Dietary Fiber from Mango Byproducts: Characterization and Hypoglycemic Effects Determined by in Vitro Methods

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Mango (*Mangifera indica* L.) byproducts, which represent 35–60% of the processed fruit, are a potential source of dietary fiber. After ethanolic purification, we found that peels and fibrous waste pulp had a high dietary fiber content (74% of the dry matter) with a soluble/insoluble ratio close to 1 and a 15–20% uronic acid content. The fiber water-soluble fraction showed shear-thinning behavior. In vitro studies indicate that these fibers decreased total starch digestibility and slowed the final rate of amylolysis of mashed potatoes as the starch source. Glucose diffusion was also retarded in the presence of mango fiber. These results suggest that mango byproducts are a good source of dietary fiber which could be of potential benefit in controlling plasma glucose.

INTRODUCTION

Among tropical fruit, the mango (*Mangifera indica* L.), with a current annual world production of about 14 440 000 metric tons (Food and Agricultural Organization, 1985), is second to the banana. In the processing industry, 35–60% of this fruit is discarded as waste (Ram, 1973; Beerh et al., 1976), mainly in the form of peel, stones, and pulp. The seed kernel is a source of fat (11–13%) and carbohydrate (65–67%) (Lasztity et al., 1988). The peel and fibrous pulp containing many flavoring substances and rich in sugars can be used for preparation of wine and vinegar after fermentation (Beerh et al., 1976). A U.S. patent has been published indicating that palatable and edible food products usable as bakery-type products have been prepared from these fruit portions (Johnston, 1981). Moreover, studies with different mango varieties suggest that a high-quality mango pectin, comparable to that of apples and oranges, can be obtained from the peel (Srirangarajan and Shrikhande, 1979; Kratchanova et al., 1991; Fishman et al., 1991).

The polysaccharides composing the major part of dietary fibers in fruits and vegetables are beneficial to diabetics and heart patients since the fibers lower blood sugar and serum cholesterol levels (Jenkins et al., 1978; Stasse-Wolthius et al., 1980). In fact, the most likely explanation for the reduction of postprandial hyperglycemia by viscous fibers is decreased amylase activity (Isaksson et al., 1982; Dunaif and Schneeman, 1981) and a direct delaying effect on glucose absorption in the gastrointestinal tract due to alteration in the diffusion of the digestion end product within the lumen (Blackburn et al., 1984; Wood et al., 1990). Mango byproducts, rich in pectic substances, represent a potential fiber source likely to influence metabolic parameters in humans.

The purpose of the present work was to obtain a product from mango wastes which could be used as dietary fiber and to evaluate the potential hypoglycemic effects of these fibers by several in vitro tests. Different mango waste materials were characterized after ethanolic purification, and their effects on enzymatic degradation of starch and glucose diffusion were determined.

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EXPERIMENTAL PROCEDURES

Materials. Three cultivars of *M. indica* [Kent (K), Mangot (M), and Amélie (A)] from the Korrogho Experimental Station (Ivory Coast) were used for purée extraction in a PH3-B pulper (Auriol Co.). The fruits were ripe when processed. To obtain this stage of maturity, they had to be stored for 15–30 days at 25 °C to allow maturation before processing. The byproducts were peel (P) (obtained from fruit not peeled before processing), skin (S) (from peeled fruit), fibrous pulp waste (FPW) (after refining of purée), and seeds (see Scheme I). Skin and peel were obtained from the Kent cultivar and FPW was obtained from all three cultivars. These products were freeze-dried, ground, and sifted (diameter less than 0.5 mm).

Preparation of Alcohol-Insoluble Solids (AIS) and Chemical Characterization. The material was immersed for 10 min in boiling 95% ethanol under manual stirring. The mixture was then filtered on a G2 sintered glass filter, washed with 70% ethanol until the eluate became colorless, and dried by sequential rinsing with absolute ethanol, acetone, and ether and finally under vacuum (24 h, 40 °C). The residue was hand-ground in a mortar.

