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Chemical Composition and Functional Properties from Different Sources of Dietary Fiber

Yesica N. Mora[1], Juan C. Contreras[1], Cristóbal N. Aguilar[1], Paola Meléndez[1], Ileana De la Garza[2], Raúl Rodríguez[1,*]

[1]Food Research Department (D.I.A.), Autonomous University of Coahuila, Saltillo, Mexico
[2]Analytical Chemistry Department, Autonomous University of Coahuila, Saltillo, Mexico
*Corresponding author: rrh961@hotmail.com

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Abstract Dietary fiber (DF) is considered as an important element in nutrition and health. By this reason, there is need for identify new sources of DF that contributes to improving human health and nutrition and /or animal. Different new DF sources were evaluated such as sotol pineapple (SP), green beans (GB), some agro-residues derived from sotol production (SW), red (RPPH) and green prickly (GPPH) pear husk, wheat bran (WB) and corn flour. These last two used as control. SW was rich in DF (77%), while corn (26.56%) and RPPH (14.03%) presented the lowest DF content in dry base. SW, GB and GPPH presented high content of minerals as potassium, calcium and iron. The water holding capacity of the materials was 9.84 mL/g for GB and around 7 ml/g for GPPH/RPPH. The material with high oil holding capacity was SW (3.32 mL/g). The best emulsifying ability and stability were observed in SP (80 and 94.6%), SW (81.6 and 90%) and GPPH (68.3 and 95%) respectively. All these results indicated that some that these materials have potential to be utilized as functional ingredients in foods.

Keywords: *dietary fiber, functional properties, sotol, green beans, prickly pear husk, wheat bran, corn flour*

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1. Introduction

Food satisfies a primary biological need and influences human behavior related to its consumption and nutritional status. A good diet should include different nutrients which provide defined biological functions in the body; proteins, lipids, carbohydrates, vitamins, minerals and dietary fiber are the most important nutrients. Dietary fibers are considered today as an important element in nutrition and health [1,2,3,4]. Dietary fiber includes molecules as cellulose, hemicellulose, lignin, pectin, gums, mucilage and other polysaccharides and oligosaccharides associated with plants. The main characteristic of those molecules is it resistant to the digestion process and the subsequent absorption in the human small intestine, other particular characteristic is the complete or partial fermentation in the large intestine [5]. Dietary fiber is a not digestible fraction, whereas cereals, vegetables, tubers, fruit and algae, all of which are characterized by high dietary fiber concentration, low digestibility and low caloric content [6,7].

The addition of dietary fiber to foods can affect the texture; by this way the most common uses are as texturing and stabilizing agent (dispersions, emulsions, etc.), through gel formation or the continuous [8]. Insoluble dietary fiber increases the food firmness of products and provides high fat absorption capacity [9]. The functional properties of dietary fiber are related to chemical composition and due by the process conditions to obtain food, the main physicochemical properties are size of the particle, swelling, cation exchange, water and oil-holding capacities, absorption and fermentation of organic molecules, among others [10,11,12,13,14].

The principal physiological effect of fiber is its ability to swell after water absorption, which occurs due to three mechanisms: carbohydrates with free polar groups (pectin), interaction with hydrophilic bonds or retention within the matrix [15]. These mechanisms lead the gel formation and a consequent increase in feces volume, which generates more frequent intestine peristaltic movements. This facilitates the transit of the feces and the intestinal distention, thus aids in reducing the probability of intestinal tract disorders and constipation [16]. Other technological application is the fact that fiber improves the foams and emulsions stability; while in gel form it also displays exceptional fatlike characteristics [17].

Fruits, cereals, legumes and grains are considered good source of dietary fiber. While fruits and vegetables co-products can be used for production of food ingredients, per example, polyphenols, protein isolates and dietary fiber [18]. The objectives of the food industry, together with the need to find a way to eliminate the high proportion of byproducts and effluents that constitute a problem due to its useless accumulation and increased cost in the disposal management, open the possibility to be considered as raw material for the production or enrichment the other food [19].

