutritional significance of this product as a potential fiber source is well worth investigating.

With regard to kiwi pomace, the carbohydrate content is considerably less than in pear (43.8% of decrease on pear pomace). The main sugars in the SPM in increasing order are rhamnose, glucose, arabinose, galactose, and uronic acid. Most of the soluble fiber is derived from pectic polysaccharides because these components come from pectic side chains (Brett and Waldron, 1990). The bulk of the insoluble fiber can be inferred to have arisen from cellulose, pectic polysaccharides, and hemicelluloses such as glucuronoxylans and xyloglucans. The presence of small but significant amounts of glucuronoxylans in the IRM can be inferred from the content of xylose released on 1 M H_2SO_4 hydrolysis, which is severalfold more than the amount of glucose released in the same conditions. The amount of glucose released from xyloglucans is usually more than the amount of

Table 3. Monosaccharide Composition in Insoluble Residue Material (IRM) and Soluble Polymeric Material (SPM) of Pear and Kiwi Pomaces Expressed as Percent of Dry Matter

		composition of sugars								
	hydrolysis	Rha	Fuc	Ara	Xyl	Man	Gal	Glc	uronic acid	total
pear pomace										
IRM	Saeman	0.33 ± 0.02	0.28 ± 0.01	1.47 ± 0.09	11.94 ± 0.72	0.51 ± 0.03	0.73 ± 0.04	10.31 ± 0.70	2.68 ± 0.50	28.25 ± 1.53
	1 M H_2SO_4	0.32 ± 0.01	0.33 ± 0.10	1.51 ± 0.10	11.89 ± 0.81	0.03 ± 0.00	0.28 ± 0.02	0.68 ± 0.67	2.89 ± 0.15	17.93 ± 1.07
SPM	1 M H_2SO_4	0.18 ± 0.01	0.07 ± 0.00	0.86 ± 0.06	0.29 ± 0.01	0.16 ± 0.01	0.32 ± 0.02	0.22 ± 0.01	5.27 ± 0.48	7.37 ± 0.55
kiwi pomace										
IRM	Saeman	0.12 ± 0.00	0.06 ± 0.00	0.44 ± 0.02	1.97 ± 0.10	0.78 ± 0.05	0.80 ± 0.04	7.16 ± 0.43	1.51 ± 0.12	12.84 ± 0.72
	1 M H_2SO_4	0.09 ± 0.00	0.13 ± 0.00	0.62 ± 0.03	1.90 ± 0.10	0.29 ± 0.01	0.63 ± 0.04	0.33 ± 0.02	1.12 ± 0.05	5.11 ± 0.37
SPM	1 M H_2SO_4	0.11 ± 0.01	0.05 ± 0.00	0.32 ± 0.02	0.10 ± 0.01	0.24 ± 0.01	0.70 ± 0.55	0.16 ± 0.01	5.43 ± 0.51	7.11 ± 0.50

Table 4. Lignin, Cellulose, Noncellulosic Polysaccharides, and Dietary Fiber Contents Expressed as Percent of Dry Matter

	pomace	
	pear	kiwi
lignin	5.2	3.2
cellulose	9.6	6.8
noncellulosic polysaccharides		
neutral	18.0	6.3
acidic	8.2	6.9
total	26.2	13.2
dietary fiber	41.0	23.2

xylose (Selvendran and King, 1989). A significant proportion of the glucuronoxylans of kiwi pomace would have arisen from the seed hulls. It should be remembered that the seeds were not removed during the preparation of the pulp.

In addition, the remainder of the IRM carbohydrate in kiwi pomace comprised poorly branched pectic polysaccharides as indicated by the levels of uronic acids (1.51%) and low levels of the neutral sugars galactose (0.8%) and arabinose (0.4%). The pectic polysaccharides may be closely associated with the cellulose as has been reported recently (Redgwell et al., 1986; Selvendran and Robertson, 1990). A smaller but significant amount of hemicellulose is present in the IDF residue, as indicated by the content of other neutral sugars including xylose and mannose, 15.3% and 6.1%, respectively, of total carbohydrate. Negligible traces of rhamnose and fucose were detected in both samples.

The data for cellulose, noncellulosic polysaccharides, neutral and acidic sugars, lignin, and TDF are summarized in Table 4. The amount of noncellulosic polysaccharides (NCP) represents the main fraction in both TDF pomaces (63.9% and 56.9% in pear and kiwi, respectively) followed by cellulose and lignin. NCP consist mainly of neutral sugars in pear pomace, while acidic sugars are the major carbohydrate component of kiwi pomace NCP.