Water-soluble and insoluble fiber fractions were determined by the enzymatic–gravimetric method of Prosky et al. (1988). Individual neutral sugars were analyzed by gas–liquid chromatography as their alditol acetates according to the method of Hoebler et al. (1989). Uronic acids (such as anhydrogalacturonic acids) were determined according to the automated *m*-phenylphenol method (Thibault, 1979). All determinations were done in duplicate.

Since it is likely that the utilization of mango fiber would depend on a pooling of all wastes from processing industries, such a mixture was simulated before viscosity and glucose diffusion determinations.

Two mixtures of mango fiber in different proportions were prepared from AIS of the material. Mixture 1 consisted of FPW K, FPW M, FPW A, and P K (1:1:1:1) and mixture 2 of FPW K, FPW M, and FPW A (1:1:2).

Viscosity Measurements. To compare the rheological behavior of each fiber and of the two mixtures, apparent viscosity values of water-soluble fractions were obtained as follows: a fiber suspension (AIS) at 4% (w/v) was prepared from NaCl solution (154 mM). The mixture was stirred for 30 min at room temperature and then centrifuged (4000*g*) for 10 min. The supernatant was filtered on Whatman 41 filter paper, and an aliquot was used for viscosity measurements in a rotational viscometer

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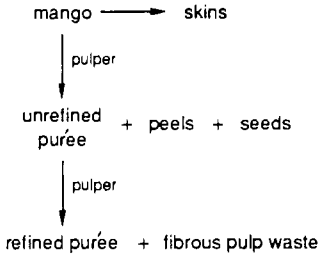
Scheme I. Procedure for Industrial Extraction of Mango Puree



(Low Shear 40, Mettler) at 37 °C and with shear rates from 1 to 100 s^{-1} and back to 1 s^{-1}.

To evaluate the effect of free soluble sugars, the viscosity of a suspension of unpurified K FPW (10.8% w/v) was compared with that of a suspension of purified K FPW (AIS). Fiber concentration was calculated so as to have the same AIS concentration as in the study previously described (4% w/v). The concentration of the alcohol-soluble fraction was 6.8% (w/v) in the unpurified K FPW suspension. Sugar viscosity was determined from a solution of alcohol-soluble solids at 6.8% (w/v).

To relate the viscosity of the water-soluble fraction of a sample to its total sugar content, the fraction of AIS extracted by NaCl solution as described above was analyzed for neutral and acidic sugars. Galacturonic acid (expressed as the anhydro form) and total neutral sugars (expressed as anhydroglucose) were determined, respectively, by the *m*-phenylphenol (Thibault, 1979) and orcinol methods (Tollier and Robin, 1979) (responses were corrected for mutual interferences). All results are averages of at least two determinations.

Determination of Starch Digestibility. The starch source was dehydrated mashed potatoes (72.3% starch content; Vico) determined after starch solubilization by 90% dimethyl sulfoxide at 110 °C, followed by starch hydrolysis with amyloglucosidase (from *Aspergillus niger*, Merck 100 units/mg, Art. 1332). Glucose was analyzed by the GOD-POD method according to the method of Colonna et al. (1981). A dry sample of mashed potatoes containing 2 g of starch was mixed in an Erlenmeyer flask with mango fiber (AIS) at a 10:1 starch/total dietary fiber ratio corresponding to a fiber-rich diet. A volume of 0.1 M Tris-maleate buffer (pH 7) was added to obtain a mixture at 8% (w/v), i.e., the approximate concentration in intestinal lumen (Champ et al., 1988). The suspension was shaken in a water bath for 150 min at 37 °C. At 0 min, a porcine pancreatic α-amylase preparation (Merck 300 units/mg, Art. 16312) (165 IU/g of starch) was added. Samples collected at various intervals between 0 and 150 min (0, 2, 5, 7, 10, 15, 20, 30, 45, 60, 90, 120, and 150 min) were homogenized in 5 mL of ethanol 95°GL–pure acetic acid (100/1.5) (v/v). The tubes were kept overnight at 0 °C and centrifuged for 10 min (4000*g*). Alcohol-soluble dextrins were determined using the orcinol–sulfuric acid method (Tollier and Robin, 1979). Starch degradation without fiber addition was used as reference. The curves represent means of two experiments for each fiber source and three for the reference. Initial and final rates were calculated as described by Delort-Laval and Mercier (1976). Intra-assay repeatability was 4% at 30 min, 3% at 60 min, and 5% at 150 min.