Some examples of co-products are the wastes from sotol industry and husk of fruit as prickly pear. Use of agro industrial wastes as unconventional sources of fiber may be useful from economical, social, nutritional and environmental standpoints; because the wastes economic value is low, some has low fat content and can be a good source of fiber and minerals. The aim of this work was to determine the chemical and functional properties of novel dietary fibers, from different unconventional sources including green beans, sotol pineapple, prickly pear husks (green and red), sotol wastes, corn flour and wheat bran, which can be used as functional dietary fibers.

2. Methods and Materials

2.1. Vegetal Material and Sample Preparation

Wheat bran, corn, green beans, sotol pineapple and wastes, green and red prickly pear husks were used. Wheat bran, green beans and prickly pear husks were obtained from a local supplier (Saltillo, Coahuila, Mexico). Corn from a triple hybrid (An-Exp-II [AN-(CS8xML) x AN-Tep-3]) was provided by researchers of the Universidad Autonoma Agraria Antonio Narro. Sotol pineapple and wastes were provided by the Sotolera Nazas (Durango, Mex.). Prickly pear husks were removed from fruits and spines, epidermis and glochis were manually removed from husks. All samples were dried at 65°C and ground; then, samples were sieved and the particles in range from 75 to 425 µm were recollected. All the samples were stored at room temperature, under light protection until it analysis.

2.2. Chemical Analysis

Proximate analysis from the waste samples were done using AOAC methods [20]: fat content (Method 985.15) was measured by extraction with ethyl ether in a Soxhlet system and ash content (Method 923.03) was determined by sample incineration at 550°C for 5 hours in muffle furnace. Total soluble carbohydrates (TSC) was analyzing using the Antrona method [21], reducing soluble carbohydrates (RSC) with DNS method [22] and total dietary fiber (TDF) with a gravimetric-enzymatic method using the TDF-KIT (MEGZYME®) following the manufacturer instructions.

2.3. Macro and Microelements

Ashes were recovered from chemical analysis, 100 mg of the sample were weighed and recovering with 5 mL of HCl 6M. Then it was diluted until 100 mL with deionized water. Samples were run in triplicate. Samples were analyzed using an atomic absorption spectrophotometer (VARIAN-AA240FS). In this case, sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca), manganese (Mn), cooper (Cu), iron (Fe) and zinc (Zn) were determined.

2.4. Functional Properties

2.4.1. Water-Holding Capacity (WHC)

Tenmilliliters of distilled water were added to 500 mg of dried powdered samples in a 50 mL centrifuge tube. The samples was stirred and left, at room temperature, for 18 h. After centrifugation at 3000g for 20 min, supernatant was discarded and the residue was weighted [10]. Results were expresses as g of water/ g dry base.

2.4.2. Swelling Capacity (SC)

The dried powder sample (500 mg) was weighed in a 10 mL measuring cylinder (0.1 mL graduations), then was added 10 mL of distilled water. Total volume (mL) occupied by the sample was measured. After that, it was gently stirred to eliminate trapped air bubbles and left on a level surface, at room temperature, 24h to settle the sample [12]. The volume (mL) occupied by sample was measured and SC and expressed as mL of water/ g of dry base.

2.4.3. Oil-Holding Capacity (OHC)

Tenmilliliters of commercial virgin olive oil (0.5°) was added to 500 mg of dried powder samples in a 50 mL centrifuge tube. Sample was stirred and left, at room temperature, for 18h. After centrifugation at 3000g for 20 min, supernatant was discarded and residue was weighted [10]. Results were expressed as g of olive oil/ g dry base.

2.4.4. Organic Molecule Adsorption Capacity (OMAC)

In centrifuge tubes (50 mL) were weighed 500 mg of each sample, were added 10 mL of commercial sunflower oil and manually shaken for 10 min. After 24 h, at room temperature, without movement samples were centrifuged (3000g) for 10 min, supernatant was removed immediately and pellet was weighed (g) [10].Results were expressed as mL/ g dry base.

