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Dietary Fiber Components in Yellow Passion Fruit Rind—A Potential Fiber Source

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Within the framework for searching for new dietary fiber (DF) sources to remedy the increasing shortage of currently available sources, connected to an upsurge of diabetes, colon cancer, and other diverticular diseases in certain Ivorian areas, yellow passion fruit (*Passiflora edulis* f. *flavicarpa*) rind, a byproduct from the juice industry that is available in large quantities, was investigated. The results showed that, as determined by the AOAC enzymatic−gravimetric method, the total dietary fiber (TDF) in alcohol-insoluble material (AIM) from yellow passion fruit (YPF) rind was >73% dry matter of which insoluble dietary fiber accounted for >60% (w/w). The determination of DF using the Saeman hydrolysis method revealed that nonstarchy polysaccharides were the predominant components (~70%, w/w), of which cellulose appeared to be the main fraction. The water holding and oil holding capacities of the fiber-rich material were >3 g of water/g of fiber and >4 g of oil/g of fiber, respectively. All these results lead to the conclusion that DF from YPF rind, prepared as AIM, may be suitable to protect against diverticular diseases.

KEYWORDS: ***Passiflora edulis* f. *flavicarpa* rind**; **alcohol-insoluble material**; **dietary fiber**; **nonstarchy polysaccharides**; **water holding capacity**

INTRODUCTION

Various studies indicate that dietary fiber (DF) may be protective against cardiovascular diseases, diabetes, obesity, colon cancer, and other diverticular diseases (*1*–*5*). These findings have aroused a special interest in the search for dietary fiber-rich plant sources, primarily in Western societies where a high prevalence of these diseases has been observed. Until recently, Southern (and African) societies have generally been well-enough spared from these diseases, most likely thanks to a fiber-rich diet. However, the ceaseless disappearance of forests, as a consequence of desert expansion, associated with the phenomenon of periodical drought and civil conflicts have provoked, in various African regions, a severe shortage of commonly available dietary fiber-rich fruits and vegetables. At the same time, an upsurge of cardiovascular, diabetes, and diverticular diseases has been observed. Therefore, there is an urgent need to find new dietary fiber-rich sources, available in large quantities, to possibly prevent the occurrence of these diseases. Yellow passion fruit (YPF) rind, a byproduct from industrial juice production in most tropical and subtropical regions, may be a good dietary fiber source. In the Ivory Coast, juice extraction from fruits cogenerates large amounts (~3×10^5 tons/year) of pulps, rinds, and seeds that are hitherto discarded as agro-waste (*6*). We previously reported that YPF rind is a pectin-rich source (*6*). It also recently was reported that this passion fruit byproduct has proven to be a good source of fiber and that it could be used as a raw material for pectin extraction (*7*). However, little information is actually available on the DF components and polysaccharide composition of YPF rind.

DF initially was defined as plant cell wall remnants that are resistant to hydrolysis by human alimentary enzymes (*8*). The definition subsequently was extended to include all polysaccharides and lignin in the diet that are resistant to endogenous secretions of the human digestive tract (*9*). Accordingly, DF refers to nonstarchy polysaccharides, resistant starch, and lignin, upon which basis the AOAC total dietary fiber (TDF) method has evolved (*10*). From the TDF in plant materials, insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) also can be determined using the AOAC method. IDF may be protective against colonic and other diverticular diseases by improving the bowel transit time, whereas SDF may be able to prevent cardiovascular diseases and diabetes by reducing serum cholesterol and impeding excessive glucose absorption. IDF is important to intestinal regulation, whereas the soluble fraction is involved in the reduction of both blood cholesterol and intestinal glucose absorption (*3*). The aim of this study was to examine dietary fiber content and polysaccharide composition of YPF rind for possible use as a new fiber source.