Glucose Dialysis Retardation Index. Prior to the glucose diffusion assay in the presence of fiber, it was necessary to remove glucose and other sugars from the material which still contained 1 (mixture 1)–6% (mixture 2) glucose (percent of dry matter). An aliquot of the two mixtures of mango fiber (AIS) was extensively dialyzed against distilled water. Four volumes of 95% ethanol were then added for precipitation of the soluble fraction. After being kept overnight at room temperature, the mixture was filtered on crucible G2, dried by sequential rinsing with absolute ethanol and acetone, and then placed under vacuum at 40 °C for 24 h. The residue was ground in a ball mill and used for measurement of the glucose dialysis retardation index according to the method of Adiotomre et al. (1990), with some modifications: the dialysis bags used (MW 12 000–14 000) (20/32, Visking, Poly Labo, Strasbourg) were filled with 7 mL of a 1 g of sodium azide/L and 2.52 mg glucose solution. Measurement

Table I. Composition of Mango Fiber after Ethanolic Purification (Grams per 100 g of AIS Material)[a]

	Kent S	Kent P	Kent FPW	Mangot FPW	Amélie FPW
yield of AIS	30.70	49.70	36.70	41.40	34.20
ash	5.67	6.10	5.03	6.52	6.05
protein (N × 6.25)	7.73	6.56	5.59	6.45	4.67
total dietary fiber[b]	71.10	76.80	74.50	74.60	72.00
water-soluble fiber	35.30	36.30	33.70	33.80	33.90
water-insoluble fiber	35.80	40.50	40.80	40.80	38.10
neutral sugars[c]					
rhamnose	1.06	1.02	0.92	0.86	0.86
arabinose	9.90	9.81	8.01	7.91	8.65
xylose	2.23	2.62	2.97	2.88	2.66
mannose	1.68	1.58	1.92	1.70	1.84
galactose	11.10	8.57	5.82	7.15	6.77
glucose	21.00	23.00	26.60	26.60	25.60
uronic acid[d]	14.70	15.90	20.30	18.70	16.90
total sugars	61.67	62.50	66.54	65.80	63.28

[a] Key: S, skin; P, peel; FPW, fibrous pulp waste. [b] Total dietary fiber (Prosky et al., 1988). [c] Neutral sugars (Hoebler et al., 1989). [d] Galacturonic acid (Thibault, 1979).

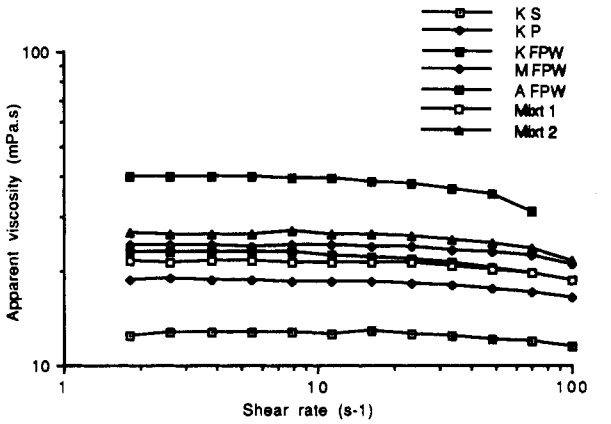


Figure 1. Flow curves obtained at 37 °C using a rotational viscometer (Low Shear 40). Aqueous extract of fiber suspension at 4% AIS (w/v): S, skin; P, peel; FPW, fibrous pulp waste; K, Kent; M, Mangot; A, Amélie; mango fiber mixture 1; mango fiber mixture 2.

with highly viscous guar gum (Satia Baupte) (4139 mPa s in solution at 1% w/v) was performed for comparative purposes. Results represent means ± SEM of 6 determinations for mango fiber and guar gum and 11 for controls (without fiber).