2.4.5. Cation Exchange Capacity (CEC)

In centrifuge tubes (50 mL) were placed 2g of the sample in an excess of 2 N hydrochloric acid (20mL), after 24h, at room temperature, hydrochloric acid was removed by filtration and was added a saturated solution of chloride sodium and washed with distilled water. H^+ ions captured by the sample were determined by titration with NaOH 0.5 M, reporting the result in milliequivalents of H^+ / g sample [23].

2.4.6. Emulsifying Activity (EA) and Emulsion Stability (ES)

One hundred milliliters of 2 g/100 mL of each sample (2 g/100 mL) suspension was homogenized using a WiseTis* HG-15 D homogenizer at 4489g for 2min. Then, 100 mL of corn oil was added to each sample and homogenized for 1 min at 5976g. The emulsions were centrifuged in 15mL graduated centrifuge tubes at 1200g for 5min, and finally the emulsion volume was measured. Emulsifying activity was expressed as the ml of emulsified layer volume of 100mL entire layer in centrifuge tube. Emulsion stability was determined by heating the prepared emulsions to 80°C for 30min, cooling them to room temperature and centrifugate at 1200g for 5min. Emulsion stability was expressed as ml of the remaining emulsified layer volume of 100 mL from the original emulsion volume [24].

2.4.7. pH

One hundred milliliters of deionized, boiled and cold water was added to 10g of sample. Then they were mixed for 30 minutes, after that, supernatant was discarded. Sample was stranded for 10min and pH was measured using a potentiometer (Thermo Orion 420) [25].

2.5. Statistical Analysis

All determinations were made in triplicate under a randomized complete block design, when needed, mean comparisons were performed using the Tukey´s Multiple Range Procedure ($P < 0.05$) using the Infostat software. Differences between means at the 5 % level were considered significant. In order to compare the chemical composition and functional characteristics of each sample was done a principal components analysis, using the Infostat software.

3. Results and Discussion

Particle range used in the experiments was from 75 to 425 microns, since particles smaller than 50 microns may cause lumps on food mixes and particles larger than 500 microns would be difficult to chew [26]. The highest moisture content was observed in green beans and prickly pear husk with around 90 g/100 g moisture; while corn (7.99 ± 0.81 g/100 g) and wheat bran (9.02 ± 0.13 g/100 g) had the lowest moisture values. Prickly pear husk has moisture characteristic like semi-desert plants and this characteristic helps to abide this type of ends weather [27]. Significant differences were observed between moisture content of sotol pineapple (67.22 ± 1.9 g/100 g dry base) and sotol wastes (9.65 ± 0.09 g/100 g dry base). This is because after fermentation of the pineapple, the liquid is removed and the wastes are discarded.

3.1. Proximate Composition

Chemical composition of the analyzed samples is shown in Table 1. Significant differences ($P < 0.05$) were observed among samples for ash, fat, dietary fiber content, as well as in total and reducing soluble carbohydrates concentrations. The ash content of green and red prickly pear husks and sotol wastes was higher than other material studies in this work (Table 1). Obtained results from prickly pear husks were similar to those reported by Bensadon*et al.*,[28] for pulp of prickly pears. Respect to the mineral content, these materials can be food supplement because it matches with the recommended daily intakes for some minerals and trace elements. The highest fat content was observed in corn with 7.58 g / 100 g dry base, all other vegetal material showed lower amounts as sotol pineapple and its wastes, green beans and prickly pear husks.

Table 1. Proximate composition of analyzed samples

Sample	Ash	Fat	TSC	RSC	TDF
WB	4.73 ± 0.08 ^{e}	3.66 ± 0.27 ^{b}	18.94 ± 1.3 ^{d}	6.80 ± 0.28^{c}	41.83 ± 6.5 ^{b}
Corn	1.56 ± 0.07^{g}	7.58 ± 0.05^{a}	21.37 ± 0.7 ^{d}	6.23 ± 0.26 ^{c}	26.56 ± 1.4^{c}
SP	3.36 ± 0.03^{f}	1.24 ± 0.25 ^{d}	93.99 ± 4.2 ^{a}	27.25 ± 2.3 ^{a}	45.1 ± 1.36 ^{b}
SW	11.85 ± 0.5 ^{c}	1.07 ± 0.14 ^{d}	14.51 ± 2.1 ^{d}	6.00 ± 0.05 ^{c}	77.88 ± 2.4 ^{a}
GB	9.06 ± 0.03^{d}	1.30 ± 0.04 ^{d}	39.97 ± 9.1 ^{c}	18.94 ± 1.7 ^{b}	45.25 ± 0.6^{b}
GPPH	18.10 ± 0.08 ^{a}	1.21 ± 0.15 ^{d}	28.4 ± 10.2^{b}	27.74 ± 2.9^{a}	33.13 ± 1.7^{c}
RPPH	13.29 ± 0.17 ^{b}	2.33 ± 0.18^{c}	60.35 ± 6.8 ^{c}	31.78 ± 0.46 ^{a}	14.03 ± 1.0^{d}

