Characterization of Syrups and Dietary Fiber Obtained from Mesquite Pods (*Prosopis pallida* L)

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Milled mesquite pods (*Prosopis pallida*) were washed in a pilot plant with water at two different weight:water ratios, times, and temperatures to obtain aqueous extracts and solid residues. The extracts were concentrated under two different conditions to obtain syrups or "algarrobinas", and the residues were dried and milled to yield dietary fiber (DF) concentrates. Total soluble sugars, protein, ash, and polyphenolic compounds were analyzed in syrups and DF concentrates, as well as fiber, starch, and fat in the fiber concentrates. The proximate composition of mesquite pulp was also analyzed. The main components of mesquite pulp were dietary fiber (257.1 g/kg) and soluble sugars (539.5 g/kg). Syrups were compared to three others commercialized locally in some regions of Peru, showing less sucrose inversion than in the commercial ones and the same brown color. Of the two fiber products obtained, one of them was a concentrate rich in total DF (801.9 g/kg) composed of mainly insoluble fiber. The other product had a lower DF content (447.7 g/kg) but a higher soluble sugar concentration (263.3 g/kg). The potential application of these products in the food industry is discussed.

Keywords: *Mesquite pods; Prosopis pallida; syrup; dietary fiber; pilot plant*

INTRODUCTION

Mesquite (*Prosopis* spp.) are thorny and woody leguminous plants growing wild in arid and semiarid regions worldwide with sizes varying from shrubs to full size trees. The special interest of this crop is related to its adaptation to extreme weather and soil conditions, tolerating high temperatures and low rainfall, and growing in saline soils as well as in nitrogen-poor soils due to its capacity to fix nitrogen (Becker et al., 1984; Felker, 1981; Silva, 1988). This makes *Prosopis* spp. a suitable plant to fight desertification, and the extension of its culture is recommended to promote development in drylands.

Prosopis spp. produce indehiscent fruits—mesquite pods—characterized by their high sugar (13−50%), dietary fiber (27−32%), and protein (11−17%) content (Becker et al., 1984; Bravo et al., 1994). Sugars, mainly sucrose, are concentrated in the pod pericarp and protein in the seed, which also contains a galactomannan gum similar to carob bean gum. *Prosopis* plants may produce pods twice yearly, constituing a potentially important crop considering the deprived conditions of the semidesertic areas where they grow. The use of *Prosopis* pods for human consumption dates from far back. When the Spaniards arrived in South America, specially in Peru, Chile, and Argentina, they found that the indians included *Prosopis* pods in their diets (Silva, 1990). In Chile, a refreshment called "añapa" is prepared from mesquite pods (Habit et al., 1981). In Mexico, "mezcal", a distilled drink produced from mesquite pods, is popular (Del Valle et al., 1987), like the "algarrobina cocktail" in Peru. However, the most extended use of this fruit nowadays is as animal forage. Some efforts have been made to promote mesquite pod use in the food industry, focused mainly on their utilization as a protein and dietary fiber source (Meyer et al., 1986; Del Valle et al., 1986, 1988; Zolfaghari et al., 1986). Also, many studies on mesquite gum properties have been carried out (Fernandes and Figuereido, 1995; Beristain et al., 1996; Goycoolea et al., 1995).

In the present work, we have studied the development of a technological process to use the fruit of *Prosopis pallida*. This species, morphologically and compositionally similar to *P. juliflora*, is common in desert areas of Peru, Mexico, Brazil, and other South American countries.

The average *P. pallida* pod weight is 12 g of which over 90% is constituted by the pulp (pericarp); seeds are small and numerous (about 25 seeds per pod). Previous analysis of this species carried out by our group showed that sucrose (46.3% dry matter) and dietary fiber (32.2% d.m.) were the main constituents of the pericarp, with appreciable amounts of protein (8.1%) and ash (3.6%), and minor quantities of polyphenolic compounds (1.2%) (Bravo et al., 1994; Grados et al., 1993). The endosperm gum was a galactomannan with a galactose:mannose ratio (1:1.36) similar to guar gum. Locally, some products from *P. pallida* pods such as syrups (algarrobina), instant coffee substitute, etc. are homemade and even commercialized in Peru.

The objective of the present work was to study two pilot plant processes to obtain syrup and dietary fiber concentrates from *Prosopis pallida* pods, analyzing the chemical composition of the final products.