RESULTS

Physicochemical Characteristics. The various mango byproducts were rich in free sugars, and alcohol-soluble solids (ASS) represented more than half of the material. Sugar content varied with the origin of the fraction and the cultivar. For Kent, S contained more sugars than P and FPW, and Mangot had the lowest sugar content (Table I). Ethanolic purification yielded an odorless white to light-brown material.

Comparison of the different fractions showed slight variations in AIS composition. The mean total dietary fiber content was 74%, with a soluble/insoluble ratio close to 1 (from 0.83 to 0.99) (Table I).

The composition of sugar residues showed predominance of glucose, uronic acids, arabinose, and galactose. Kent S was particularly rich in galactose (Table I).

The aqueous fiber extracts had similar rheological behavior. Their apparent viscosity was almost constant up to 20 s^{-1}, whereupon it decreased slightly with increasing shear rate (Figure 1). The Amélie FPW had the highest viscosity as well as greater uronic acid content, whereas Kent S had the lowest viscosity. The other fibers and the

Table II. Viscosity Characteristics of Mango Fiber (Average of Duplicates)[a]

	concn of initial suspension in AIS, % (w/v)	app viscosity at 1.83 s^{-1}, mPa s	solubilized sugars, g/100 g of dry matter		pH of extract
			total[b]	acid[c]	
KS	4	12.5	31.5	4.81	4.86
KP	4	18.8	28.8	5.67	5.01
K FPW	4	23.2	26.3	5.12	5.01
M FPW	4	24.2	26.8	5.09	5.15
A FPW	4	40.1	29.5	6.81	4.91
mixture I	4	21.7	26.2	5.21	5.02
mixture II	4	26.5	25.5	5.23	4.99
unp K FPW	4	502	49.9	1.63	3.56
K FPW ASS	0	0.89	80.5	0.82	4.60

[a] Key: S, skin; P, peel; FPW, fibrous pulp waste; K, Kent; M, Mangot; A, Amélie. [b] Expressed as anhydroglucose form (Tollier and Robin, 1979). [c] Expressed as anhydrogalacturonic form (Thibault, 1979).

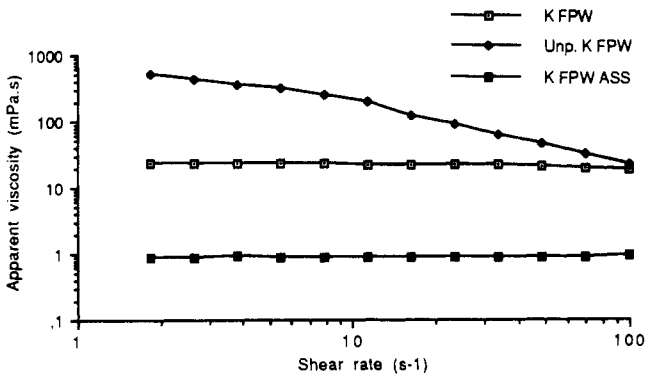


Figure 2. Viscosity of unpurified fibrous pulp waste (Kent variety) compared to the viscosity of purified fiber and to a solution of sugars corresponding to the sugar concentration of the unpurified fibers measured at 37 °C using a rotational viscometer (Low Shear 40). Aqueous extract: K FPW ASS, alcohol-soluble solids of Kent fibrous pulp waste at 6.8% w/v; K FPW, Kent fibrous pulp waste at 4% AIS w/v; Unp K FPW, unpurified Kent fibrous pulp waste at 4% AIS w/v and 6.8% ASS w/v.

two mixtures had intermediate values (Table II). Figure 2 shows that the flow behavior of unpurified material was shear-thinning and that viscosity was inversely related to the shear rate. Soluble sugars had a synergistic action in the presence of fiber and increased by more than 20 times the viscosity value of the fiber to 1.83 s^{-1}. The solution containing only ASS had a viscosity approaching that of water. The different aqueous fiber extracts were in the pH range 4.86–5.15.