g/ 100 g dry base. Mean ± SD. g/ 100 g dry base. Different letter in the same column are significantly different ($p < 0.05$) according to Tukey's Multiple Range test.

No significant differences were observed in fat content neither between prickly pear husk or between pineapple and sotol wastes. Most legumes are very poor in fats; green beans are not the exception [19].Sotol pineapple has the highest content of total sugars, followed by green prickly pear husk, green bean and red green prickly pear husk (Table 1). The fermented residues of sotol contain the least amount of sugar, this due by the fermentation process suffered. From the amount of total soluble sugars, those that are available are called reducing sugars. These results indicate that the evaluated vegetal materials contain nutrients that can still be used by the organism and / or intestinal bacteria as probiotics [29,30]. The green beans and sotol wastes presented the highest content of dietary fiber, however the latter, has low amount of available sugars (Table 1). Meanwhile, red prickly pear husk had the lowest dietary fiber but higher sugar available than others.

3.2. Mineral Composition

Every form of living matter requires these inorganic elements or minerals for their normal life processes [31,32]. Macroelements are needed in large quantities (more than 100 mg per day), while trace elements are needed in smaller amounts [33,34]. Table 2 shows the mineral content for each raw materials with atomic absorption spectroscopy. Sotol wastes have the highest minerals content, followed by green beans and green prickly pear husk; while corn has lowest mineral content (Table 2). Potassium and calcium were the predominant macroelements red and green prickly pear husk, these results are lower than those reported by El Kossori*et al.* [35]; this may be attributed to the different origins of the prickly pear husk materials.

Table 2. Mineral composition of raw material samples

Sample	Na	K	Ca	Mg	Fe	Mn	Zn	Cu
WB	19.29 ± 1.75^{b}	554.4 ± 24.4^{c}	52.97 ± 1.8^{e}	185.92 ± 12.67^{c}	6.92 ± 0.32^{c}	6.88 ± 0.3^{b}	5.64 ± 0.05 ^{a}	0.75 ± 0.02^{b}
Corn	6.08 ± 0.95 ^{b}	12.5 ± 3.36^{c}	4.31 ± 0.4^{e}	81.89 ± 5.26 ^{d}	1.01 ± 0.09^{e}	2.59 ± 0.05^{d}	2.58 ± 0.04 ^{c}	0.12 ± 0.0^{b}
SP	10.82 ± 0.65 ^{b}	317.3 ± 94.5^{c}	302.4 ± 77.55^{d}	19.77 ± 4.94^{e}	1.07 ± 0.26^{e}	0.27 ± 0.08^{f}	0.42 ± 0.08 ^{e}	0.18 ± 0.05 ^{b}
SW	704.42 ± 38.5^{a}	64.9 ± 2.48^{c}	1519.1 ± 61.07 ^{a}	266.64 ± 25.97^{a}	17.65 ± 1.14^{a}	4.74 ± 0.0^{c}	5.01 ± 0.36^{b}	45.97 ± 2.08^{a}
GB	34.25 ± 3.3^{b}	1698.2 ± 63.97 ^{b}	437.04 ± 11.03 ^{d}	234.47 ± 16.19 ^{b}	13.93 ± 0.78 ^{b}	3.29 ± 0.13^{d}	2.75 ± 0.18^{c}	0.78 ± 1.35^{b}
GPPH	21.28 ± 3.9 ^{b}	3071 ± 120.9^{a}	1158.3 ± 43.21 ^{b}	288.72 ± 16.74^{a}	4.1 ± 0.36^{b}	23.04 ± 0.81^{a}	0.91 ± 0.1^{d}	0.48 ± 0.0^{b}
RPPH	36.04 ± 0.84^{b}	1895.4 ± 7.05^{b}	717.96 ± 9.4^{c}	134.35 ± 30.0^{d}	5.8 ± 1.43 ^{c}	1.63 ± 0.3^{e}	0.57 ± 0.19^{e}	0.22 ± 0.0 ^{b}