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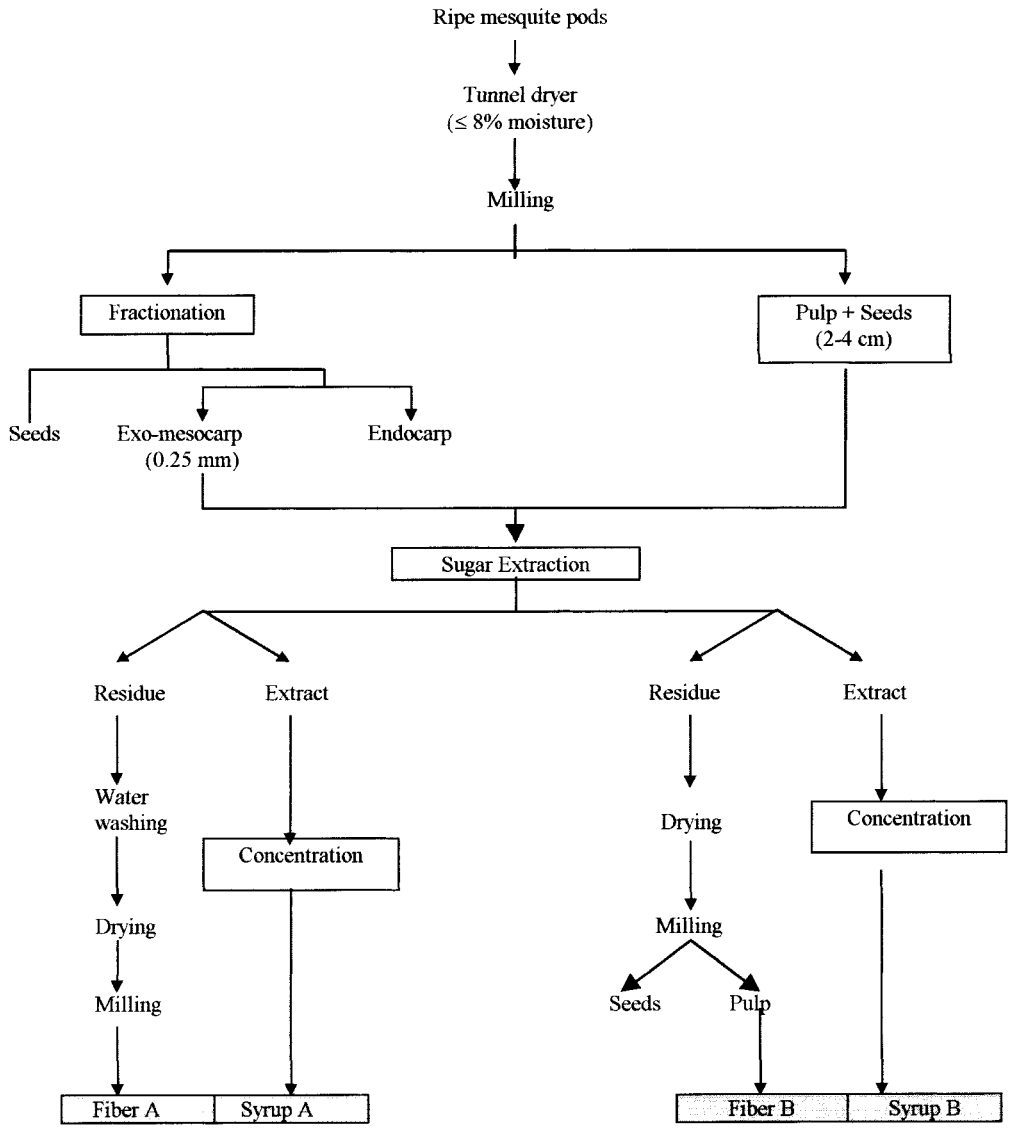

Figure 1. Scheme of the technological process followed at the pilot plant to obtain fiber concentrates and syrups from mesquite pods. The treatments within a clear box are different in the two processes (for full details see Materials and Methods).

MATERIALS AND METHODS

Ripe mesquite pods (*Prosopis pallida* L) were collected from the experimental field of the University of Piura (Piura, Peru) as well as from *Prosopis* trees growing in the surrounding rural areas. Pods were selected to eliminate those damaged by insects, washed with water to remove sand, drained, and finally dried in an air-circulating tunnel dryer at 80−90 °C to reduce the initial pod moisture from 12 to 8%.

Whole pods were milled in a domestic electric mincer (Tefal, Selongey, France) to separate pulp and seeds. Pulp was milled in a Cyclone sample mill (Tecator, Höganäs, Sweden) to a particle size less than 1 mm.

Syrups commercialized in the region of Piura were purchased in local markets and analyzed for comparison. These syrups were "Algarrobina" La Española, "Algarrobina Especial", Bauvi E. I. R. L., and "Algarrobina U. N. P." Centro de Procesamiento de Productos Agropecuarios, all elaborated in Piura (Peru).