Starch Hydrolysis in Vitro. During the first 10 min of enzymatic amylolysis, starch was quickly hydrolyzed by the amylase added at time 0. Speed decreased until the 45th min, after which time the curve became linear (Figure 3). Until the 20th min, there was no difference in starch degradation between the reference and starch plus fiber. From the 30th min, fiber began to delay hydrolysis, and the final rates were 0.51, 0.22, 0.28, 0.13, and 0.17%, respectively, for reference, Kent FPW, Kent S, Mangot FPW, and Amélie FPW. At the end of the incubation period, 71.9% of the starch was hydrolyzed in the reference sample, whereas the hydrolysis rate was between 56.6 and 63.1% when fibers were present. However, none of the differences between fibers were significant.

Glucose Dialysis. Both mango fiber mixtures delayed glucose diffusion, the more important effect being with mixture 2. This retarding effect was greater after 30 than after 60 min. Neither mango fiber mixture had a greater effect than guar gum used as control (Table III).

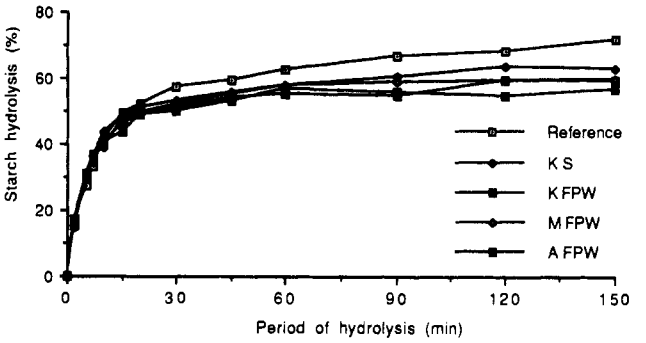


Figure 3. In vitro starch hydrolysis kinetics using porcine pancreatic α-amylase (Merck 300 units/mg) (165 IU/g of starch). Percentage of hydrolysis is expressed in glucose. Fiber is added according to a 10/1 starch/total dietary fiber ratio: reference, starch without fiber; K S, starch + Kent skin; K FPW, starch + Kent fibrous pulp waste; M FPW, starch + Mangot fibrous pulp waste; A FPW, starch + Amélie fibrous pulp waste. Results are the means of three determinations for reference and two determinations for starch plus fiber. Intraassay repeatability was 4% at 30 min, 3% at 60 min, and 5% at 150 min.

Table III. Retarding Effect of the Fiber on Glucose Movement (Glucose Dialysis Retardation Index)[a]

	30-min dialysis		60-min dialysis	
	gluc in dialysate, μmol/L	gluc dialysis retdn index,[b] %	gluc in dialysate, μmol/L	gluc dialysis retdn index, %
control	71.4 (1.02)[c]	0	93.2 (1.06)	0
mango fiber				
mixture 1	55.9 (1.54)	21.7	75.0 (1.64)	19.5
mixture 2	47.8 (2.04)	33.1	66.7 (2.44)	28.4
guar gum	40.0 (2.95)	44.0	51.9 (2.24)	44.3

[a] n control = 11; n mango fiber = 6; n guar gum = 6. [b] Glucose dialysis retardation index = 100 − [(fiber × 100)/control]. [c] Mean (SEM).

DISCUSSION

Industrial processing of mango juice or nectar extraction requires the use of several cultivars depending on juice yield, taste intensity (sweet or acid), and aroma. The byproducts obtained from such processing are thus of diverse origin. Despite variations in the juice yield or sugar content of cultivars, the physicochemical characterization of different fractions indicates that the compositions of the purified material obtained by ethanol treatment were very similar.

The AIS yields (31–50%) were lower than those obtained from citrus wastes (45–75%; Ting and Roussef, 1983) or from beet pulp (90%; Michel et al., 1988). However, the purified material had a balanced ratio of soluble/insoluble dietary fiber and a 15–20% uronic (probably galacturonic) acid content (King et al., 1988; Fishman et al., 1991). The total hemicellulose, cellulose, and uronic acid content (62–67%) was intermediate between values obtained for beet fiber (74–87%) (Schweizer and Würsch, 1979) and for orange and grapefruit peels (31–50%) (Eaks and Sinclair, 1980; Braddock and Graumlich, 1981) or for commercial apple fiber (57.2%) (Renard and Thibault, 1991).