mg /100 g dry base. Different letter in the same column are significantly different ($p < 0.05$) according to Tukey's Multiple Range test

There were observed significant differences between pineapple and sotol wastes (Table 2); while pineapple is rich in fermentable sugars, sotol wastes are rich in fiber and minerals, because sugars consumption by bacterial strain made more available the minerals. The trace element predominant in all tested samples was iron, even more clearly in sotol wastes and green beans. The importance of mineral elements in human, animal and plant nutrition has been well recognized. When a trace element is deficient, a characteristic syndrome is produced which reflects the specific functions of the nutrient in the metabolism. The trace elements are essential components of enzyme systems [33]. Sotol wastes and green beans have can be considered a good source of iron; while the green prickly pear husks is a good source of manganese, an important metabolism cofactor [33].

3.3. Functional Properties

Significant differences ($P < 0.05$) were found in pH among the samples. Wheat bran showed the highest pH value (6.37 ± 0.01) follow by corn (6.12 ± 0.005); while green prickly pear husk has the lowest value (4.58 ± 0.01), even less than red prickly pear husk (5.26). Also sotol pineapple (4.94 ± 0.03) is more acid than sotol wastes (5.95 ±0.005). Raw materials with low pH as prickly pear husks or pineapple sotol can be used in food manufacture as jams, juices or yogurt [36].Functional properties of the extract plant fiber depend on particle size, extraction conditions, structure of plant polysaccharides and vegetal source. The functional properties have showed in Table 3.

Table 3. Functional properties of different sources of dietary fiber

Sample	SC (mL/g)	WHC (mL /g)	OHC (mL/g)	OMAC(mL /g)	CEC (meq H+/g)
WB	2.92 ± 0.21 c	5.2 ± 0.34 c	2.18 ± 0.18 b	2.37 ± 0.15 b	7.05 ± 0.12 b
Corn	0.79 ± 0.0d	2.05 ± 0.09 d	0.87 ± 0.05 d	1.92 ± 0.86 b	3.8 ± 0.06 c
SP	3.91 ± 0.31b	5.09 ± 0.22 c	1.66 ± 0.1 c	1.75 ± 0.25 c	8.3 ± 0.21 a
SW	2.1 ± 0.51 d	4.4 ± 0.26 c	3.32 ± 0.17 a	2.97 ± 0.33 b	8.3 ± 0.26 a
GB	8.09 ± 0.56 a	9.84 ± 0.04 a	1.2 ± 0.05 c	1.42 ± 0.13 c	8.65 ± 0.39 a
GPPH	4.58 ± 0.34 b	7.03 ± 0.07 b	1.68 ± 0.17c	1.4 ± 0.02 c	6.74 ± 0.12 b
RPPH	3.99 ± 0.0 b	7.48 ± 0.7 b	2.21 ± 0.36b	4.4 ± 0.7a	6.66 ± 0.37 b

Different letter in the same column are significantly different ($p < 0.05$) according to Tukey's Multiple Range test

The SC and WHC indicates that the materials tested could be used as food ingredients, and may produce the effect of satiety and increased fecal bolus [37]. Green beans showed higher SC (Table 3), while corn presented the lower value. Green beans showed highest SC, while corn presented lowest value (Table 3). Swelling capacity and water retention are the most studied hydration properties [38]. SC of green beans is higher than that reported by wheat (7.1 mL/g), apple (3.4 mL/g) and oat (2.3 mL/g) [23], but lower than other dietary fiber such as potatoes waste [39] or okara (9.44 mL/g) [19]. The differences in this capacity are explained by the different chemical composition of each plant material.