Technological Processes. Figure 1 shows a scheme of the two processes followed at the University of Piura's pilot plant to obtain syrups and dietary fiber concentrates. In process A, whole pods were milled in a prototype hammer mill provided with 15 hammers and a screen size of 5 mm diameter. Rotation speed was 860 rpm. After sieving and air separation, pulp fractions of various particle sizes were separated from seeds. Only one pulp fraction, the major one with a particle size ≥0.25 mm, was used to obtain syrup and dietary fiber. This fraction was soaked with water (1:5, w/v) for 30 min at room temperature. After filtration, new pulp in a proportion of 1:4 (w/v) was added to the sugar extract obtained before, soaked again for 30 min, and filtered. The juice from this second extraction (approximately 23°Brix) was concentrated by heating at 60 °C with occasional stirring for 20 h, yielding syrup A of 65°Brix. The residues from the two washing steps were combined, thoroughly washed with running water, dried at 80 °C for 6 h, and milled, obtaining fiber product A.

In process B, whole pods were milled in a hammer mill into pieces 2−4 cm long. These pieces, without previous separation of seeds, were washed with water (1:3, w/v) at 60 °C for 25 min with constant stirring. After draining and pressing, a sugar extract of 8−10°Brix was obtained. This extract was further enriched in soluble sugars by adding fresh pod pieces in two consecutive steps in which the extraction conditions were as described above. The final extract (25°Brix) was vacuum-concentrated at 60 °C to obtain syrup B with 65−68°Brix. The residues were dried in a tunnel dryer with air circulation at 80 °C during 16 h, and then milled in the prototype hammer mill. Seeds were air-separated from the pulp, this one constituting the fiber product B.

Analytical Methods. Dietary fiber (DF) was determined by an enzymatic−chemical procedure (Mañas and Saura-Calixto, 1995). After enzymatic hydrolysis of digestible com-

ponents, insoluble and soluble dietary fiber fractions were separated and chemically hydrolyzed. Insoluble dietary fiber (IDF) fractions were hydrolyzed with sulfuric acid (12 M H_2SO_4, 30 °C, 1 h, and then diluted to 1 M H_2SO_4, 100 °C, 90 min). The remaining residues were gravimetrically quantified as Klason lignin after drying at 105 °C to constant weight. Soluble dietary fiber (SDF) fractions were hydrolyzed with 1 M sulfuric acid as described.

Constituent neutral sugars (NS) and uronic acids (UA) were quantified in the hydrolysates. UA were quantified spectrophotometrically by the Scott method (Scott, 1979) using galacturonic acid as standard. NS were determined by gas chromatography as alditol acetates using inositol as internal standard (Englyst and Cummings, 1988). A Shimadzu GC-14A (Shimadzu Co., Kyoto, Japan) gas chromatograph fitted with a flame ionization detector and an AOC-14 autoinjector, and connected to a C-R4A Chromatopac computing system, was used. The column was a SP-2330 capillary column (30 m × 0.32 i.d., catalog no. 2-4073; Supelco, Bellefonte, PA). Operation conditions were as follows: column temperature, 240 °C (isothermal); injector and detector temperature, 270 °C; carrier gas, nitrogen. IDF was calculated as (NS + UA) + KL, and SDF as (NS + UA).

Soluble sugars were quantified using Kontron HPLC equipment consisting of a 360 autosampler, a 325 pump system, and a 450-MTZ data system (Kontron, Milan, Italy) fitted to a R-401 Waters differential refractometer (Waters, Millipore Co., Milford, MA) and a Jones Chromatography thermostatic oven. Sugars were extracted from mesquite pulp and the fiber concentrates with water for instrumental analysis (Panreac Química S. A., Barcelona, Spain) during 1 h in a water bath at 60 °C with constant shaking. After centrifugation (15 min, 3000*g*), supernatants were filtered through C-18 Vac/1 cm^3 Set-Pak cartridges (catalog no. 23590; Waters, Millipore Co.) to remove polyphenolic compounds and through 0.45 μm filters for aqueous solutions (part no. SLHA025BS; Millipore S. A., Molsheim, France). Syrups were conveniently diluted and filtered. Fifty microliters was injected into a Bio-Rad Aminex HPX-87P column (300 × 7.8 mm) with two Bio-Rad microguard cartridges (30 × 4.6 mm, catalog no. 125-0118; Bio-Rad, Hercules, CA). The column was isocratically eluted with degasified water for instrumental analysis (Panreac) at 85 °C at a flow rate of 0.6 mL/min. Known standards were used to identify and quantify sugars.