The rheological (not Newtonian) behavior of mango fiber was comparable to that obtained by Edwards et al. (1987) for viscous gums, although apparent viscosity values for similar shear rates were lower. The viscosity differences between mango fibers (AIS) were apparently due to the high solubilization of fiber components rich in galacturonic acid, thus confirming the relationship between mango

nectar viscosity and pectic substances content noted by Saeed et al. (1975). The total sugar content of unpurified Kent FPW corresponds to the value reported by Beerh et al. (1976) for pulp wastes (51.3%). The synergistic effect of sugars on viscosity in the presence of pectins has been demonstrated by Manohar et al. (1990). According to Chan and Kwok (1975), the sugars from mango pulp are (in relative values) sucrose (74.1%), fructose (20.6%), and glucose (6.3%). Nahar et al. (1990) also noted a predominance of sucrose in pulp.

The various mango fiber fractions modified enzymatic starch degradation similarly. Compared to the reference, the initial rate of amylolysis was not modified by the presence of fiber, but a decrease in final rate and total starch degradation was noted. This decrease in the amylolysis rate may be attributed to a direct effect of fiber on amylase activity due to adsorption of the enzyme on the fibers or a decrease in activity due to viscosity or pH modification of the medium (Isaksson et al., 1982). Fiber concentration (Hansen and Schulz, 1982) or the presence of soluble inhibitors related to unpurified fibers (Liener and Kakade, 1980) may also influence the accessibility of the enzyme to its substrate. Mango fiber can interfere in adsorbing enzyme because of its large concentration in free carboxylic groups (the pH values of different extracts ranged from 4.86 to 5.15).

Glucose diffusion is closely related to soluble fiber content and solution viscosity (Rainbird et al., 1984; Ebihara and Kiriyama, 1982; Wood et al., 1990). Thus, in our study, fiber mixture 2, with greater Amélie FPW content (the most viscous sample), had the higher index. The index obtained for guar gum is close to the one (43.3%) reported by Adiotomre et al. (1990) in spite of the lower concentration in glucose used. The retardation effect due to mango fiber corresponded to about half that due to guar gum, which has much higher solubility (100% soluble fibers) than mango fiber (50% soluble fibers).

The processing of mango, to produce fruit juices, leads to large quantities of wastes. In India, the leading producer of mangoes, more than 3 million metric tons of wastes is available each year as a possible source of dietary fiber. The purified materials obtained after simple ethanolic extraction of the byproducts are especially rich in pectic substances and have a high ratio of soluble/insoluble dietary fiber. The rheological behavior of their water-soluble fraction is comparable to that of viscous gums. Without any purification, mango fibers have a very high viscosity (at low shear rates) due to a synergistic effect of soluble sugars on fiber viscosity. Starch degradation and glucose diffusion are delayed in the presence of mango fiber. Now, viscous solutions which reduce starch digestibility in vitro can decrease glycemic postprandial response (Champ et al., 1988). Thus, mango fiber could be of potential benefit in controlling plasma glucose. Moreover, as for beet pulp (Christenssen, 1989), citrus fiber (Lynn, 1980), and apple pomace (Walter et al., 1985), mango byproducts that bring a pleasant "fruity" taste can be incorporated in unpurified form as a useful ingredient in high-fiber foods and are thus of economic interest to producers.

LITERATURE CITED

Adiotomre, J.; Eastwood, M. A.; Edwards, C. A.; Brydon, W. G. Dietary fiber: in vitro methods that anticipate nutrition and metabolic activity in humans. *Am. J. Clin. Nutr.* **1990**, *52*, 128–134.

Beerh, O. P.; Raghuramaiah, B.; Krishnamurthy, G. V.; Girhidar, N. Utilization of mango waste: recovery of juice from waste pulp and peel. *J. Food Sci. Technol.* **1976**, *13*, 138–141.

Blackburn, N. A.; Redfern, J. S.; Jarjis, H.; Holgate, A. M.; Hanning, I.; Scarpello, J. H. B.; Johnson, I. T.; Read, N. W. The mechanism of action of guar gum in improving glucose tolerance in man. *Clin. Sci.* **1984**, *66*, 329–336.