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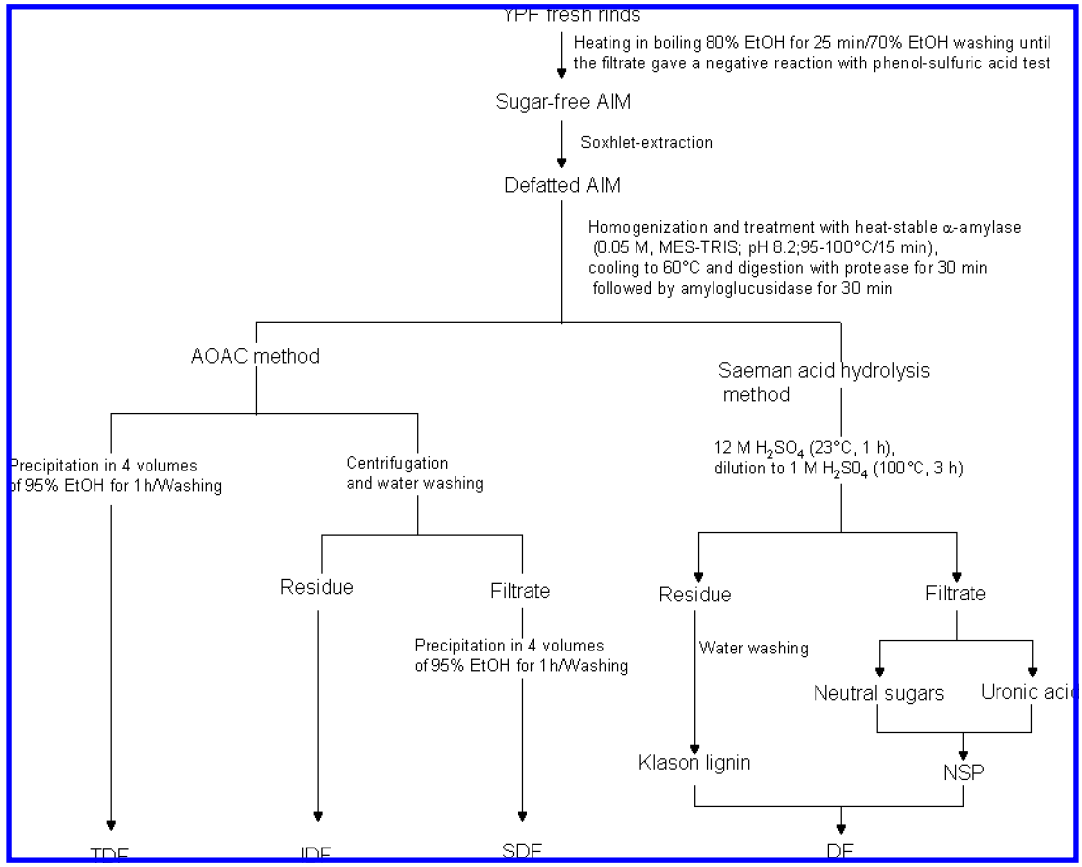

Figure 1. Scheme of isolation and characterization of dietary fiber-rich material from YPF rind.

MATERIALS AND METHODS

Samples, Reagents, and Enzymes. Mature ripe-dropped YPF was purchased from a local producer cooperative, in a city named Bacon, located in the southeastern region of the Ivory Coast. Fresh YPF rinds, remaining after industrial juice extraction, were kindly offered by an Ivorian juice factory (ATOU, Abidjan, the Ivory Coast). These rinds were collected in 80% (v/v) ethanol for transportation from the factory to our laboratory. *n*-Hexane, 2-(*N*-morpholino)ethanesulfonic acid (MES), and tris(hydroxymethyl)aminomethane (Tris) were obtained from Sigma Chemical Co. (St. Louis, MO). Heat stable α-amylase (EC 3.2.1.1, termamyl) was procured from Novozymes (Bagsvaerd, Denmark). Amyloglucosidase (EC 3.2.1.3) and protease were purchased from Sigma Chemical Co. (St. Louis, MO). All enzyme preparations were stored at 4 °C until use. The experiments performed are briefly summarized in **Figure 1**.