Soluble polyphenols (SPP) were analyzed in the diluted syrups as well as in extracts obtained from the pulp and fiber concentrates. Sample (1 g) was successively washed with 40 mL each of methanol/water (1:1, v/v; 1 h, room temperature, constant shaking) and acetone/water (7:3, v/v; 1 h, room temperature, constant shaking) in 50 mL centrifuge tubes. After centrifugation (15 min, 3000*g*), supernatants were combined and made up to 100 mL. Total polyphenols were quantified as tannic acid equivalents using Folin−Ciocalteau's reagent (Montreau, 1972). Catechic polyphenols were quantified with HCl−vanillin reagent (Swain and Hillis, 1959).

Condensed tannins (CT) were analyzed in the residues obtained after the extraction of SPP. These residues were treated with 5% HCl−butanol (3 h, 100 °C) (Reed et al., 1982) to obtain anthocyanidin solutions that were quantified by reading their absorbance at 553 nm in a Perkin-Elmer Model Lambda 12 spectrophotometer (Perkin-Elmer Ltd., Beaconsfield, England). CT from the Mediterranean carob pod (*Ceratonia siliqua* L) were used as standard.

Total starch was determined after dispersion of the starch granules in 2 M KOH at room temperature (30 min, constant shaking) and hydrolysis of the solubilized starch with amyloglucosidase (EC 3.2.1.3; catalog no. 102857; Moehringer-Mannheim, Germany) (Goñi et al., 1997). Glucose was quantified using the Peridochrom Oxidase/Peroxidase (GOD−PAP) reagent (catalog no. 676543, Boehringer-Mannheim). Total starch was calculated as glucose × 0.9.

Total nitrogen was determined in the samples by the Kjeldahl method. A 1030 Kjeltec Autoanalyzer (Tecator, Höganäs, Sweden) was used. Protein was calculated as N × 6.25. *Fat* was quantified after extraction with light petroleum in a Soxtec System HT (Soxtec Extraction Unit 1043 and Service Unit 1046; Tecator, Höganäs, Sweden). *Ash* was quantified after calcination in a muffle furnace at 550 °C for 6h.

Color. A Hunterlab D25-9 colorimeter (HunterLab Inc., Reston, VA) was used to measure color dimensions *L*, *a*, and *b* in syrups and fibers in triplicate. The *viscosity* of syrups was measured at 25 °C using a Brookfield DV-I digital viscometer (Brookfield Engineering Laboratories Inc., Stoughton, MA). Measures were performed in triplicate after 5 min equilibration of the samples. *pH* values of syrups were measured in 50% (w/w) aqueous solutions.

Samples were analyzed in triplicate. Data are presented as mean values and standard deviations.

Table 1. Composition (g/kg Dry Matter) and Color Dimensions of Mesquite Pulp (*Prosopis pallida*) and Dietary Fiber Concentrates[a]

	pulp	fiber A	fiber B
dietary fiber			
TDF	257.1 ± 0.51	801.9 ± 13.4	447.7 ± 7.7
IDF	231.4 ± 0.55	764.4 ± 20.4	391.4 ± 6.3
SDF	25.7 ± 0.50	37.5 ± 9.2	56.3 ± 2.9
soluble sugars	539.5 ± 0.43	19.7 ± 0.7	263.3 ± 9.5
total starch	8.4 ± 0.19	10.5 ± 2.2	21.4 ± 2.4
total SPP	12.4 ± 0.4	4.1 ± 0.1	13.5 ± 0.1
catechins	1.8 ± 0.2	1.6 ± 0.1	2.3 ± 0.1
condensed tannins	2.6 ± 0.1	7.3 ± 0.6	6.9 ± 0.2
protein	40.1 ± 0.8	29.0 ± 0.4	120.2 ± 1.2
fat	7.1 ± 0.3	7.9 ± 0.3	15.3 ± 7.0
ash	36.7 ± 0.1	16.7 ± 0.1	35.1 ± 0.4
moisture	56.3 ± 1.7	57.0 ± 4.1	41.4 ± 1.4
color dimensions			
L	ND	67.06 ± 0.36	62.41 ± 0.10
a	ND	0.33 ± 0.12	0.48 ± 0.10
b	ND	20.30 ± 0.16	18.94 ± 0.22

[a] Mean values ± STD ($n = 3$). Abbreviations: TDF, total dietary fiber; IDF, insoluble dietary fiber; SDF, soluble dietary fiber; SPP, soluble polyphenols; ND, not determined.