Braddock, R. J.; Graumlich, T. R. Composition of fiber from citrus peel, membranes, juice vesicles and seeds. *Lebensm. Wiss. Technol.* **1981**, *14*, 229–231.

Champ, M.; Cherbut, C.; Leclère, C.; Cohen, A. How viscous dietary fiber may affect absorption of nutrients? *FASEB J.* **1988**, *2*, A443 (abstract).

Chan, H. T.; Kwok, S. C. M. Identification and determination of sugars in some tropical fruit products. *J. Food Sci.* **1975**, *40*, 419–420.

Christensen, E. H. Characteristics of sugarbeet fiber allow many food uses. *Cereal Foods World* **1989**, *34*, 541–544.

Colonna, P.; Buléon, A.; Mercier, C. Pisum Sativum and Vicia Faba carbohydrates: structural studies of starches. *J. Food Sci.* **1981**, *46*, 88–93.

Delort-Laval, J.; Mercier, C. Selection of treatments and study of their influence on the carbohydrate fraction of wheat, barley and maize. *Ann. Zootech.* **1976**, *25*, 3–12.

Dunaif, G.; Schneeman, B. O. The effect of dietary fiber on human pancreatic enzyme activity in vitro. *Am. J. Clin. Nutr.* **1981**, *34*, 1034–1035.

Eaks, I. L.; Sinclair, W. B. Cellulose-hemicellulose fractions in the alcohol-insoluble solids of valencia orange peel. *J. Food Sci.* **1980**, *45*, 985–988.

Ebihara, K.; Kiriyama, S. Comparative effects of water-soluble and water-insoluble dietary fibers on various parameters relating to glucose tolerance in rats. *Nutr. Rep. Int.* **1982**, *26*, 193–201.

Edwards, C. A.; Blackburn, N. A.; Craigen, L.; Davidson, P.; Tomlin, J.; Sugden, K.; Johnson, I. T.; Read, N. W. Viscosity of food gums determined in vitro related to their hypoglycemic actions. *Am. J. Clin. Nutr.* **1987**, *46*, 72–77.

Fishman, M. L.; El-Atawy, Y. S.; Sondey, S. M.; Gillespie, D. T.; Hicks, K. B. Component and global average radii of gyration of pectins from various sources. *Carbohydr. Polym.* **1991**, *15*, 89–104.

Food and Agricultural Organization. *Annuaire FAO de la production 1985*; Statistiques No. 70; FAO: Rome, 1985.

Hansen, W. E.; Schulz, G. The effect of dietary fiber on pancreatic amylase activity in vitro. *Hepato-Gastroenterology* **1982**, *29*, 157–160.

Hoebler, C.; Barry, J. L.; David, A.; Delort-Laval, J. Rapid acid hydrolysis of plant cell wall polysaccharides and simplified quantitative determination of their neutral monosaccharides by gas-liquid chromatography. *J. Agric. Food Chem.* **1989**, *37*, 360–367.

Isaksson, G.; Lundquist, I.; Ihse, I. Effect of dietary fiber on pancreatic enzyme activity in vitro. The importance of viscosity, pH, ionic strength, adsorption and time of incubation. *Gastroenterology* **1982**, *82*, 918–924.

Jenkins, D. J. A.; Wolever, T. M. S.; Leeds, A. R.; Gassul, M. A.; Haisman, P.; Dilawari, J.; Goff, D. V.; Metz, G. L.; Alberti, K. G. M. M. Dietary fibres, fibre analogues, and glucose tolerance: importance of viscosity. *Br. Med. J.* **1978**, *1*, 1392–1394.

Johnston, I. F. U.S. Pat. 4,267,196, 1981.

King, K.; Norton, G.; Mitchell, J. R.; Caygill, J. A study of factors affecting in-situ de-esterification of mango (*Mangifera indica*) pectin. *J. Sci. Food Agric.* **1988**, *45*, 231–241.

Kratchanova, M.; Bénémou, C.; Kratchanov, C. On the pectic substances of mango fruits. *Carbohydr. Polym.* **1991**, *15*, 271–282.