From Tables 1–3, the following can be inferred. Soluble fiber contents of both pear and kiwi pomaces obtained by gravimetric methods and detailed sugar analysis are highly comparable, despite the high ash content of the SPM. The insoluble fiber contents of pear pomace by gravimetric and sugar analysis are 36.3% and 28.3%, respectively, and the corresponding values for kiwi pomace are 18.7% and 12.8%. Bearing in mind that the ash content of the IRM (unlike SPM) of both pomaces is low, it would appear that the gravimetric value for the insoluble fiber content of both pomaces is more correct. The values for IDF of both pomaces obtained by sugar analysis have to be corrected for Klason lignin content, and the corrected values are about 10% lower than the actual values. This difference could be attributed to two main factors: (i) loss of acid-soluble lignin during acid hydrolysis and (ii) loss of sugars during acid hydrolysis of polysaccharides; small losses during the derivatization steps are also possible.

On the other hand, the colorimetric data of total neutral sugar are always lower than that obtained by GLC. Colorimetric methods tend to be inaccurate because of the different response factors of component sugars (Lahaye, 1991). In GLC methods, such response factors are accounted for. The error could also be due to the presence of some residual polyphenols. In the literature, the colorimetric reagents are different from those employed in this work and give an overestimation of sugar. The Prosky procedure gives realistic and accurate estimates of DF content for these two materials.

Because pectic substances (PS) have important physiological and specific nutritional effects (Brand et al., 1989; Schneeman, 1990) and they are present in significant amounts in these samples, especially in the SPM, a fractional extraction and quantitative determination of pectic substances has been carried out.

The fractionation procedure involves the progressive extraction of the pectic substances from IRM and SPM fractions by water (extraction of high methoxyl pectins), ammonium oxalate (extraction of low methoxyl pectins), and cold alkali (extraction of the protopectins). Values for the levels of extracted pectin from these pomaces are summarized in Table 5. For comparative purposes, total uronic acid values of IRM and SPM residues obtained by the chemical procedure are also given. There are no significant differences between the overall recoveries of pectic substances from the fractionation procedure and the chemical one, which confirms the accuracy of the extraction procedure. The types of PS are quite similar in both pomaces. The majority of the pectic polysaccharide fraction was released by alkali extraction from IRM residues. Hence, protopectins are the main type of PS and represent 84% of the total pectin content in both IRM samples.

In contrast, the pectic polysaccharides released from SPM residues were, as expected, very different from those from IRM fractions. The majority was extracted in water (97.8% and 88.2% of the total pectin for pear and kiwi pomaces, respectively). This suggests that the PS belonging to SDF are predominantly high methoxyl pectins.

The samples analyzed in this study contain relatively high amounts of certain fiber components, but the nutritional quality remains to be evaluated. Structural differences between fiber fractions can greatly alter physiological effects of the fiber. The differences in lignified tissues between pear and kiwi pomace provide interesting information for comparison.

Pear and kiwi pomaces can be considered good raw material for high DF products. It is likely that, after drying, these samples could be used directly, since the dry material contains low amounts of protein, Klason lignin, and ash. The knowledge of DF composition could facilitate the exploitation of the sources for the preparation of nutritionally improved fiber preparations. Pear pomace, being rich in lignified fiber, could increase fecal

Table 5. Pectin Determinations in Insoluble Residue Material (IRM) and Soluble Polymeric Material (SPM) of Pear and Kiwi Pomaces Expressed as Percent of Dry Matter

	pectin as uronic acid				
fractions	high methoxyl	low methoxyl	protopectin	total	total uronic acid
IRM					
pear pomace	0.20 ± 0.02	0.19 ± 0.01	2.24 ± 0.15	2.63 ± 0.19	2.68 ± 0.50
kiwi pomace	0.10 ± 0.01	0.15 ± 0.01	1.33 ± 0.10	1.58 ± 0.11	1.51 ± 0.12
SPM					
pear pomace	5.30 ± 0.41	0.12 ± 0.01		5.42 ± 0.46	5.27 ± 0.48
kiwi pomace	5.00 ± 0.47	0.67 ± 0.05		5.67 ± 0.50	5.43 ± 0.51

bulking and binding of toxic components as other lignified tissues do. Furthermore, because these pomaces have high contents of insoluble fiber and appreciable amounts of soluble fiber and uronic acids, they could be expected to show useful properties associated with both fiber fractions. However, *in vitro* and *in vivo* studies of fiber isolated from these pomaces based on quantitative fiber composition data must be carried out before the nutritive value can be quantitatively established.

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