RESULTS

Dietary Fiber Concentrates. The proximate composition of the mesquite pulp as well as the two dietary fiber concentrates obtained following the described technological processes is shown in Table 1. Soluble sugars accounted for over 50% of the pulp dry weight, sucrose being the major constituent of this fraction as reported earlier (Bravo et al., 1994). Mesquite pulp also showed a high total dietary fiber (TDF) content (257.1 g/kg dry matter). Insoluble dietary fiber (IDF) was the main component of this fraction, with only minor amounts of soluble dietary fiber (SDF). Protein and ash were present in small quantities (about 40 g/kg), while starch and fat were minor components. Similarly, the polyphenolic compounds, both soluble polyphenols and condensed tannins, were minor constituents of mesquite pulp.

The main difference between the two fiber products was related to their dietary fiber and soluble sugar content. Fiber A contained almost twice as much total dietary fiber as fiber B. In both samples, the main fiber fraction was insoluble (95% and 87% of the TDF in fibers A and B, respectively). On the other hand, fiber B was much richer in soluble sugars. HPLC analysis of the aqueous extracts from the two fiber concentrates showed that fiber A only had appreciable amounts of sucrose (12 g/kg dry matter) and minor amounts of inulin, glucose, xylose, arabinose, and fructose (about 1−2 g/kg). However, fiber B had a very high sucrose content (180.9 g/kg dry matter); significant amounts of glucose

Table 2. Detailed Composition of the Dietary Fiber Fractions of the Two Fiber Concentrates Produced at Pilot Plant Scale (g/kg Dry Matter)[a]

	fiber A			fiber B		
	IDF	SDF	TDF	IDF	SDF	TDF
rhamnose	3.5 ± 0.1	ND	3.5 ± 0.1	tr	ND	tr
arabinose	29.4 ± 1.8	5.6 ± 0.7	35.0 ± 1.2	24.5 ± 1.6	7.3 ± 0.1	31.8 ± 1.6
xylose	192.3 ± 8.7	tr	192.3 ± 8.7	85.5 ± 4.4	2.2 ± 0.1	87.8 ± 4.3
mannose	5.2 ± 0.2	tr	5.2 ± 0.2	3.7 ± 0.7	6.2 ± 0.6	9.9 ± 0.3
galactose	12.4 ± 0.7	ND	12.4 ± 0.7	7.4 ± 0.5	5.4 ± 0.7	12.8 ± 0.6
glucose	228.4 ± 3.3	ND	228.4 ± 3.3	111.0 ± 0.9	tr	111.0 ± 0.9
total NS	475.8 ± 13.4	5.6 ± 0.7	476.8 ± 9.0	232.7 ± 6.5	21.8 ± 2.6	254.5 ± 7.2
uronic acids (UA)	76.8 ± 11.7	28.1 ± 3.8	104.9 ± 8.4	47.9 ± 0.8	34.5 ± 0.6	82.4 ± 1.4
(NS + UA)	552.6 ± 24.7	37.5 ± 9.2	590.1 ± 17.0	280.6 ± 7.0	56.3 ± 2.9	336.9 ± 8.2
Klason lignin (KL)	211.8 ± 7.5		211.8 ± 7.5	110.8 ± 1.4		110.8 ± 1.4
total dietary fiber	*764.4 ± 20.4*	*37.5 ± 9.2*	*801.9 ± 13.4*	*391.4 ± 6.3*	*56.3 ± 2.9*	*447.7 ± 7.7*

[a] Mean values ± STD (n = 4). Abbreviations: TDF, total dietary fiber; IDF, insoluble dietary fiber; SDF, soluble dietary fiber; NS, neutral sugars; ND, not detected; tr, trace amounts.

Table 3. Composition (g/kg), Color Dimensions, and pH Values of the Syrups Obtained from Mesquite Pods (*P. pallida*) following Two Technological Processes; Comparison with Commercial Mesquite Syrups[a]

	syrup A	syrup B	syrup Bauvi	syrup La Española	syrup UNP
soluble sugars (g/kg)	432.0 ± 22.3	423.5 ± 29.2	813.1 ± 134.5	607.1 ± 55.2	516.2 ± 53.1
total SPP (g/kg)	12.0 ± 0.2	11.7 ± 0.1	6.7 ± 0.1	21.5 ± 0.4	14.8 ± 0.3
protein (g/kg)	55.7 ± 6.9	53.4 ± 1.0	7.8 ± 3.3	65.5 ± 0.5	54.6 ± 4.7
ash (g/kg)	33.1 ± 0.4	35.8 ± 0.6	4.7 ± 0.7	45.0 ± 0.7	41.7 ± 1.1
moisture (g/kg)	266.3 ± 3.6	311.3 ± 0.5	152.2 ± 0.7	171.0 ± 9.6	180.9 ± 5.2
pH[b]	4.82	5.16	3.81	4.51	4.76
color					
L	3.56 ± 0.07	6.66 ± 0.02	1.08 ± 0.16	1.45 ± 0.16	2.89 ± 0.13
a	1.43 ± 0.15	0.75 ± 0.06	−1.98 ± 0.35	−1.98 ± 0.35	0.58 ± 0.36
b	4.33 ± 0.02	4.25 ± 0.04	7.69 ± 2.38	8.91 ± 1.32	4.51 ± 0.11

[a] Mean values ± STD (n = 3). SPP, soluble polyphenols. [b] pH values of 50% (w/w) aqueous solutions of syrups.