Lasztity, R.; El Shafei, M. A.; Abdel Samei, M. B.; Hatour, F. S.; Labib, M. Biochemical studies of some non-conventional sources of protein. Part 4. The proteins of mango waste stone kernels. *Nahrung* **1988**, *32*, 867–873.

Liener, I. E.; Kakade, M. L. Protease inhibitors. In *Toxic constituents of plant foodstuff*, 2nd ed.; Liener, I. E., Ed.; Academic Press: New York, 1980.

Lynn, C. C. U.S. Pat. 4,225,628, 1980.

Manohar, B.; Ramakrishna, P.; Ramteke, R. S. Effect of pectin content on flow properties of mango pulp concentrates. *J. Texture Stud.* **1990**, *21*, 179–190.

Michel, F.; Thibault, J. F.; Barry, J. L. Preparation and characterisation of dietary fibre from sugar beet pulp. *J. Sci. Food Agric.* **1988**, *42*, 77–85.

Nahar, N.; Rahman, S.; Mosihuzzaman, M. Analysis of carbohydrates in seven edible fruits of Bangladesh. *J. Sci. Food Agric.* **1990**, *51*, 185–192.

Prosky, L.; Asp, N. G.; Schweizer, T. F.; DeVries, J. W.; Furda, I. Determination of insoluble, soluble, and total dietary fiber in foods and food products: Interlaboratory study. *J. Assoc. Off. Anal. Chem.* **1988**, *71*, 1017–1023.

Rainbird, A. L.; Low, A. G.; Zebrowska, T. Effect of guar gum on glucose and water absorption from isolated loops of jejunum in conscious growing pigs. *Br. J. Nutr.* **1984**, *52*, 489–498.

Ram, K. Mango waste too can be utilised. *Indian Farmer's Dig.* **1973**, *6*, 39 and 52.

Renard, C. M. G. C.; Thibault, J.-F. Composition and physicochemical properties of apple fibres from fresh fruits and industrial products. *Lebensm. Wiss. Technol.* **1991**, *24*, 523–527.

Saeed, A. R.; El Tinay, A. H.; Khattab, A. H. Viscosity of mango nectar as related to pectic substances. *J. Food Sci.* **1975**, *40*, 203–204.

Schweizer, T. F.; Wursch, P. Analysis of dietary fiber. *J. Sci. Food Agric.* **1979**, *30*, 613–619.

Srirangarajan, A. N.; Shrikhande, A. J. Technical note: Comparative aspects of pectin extracted from the peels of different varieties of mango. *J. Food Technol.* **1979**, *14*, 539–541.

Stasse-Wolthuis, M.; Albers, H. F. F.; van Jeveren, J. G. C.; Wil de Jong, J.; Hautvast, J. G. A. J.; Hermus, R. J. J.; Katan, M. B.; Brydon, W. G.; Eastwood, M. A. Influence of dietary fiber from vegetables and fruits, bran or citrus pectin on serum lipids, fecal lipids, and colonic function. *Am. J. Clin. Nutr.* **1980**, *33*, 1745–1756.

Thibault, J. F. *Lebensm. Wiss. Technol.* **1979**, *12*, 247–251.

Ting, S. V.; Roussef, R. L. Dietary fiber from citrus wastes: characterization. In *Unconventional sources of dietary fiber*; Furda, I., Ed.; ACS Symposium Series 214; American Chemical Society: Washington, 1983; Chapter 15, pp 205–219.

Tollier, M. T.; Robin, J. P. *Ann. Technol. Agric.* **1979**, *28*, 1–15.

Walter, R. H.; Rao, M. A.; Sherman, R. M.; Cooley, H. J. Edible fibers from apple pomace. *J. Food Sci.* **1985**, *50*, 747–749.

Wood, P. J.; Braaten, J. T.; Scott, F. W.; Riedel, D.; Poste, L. M. Comparisons of viscous properties of oat and guar gum and the effects of these and oat bran on glycemic index. *J. Agric. Food Chem.* **1990**, *38*, 753–757.

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