Alcohol-Insoluble Material (AIM) Preparation. AIM was prepared from both rinds collected from the juice factory (AIM-I) and rinds obtained by processing fresh fruits in our laboratory (AIM-L). Three kilograms of fresh fruit was washed with tap water, rinsed with distilled water, and then cut into halves to remove juice sacs that contained soft orange pulp and seeds. The fresh rinds were combined, weighed, and then crushed into small pieces (0.8−1 mm) in a fruit mill. Crushed rinds were immediately heated in boiling 80% (v/v) ethanol for 25 min (rind/solvent ratio, 1:10, w/v) and filtered through G2-sintered glass. The residue was washed with 70% (v/v) ethanol to remove free sugars (and possibly pigments and other impurities) until the filtrate gave a negative reaction with the phenol-sulfuric acid test (*11*). The residue was dried by solvent exchange (95% ethanol and absolute acetone), placed in a fume hood for 5 h to let residual acetone evaporate, and finally dried in an air-circulated oven at 35 °C for 24 h and weighed. Dried AIM was powdered to pass through a 0.25 mm mesh screen, packaged in separate sealed polyethylene bags, and stored at room temperature in a desiccator until use. Experiments were carried out in triplicate.

Proximate Analysis. Ash, fat, moisture, and protein contents were determined by conventional methods (*12*).

DF Determination. TDF, IDF, and SDF in AIM-I and AIM-L were measured by the enzymatic−gravimetric AOAC method using MES-Tris buffer (*13*). AIM-I and AIM-L were first defatted by Soxhlet extraction at 40 °C for 6 h using *n*-hexane (solid/solvent ratio, 1:5, w/v) because of unknown fat content. Defatted samples of AIM-I and AIM-L (1:40, w/v) were homogenized in MES/Tris buffer (0.05 M, pH 8.2) by stirring and treated with heat-stable α-amylase (0.1 mL/g of AIM) for 15 min in a water bath at 95−100 °C with continuous agitation. After cooling to 60 °C, the samples were digested with protease (0.1 mL/g of AIM) in MES/Tris buffer (0.05 M, pH 8.2) for 30 min in a water bath at 60 °C with continuous agitation. Finally, after adjusting the reaction mixture to pH 4.7, an amyloglucosidase solution (0.3 mL/g of AIM) was added and incubated for 30 min in a water bath at 60 °C under continuous agitation.

To determine the TDF content, 95% (v/v) ethanol, heated to 60 °C, was added to the digested sample (ethanol/sample ratio, 4:1, v/v) and placed at room temperature for 1 h to enable the precipitate to form followed by filtration on G4-sintered glass. The precipitate (ethanol-insoluble material) was washed with 78% (v/v) ethanol, 95% (v/v) ethanol, and absolute acetone. After being placed in a fume hood at room temperature, for 5 h, to let the residual acetone evaporate, the insoluble material was finally oven-dried at 40 °C to a constant weight.

To determine IDF and SDF contents, the enzyme digested sample was filtered on G4-sintered glass. Insoluble material was washed 2 times with preheated water to 60 °C, and water washings were added to the filtrate. The final insoluble material was managed as described previously to give IDF. Four volumes of 95% (v/v) ethanol, preheated to 60 °C, were added to the filtrate and placed at room temperature for 1 h to let the precipitate form. After centrifugation and filtration, the recovered precipitate was oven-dried to a constant weight. TDF, IDF, and SDF were corrected for residual protein, ash, and blank. Experiments were carried out in triplicate.

DF also was determined as the sum of nonstarchy polysaccharide (NSP) and Klason lignin using the Saeman hydrolysis method with slight modifications (*6*). The residue following Saeman hydrolysis was

Table 1. Physical Composition of Industrially and Laboratory-Processed Yellow Passion Fruits

yellow passion fruit	yield (g/100 g of FW)	
	industrial process[a]	laboratory process[b]
juice	39	34.5 ± 1.9
pulp		2.1 ± 0.3
rind	53[c]	50.7 ± 1.2
seed	8	12.7 ± 0.8

[a] Data are from the juice factory (ATOU, Abidjan, the Ivory Coast). [b] Data are means ± SD ($n = 3$). [c] Data are determined from pulpy rinds.

washed thoroughly with distilled water to remove acid and dried to a constant weight. It was considered to be a Klason lignin after correction for residual protein and ash.