(38.2 g/kg), xylose (10.5 g/kg), and fructose (25.8 g/kg); and only minor quantities of inulin and arabinose (about 3 g/kg).

As to the other compounds analyzed, in general fiber B showed higher values than fiber A, suggesting a better extraction of soluble compounds following process A. Starch content was very low in both samples (Table 1). Total starch, fat, and ash were almost double in fiber B, which also showed higher amounts of total soluble polyphenols and catechins than fiber A. Only the content of condensed tannins was similar in the two products. Protein was much higher in the fiber obtained following process B, probably due to the presence of the seeds during sugar extraction.

The color dimensions of the two fiber concentrates were comparable, only fiber B showed a slightly lower *L* value (lightness). The *b* coordinate reveals the yellow color of these fibers, with very little red (*a* value) component (Table 1).

Detailed analysis of the constituent nonstarch polysaccharides and Klason lignin (KL) of the two fiber concentrates showed that glucose and xylose were the main monosaccharides in the insoluble dietary fiber fractions (Table 2). This suggests a high content of cellulose and hemicellulose. Also present were pectic substances linked to the cell wall polysaccharides as suggested by the high uronic acid content of the IDF fractions. KL content was very high in both fiber products; the amount of KL in fiber A, as with the other insoluble fiber constituents, was nearly double than that of fiber B. Concerning soluble dietary fiber, this was very low in both products, and it was made of mainly pectins (Table 2). The higher content of SDF in fiber B suggests the solubilization of some polysaccharides from the endosperm gum (galactomannan) incorporated into the SDF fraction. This was confirmed by the presence of galactose and mannose among the constituent monosaccharides. There were also soluble hemicelluloses (arabinoxylans) present in fiber B that were not removed during the extraction of soluble sugars as presumably occurred in fiber A.

Syrups. The composition and pH and color values of the analyzed syrups or algarrobinas are shown in Table 3. Three mesquite syrups commercialized locally in some regions of Peru were also analyzed for comparison. The two syrups obtained by us had a lower sugar content than the commercial ones because they were concentrated to only about 65−68 °Brix, whereas the commercial syrups were more concentrated (>75 °Brix). Algarrobina Bauvi was the syrup with the highest soluble sugar content.

The two syrups obtained had a low proportion of sucrose inversion. Syrup concentration under vacuum seemed to be better than concentration under atmospheric pressure since sucrose inversion was lower in the former (syrup B). Of the total sugar content of syrup B, obtained after vacuum concentration, 81% was sucrose while this percentage was reduced to only 66% when concentrated in an open pan as in syrup A (Table 4).

Although the commercial syrups had a higher total sugar content, they had a higher level of sucrose inversion, specially algarrobina Bauvi having only 34% as much sugar content (Table 4). U.N.P. commercial syrup most resembled those collected by us, having a sucrose content of 62% (Table 4). In each syrup, sucrose, glucose, and fructose were the main sugars, although small amounts of inulin, stachyose, and xylose were present (Table 4).

Soluble polyphenols were present in small amounts in all the studied syrups (Table 3), La Española being the algarrobina with the highest value (21.5 g/kg).

Table 4. Saccharide Content of Mesquite Syrups (g/kg Fresh Matter)[a]

	syrup A	syrup B	syrup Bauvi	syrup La Española	syrup UNP
inuline	tr	tr	ND	2.7 ± 0.8	1.6 ± 0.5
stachyose	9.8 ± 0.7	1.7 ± 0.2	9.0 ± 2.6	3.8 ± 0.6	2.9 ± 0.9
sucrose	283.4 ± 4.7	343.7 ± 22.2	275.6 ± 41.7	285.8 ± 26.0	322.0 ± 29.1
glucose	42.8 ± 1.2	30.4 ± 3.2	257.5 ± 41.8	79.3 ± 7.9	58.4 ± 7.3
xylose	29.3 ± 2.6	32.4 ± 4.6	ND	36.5 ± 1.4	35.6 ± 5.2
fructose	29.9 ± 14.0	15.1 ± 1.4	271.1 ± 48.9	198.9 ± 19.6	95.7 ± 11.2
total	432.0 ± 22.3	423.5 ± 29.2	813.1 ± 134.5	607.1 ± 55.2	516.2 ± 53.1

[a] Mean values ± STD ($n = 3$). Abbreviations: ND, not detected; tr, trace amounts.

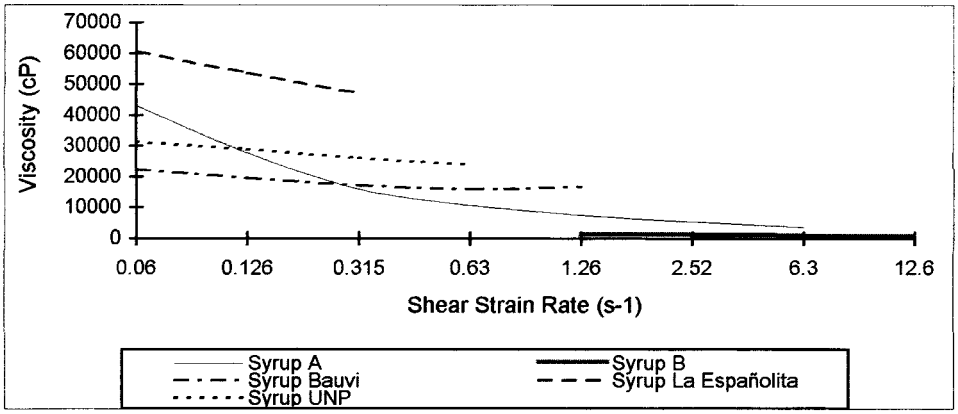

Figure 2. Viscosity of mesquite syrups.

Except for Bauvi, the protein content of these samples was over 50 g/kg. The ash content was about 30−45 g/kg in all syrups except again for Bauvi, that also showed the lowest pH value.

All the algarrobinas had a brown color with a slightly reddish tone (positive *a* value) in the test syrups. Bauvi and La Española showed the highest *b* value (yellow), although they had the lowest lightness (*L* value of the tristimulus color scale) (Table 3).

As to the rheological analysis, all syrups showed a non-Newtonian, pseudoplastic behavior (Figure 2). Commercial syrups were more viscous than the test ones due to the higher sugar concentration of the former.

DISCUSION

This paper reports on two variations of a technological process to obtain potential food ingredients from mesquite pods (*Prosopis pallida* L). The practical approach to the use of this underexploited legume crop led to the obtention at pilot plant scale of syrups and dietary fiber concentrates which have been largely characterized. The two pilot plant processes basically contemplated the extraction of soluble sugars from the sugar-rich pod to obtain syrup, also known as algarrobina, after concentration. The remaining residue constitutes a fiber-rich fraction with potential uses in the food industry. In both procedures, a fractionation step was carried out at some point of the technological process to separate seeds from the pericarp or pulp. Maximum yield of seed separation is preferred due to the potential value of some seed components, such as the gum endosperm or the protein-rich germ (Bravo et al., 1994).

Process A proved to be more effective than process B in removing soluble compounds from the small-particle-size pulp fraction used as starting material, resulting in a fiber concentrate extremely rich in total dietary fiber (TDF), mainly insoluble (fiber A). The positive implications on health of the consumption of dietary fiber are well-known. Specifically, insoluble dietary fiber (IDF) has been related to the prevention of intestinal diseases such as gallstones, constipation, diverticulosis, colon cancer, etc. (Kritchevsky et al., 1990; Johnson and Southgate, 1994; Kritchevsky and Bonfield, 1995). As a consequence of these reported beneficial effects of DF, an increased consumption of this dietary component has been recommended (British Nutrition Foundation, 1990; Cummings and Bingham, 1992). This has resulted in the proliferation of food products enriched in DF as well as in commercial dietetic items such as tablets, soluble powders, and a wide range of regime products formulated with high DF contents.

The obtention of a product such as fiber A, rich in IDF, could be of use in the food industry as an ingredient in bakery (i.e., bread, biscuits, crackers), in meat products, etc. On the other hand, the second fiber concentrate obtained in the present work, fiber B, was shown to retain a high amount of soluble sugars (263.3 g/kg dry matter) yet still having a high content of dietary fiber (413 g/kg) (Table 1). In this case, fiber B was slightly richer in soluble DF than fiber A, presumably due to the retention of some gum polysaccharides from the seed endosperm. Also, the protein content in fiber B was higher than in fiber A. The most likely origin of this protein is from the seed germ since the presence of some seed fragments in this product cannot be ruled out.