Monosaccharide Analysis. Uronic acid (as galacturonic acid) and individual neutral monosaccharides released from NSPs in AIM-I and AIM-L were determined as described previously (*6*).

Physicochemical Properties. The water holding capacity (WHC) and oil holding capacity (OHC) of DF from passion fruit rinds were determined at 25 °C by a centrifugation procedure. Samples were prepared as described elsewhere (*14*).

Statistical Analysis. All measurements were performed in triplicate for each sample, and data were statistically analyzed by one-way analysis of variance (ANOVA). Differences were considered to be significant at $p < 0.05$.

RESULTS AND DISCUSSION

Fruit Physical Composition. The processing of mature-ripe YPF, on a laboratory scale, showed that juice, pulp, rind, and seed accounted for 34.5, 2.1, 50.7, and 12.7% fresh matter, respectively (**Table 1**). These values were rather similar to those obtained from the industrially processed YPF when pulp and rind were combined together. The rind accounted for half of the fruit (on average) and appeared to be its main component.

Proximate Composition. The fat, ash, and crude protein contents of AIMs ranged from 0.8 to 1.2% (w/w), from 4.3 to 6.7% (w/w), and from 8.4 to 12.8% (w/w), respectively (**Table 2**). The protein contents of AIMs were higher than the protein content (4.05%, w/w) of passion fruit peel flour (*7*) but comparable to the protein content (14.6%, w/w) of AIS prepared from defatted passion fruit seeds (*14*). In contrast, the ash content of AIM-I (6.7%, w/w) was higher than the ash content of AIS from defatted passion fruit seeds (1.6%, w/w) (*14*).

Dietary Fiber Composition. *AOAC Method.* The measurement of the DF content of laboratory-obtained fresh rind was not very accurate due to its rather high content of soluble solids (data not shown). Therefore, fresh rind materials were first desugared by alcohol washing as suggested (*13*) before determining the DF content. In contrast, defatting was not necessary because the fat content of AIM was low (**Table 2**). AIM-L represented 14.2% fresh matter (and 82.4% dry matter) (**Table 2**). The DF composition of the two different AIMs, determined as SDF, IDF, and TDF, is shown in **Table 2**. TDF accounted for 73.5% (w/w) AIM-I and 81.9% (w/w) AIM-L, indicating that DF components were predominant in the rinds. Significant differences ($p < 0.05$) were observed between the TDF contents of AIM-I and AIM-L. These differences possibly resulted from significant differences ($p < 0.05$) in SDF amounts. Indeed, the SDF content of AIM-I was significantly lower ($p < 0.05$) than the SDF content of AIM-L, whereas they had similar IDF contents. This suggested that part of the SDF was removed during industrial juice extraction. Industrial possessing of passion fruit currently includes enzymes (such as pectinase and rapidase) for better extraction and clarification of juice (*15–17*), and these enzymes are known to cause a release of polysaccharides (especially pectic substances), which are dietary fiber components, from the cell wall. A good agreement was found between TDF and the sum of SDF and IDF whatever the AIM sample. Hence, SDF could accurately be determined by calculation from the measurement of TDF and IDF as has been suggested (*13*). The TDF amounts in AIMs were higher, as compared to that reported (57.36%, w/w dry matter) in *P. edulis* f. *flavicarpa* peel flour (*7*). This may be due to differences in the origin of YPF (Brazil in their case) or probably to differences in the methods of preparation of dietary fiber-rich materials. Indeed, contrary to our method, their dietary fiber-rich material (*P. edulis* f. *flavicarpa* peel flour) was not desugared as its content of (apparently available) carbohydrates, calculated by differences in the moisture, ash, crude protein, lipid, and soluble and insoluble dietary fiber contents, was reported to be 21.28% (w/w) dry sample.