If we judge the two technological processes studied in terms of their efficiency of sugar removal from the mesquite pod, then we should consider process B to be less effective than process A. However, other factors should be taken into account. In the first place, process A includes washing of the residues from sugar extraction with running water to achieve a complete removal of soluble components (see Figure 1). Although effective, this is an expensive step that would increase the global economical cost of the process to obtain the fiber concentrate. Moreover, considering the semi-desertic

conditions of the regions where mesquite trees grow and where the technological treatments would be carried out, this process should be ruled out unless the obtention of a fiber product virtually free of soluble sugars is the final aim (to be used, for instance, as an ingredient in diets for diabetics or in bread-making). Process B would then be the method of election, and fiber B could be used in baked products such as cookies, muffins, etc. where its sugar content (mainly sucrose) would result in a reduced use of sweeteners in their formulation with the additional economical saving. The yellow color of the two fiber concentrates would affect only slightly the final appearance of the food products.

Zolfaghari et al. (1986) prepared muffins and crackers made from wheat flour substituted with a mesquite (*P. glandulosa*) flour that contained 300 g/kg crude fiber and over 500 g/kg sugar. These authors found that this honey mesquite flour could be substituted for wheat flour up to 30% in crackers and 10% in muffins without affecting the sensory properties of these products. Similarly, Meyer et al. (1986) obtained *Prosopis* flours that were used as food ingredients in a variety of products such as bread, crackers, tortilla chips, chapatis, etc. These authors found that levels of wheat or corn flour substitution from 5% to up to 50%, depending on the food product, did not affect or even improve the organoleptic properties of the food items.

Other traditional yet limited uses of mesquite flour are as coffee and cocoa substitutes after roasting and partial sugar removal. These could be other alternative applications of the products described in this paper.

The obtention of fiber concentrates from mesquite pods constitutes an interesting agro-industrial use of this crop, but not the only one. As stated here, fiber and syrup production goes together in a simple technological process. The concentration of the sugar extracts from fiber obtention (Figure 1) can yield a good quality syrup even when this concentration is performed in a simple open pan as in process A (syrup A), so long as some precautions are adopted, such as not to exceed 60 °C to prevent sucrose inversion. Concentration under vacuum speeds up the process and renders a product (syrup B) of even better quality in terms of sugar composition (Table 4).

When compared with commercial products, the test syrups showed a lower sugar content that resulted in a lower viscosity (Table 4 and Figure 2). Nevertheless, further concentration can still be performed in the test syrups. The quality of the studied commercial products, however, appeared to be poorer than that of syrups A and B. All the commercial samples had a higher level of sucrose inversion (Table 4), which suggests that high temperatures had been used during the concentration of sugar solutions.

On the other hand, except for Bauvi, all syrups showed similar pH values and protein, ash, and polyphenolic content. Also, all of them showed brown color. This color can be originated from Maillard reactions between reducing sugars and amino acids from the protein present in the syrups (Table 3) upon heating, as well as from caramelization, a reaction that takes place when heating sugar and sugar syrups in the absence of compounds containing amino groups (Kearsley and Dziedzic, 1995; Whistler and BeMiller, 1997). In either case, brown colored products are formed, giving the characteristic appearance of these syrups. In some cases, browning reactions are not desirable, and a colorless syrup is preferred. Clarification of syrup should then be performed, and work in this respect is presently ongoing. However, colored syrups can also be desirable: brown Maillard reaction products are important contributors to the aroma and flavor of many foods such as milk chocolate or toffees. Colored algarrobina syrups present a pleasant taste and aroma that is preferred by the consumers. Therefore, depending on the future use and nonlocal commercialization of the algarrobina syrups, brown colored or water-clear clarified products could be obtained.

There are many potential uses of mesquite syrups in the food industry. Already popular in some Latin American countries are the "algarrobina cocktail", prepared diluting algarrobina syrup with milk and spirits, or mezcal and aluá, distilled and fermented drinks, respectively (Del Valle et al., 1987; Silva, 1990). However, mesquite syrups could also be used as food ingredients instead of the most commonly used glucose syrups in confectionery (caramels, toffees, gums, fudges), ice-creams, or bakery products as topping or filling, as savory sauces, or as preservers (Jackson, 1995).

CONCLUSIONS

A simple and feasible technological process based on the extraction of water soluble components from mesquite pods (*Prosopis pallida*) can be applied to obtain quality syrups and dietary fiber concentrates that could be used as food ingredients. Considering the high sugar (up to 500 g/kg) and dietary fiber (322.2 g/kg) content of these mesquite pods, they constitute an excellent material for which agro-industrial uses would enhance their economic value.

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