Table 2. DF Composition and Physicochemical Properties of AIM from YPF Rind[a]

dietary fiber-rich materials	AIM-I	AIM-L
yield (g of CWM/100 g of rind fresh matter)		14.2 ± 0.3 (82.4 ± 1.1)
proximate composition (%, w/w)		
fat	1.2 ± 0.1	0.8 ± 0.1
crude protein (N × 6.25)	12.8 ± 0.2a	8.4 ± 0.4b
ash	6.7 ± 0.1	4.3 ± 0.2
AOAC method DF composition (%, w/w)		
SDF	11.6 ± 0.2a	17.9 ± 0.4b
IDF	60.8 ± 0.5	62.4 ± 0.7
TDF	73.5 ± 1.2a	81.9 ± 1.4b
Saeman hydrolysis method monosaccharide composition (%, w/w)		
rhamnose	0.9 ± 0.1a	1.8 ± 0.1b
fucose	0.7 ± 0.1	0.6 ± 0.1
arabinose	1.3 ± 0.1a	2.8 ± 0.2b
xylose	8.4 ± 0.3	9.3 ± 0.4
mannose	3.5 ± 0.1	3.1 ± 0.1
galactose	2.1 ± 0.1a	4.7 ± 0.2b
glucose	37.9 ± 1.4	36.1 ± 1.2
uronic acid	14.1 ± 0.5a	21.3 ± 0.8b
total sugar (%, w/w)	68.9 ± 1.8a	79.7 ± 1.6b
Klason lignin (%, w/w)	9.8 ± 0.1a	6.7 ± 0.2b
WHC (g of water/g of fiber)	3.7 ± 0.1	4.1 ± 0.1
OHC (g of oil/g of fiber)	4.3 ± 0.1	5.2 ± 0.1

[a] Data are means ± SD ($n = 3$). Mean values in the same line with different letters are significantly different ($p < 0.05$).

Saeman Hydrolysis Method. The monosaccharide composition of AIMs showed that glucose was (by far) the main sugar followed by uronic acid (**Table 2**), indicating that cellulose and pectic substances were the main NSPs. Total sugar accounted for 68.9% (w/w) AIM-I and 79.7% (w/w) AIM-L, showing that DF was predominantly composed of NSPs. The sum of the amounts of Klason lignin and total NSP was comparable to the amount of TDF determined using the AOAC method. Hence, this (Saeman hydrolysis) method also can be used to accurately quantify the DF in YPF rind fiber-rich material as has also been used for other plant materials (*18, 19*). The rhamnose, arabinose, galactose, and uronic acid (as galacturonic acid) contents of AIM-I were significantly lower ($p < 0.05$) than those of AIM-L. These sugars (especially galacturonic acid) are the main constituents of pectic substances. Therefore, it could be inferred that the SDF fraction lost during industrial juice extraction was primarily composed of soluble pectin.

Physicochemical Properties. The WHC values of AIM-I and AIM-L (3.7−4.1 g/g) were similar to one another as well as the OHC values (4.3−5.2 g/g) (**Table 2**). These values were

relatively close to the WHC (3.20 mL/g) and OHC (3.52 g/g) values reported for AIS prepared from defatted passion fruit seeds (*14*).

YPF rind AIM is a dietary fiber-rich fraction. IDF appears to be its main component and can be connected to a high cellulose content. As a result, YPF rind could be used as a new dietary fiber source to possibly prevent the upsurge of diverticular diseases in some African regions.

ABBREVIATIONS USED

AIM, alcohol-insoluble material; AIM-I, alcohol-insoluble material from industrially obtained rinds; AIM-L, alcohol-insoluble material from laboratory obtained rinds; DF, dietary fiber; IDF, insoluble dietary fiber; NSP, nonstarchy polysaccharide; SDF, soluble dietary fiber; TDF, total dietary fiber; YPF, yellow passion fruit; WHC, water holding capacity.

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