WHC is the ability of a moist material to retain water when is subjected to an external centrifugal gravity or compression forces. It consists of the sum of linked water, hydrodynamic water and physically trapped water, the latter contributes with major effect to this capacity [16]. The highest WHC was observed for green beans followed by green and red prickly pear husk (Table 3). These results were higher than those obtained for other fibers such as apple, oats and wheat[23], as well as orange fiber(8.39 mL/g) [40], passion fruit (3.7mL/g and 4.1 mL/g) [4], soybean(4.9 mL/g) [41], pomegranate waste (4.9 mL/g) [42], wheat husk (2.48 mL/g) and corn husk(2.32 mL/g) [43], but lower than that reported for chia(15.41 mL/g) and soybean residues(10.85 mL/g) [16]. High values of WHC suggest that the nature of constituents is hydrophilic.

OHC is also a technological property related to the chemical structure of plant polysaccharides and depends on surface properties, such as: thickness, overall charge density and hydrophobic nature of the fiber particle [44]. The highest OHC was observed in sotol waste (3.32 mL/g), while corn had the lowest value (0.87 mL/g). In contrast to WHC, green beans and prickly pear husk have a low oil holding capacity of 2.21 g/mL. These results are similar to the OHC of chia (2.02 mL/g) [16] but lower than OHC of soya (shoyu) (5.36 mL/g) [45], yellow passion fruit (4.3 and 5.2 mL /g) [4] and pea fibrous residues (6.93 mL/g) [46]. The OHC has been found to depend on surface properties, overall charge density, thickness, and hydrophobic nature of the fiber particle, where those particles with the greatest surface area possess greater capacity of adsorbing and binding components of an oily nature [47]. OHC has been associated with oil and fat absorption in the intestinal tract, also retention and subsequent removal of fat in feces.

The OMAC was observed in red prickly pear husk, followed by corn, sotol waste and wheat bran (Table 3). OMAC of red prickly pear husk was higher than OMAC of chia (1.09 mL/g) [16], wheat husk (1.98 mL/g) and corn husk (1.6 mL/g) [43]. This trait has been associated with the decreased of cholesterol in blood. Both OHC and OMAC represented the entrapment capacity of fats and oils, but OMAC also relates to the other organic molecules as cholesterol. Those result indicate that as red prickly pear husks have a great potential with hypocholesterolemic effect agent in blood; this open an opportunity research in this area.

No significant differences were found in the CEC of sotol waste, green beans or green prickly pear husk (around 8 meq H+/ g dry sample). This capacity may be the mechanism that explain bile acid sequestration by hydrophobic interactions and / or ionic that is involved in calcium and aluminum ions [14,48] and thereby decreasing the fat absorption by the human body [11,13]. Uronic or phenolic acids contents in the fiber may increase fecal excretion of bile acids which may have a hypocholesterolemic effect [48]. Also this is related with the content of free carboxyl and hydroxyl groups on the sugar residues or pectin.

The emulsifying activity is a molecule´s ability to act as an agent that facilities solubilization or the dispersion of two immiscible liquids, while emulsifying stability in the ability to maintain the integrity of an emulsion [49]. Results are showed in Figure 1. No significant differences were founded in EA between sotol pineapple and sotol wastes, but stability of sotol pineapple is higher.

Except wheat bran and corn, functional fibers studied have higher EA than other fibers as chia (44-56 mL/100 mL) [16,50], passion fruit fibrous residue (52.58 mL/100 mL) [51], lima bean fiber (49.25 mL/100 mL) [52], fibrous materials and residues of okara (52.1-58.79 mL/100 mL), corn cob (52.73-59.09 mL/100 mL), wheat straw (43.25-48.49 mL/100 mL) and rice husk (44.62-47.02 mL/100 mL) [37]. But lower than those reported for guar gum 0.1-0.2 % of concentration (90 mL/100 mL EA) and mesquite seeds galactomannan 0.1-0.5 % of concentration (95 mL/100 mL) [53]. In terms of ES, sotol pineapple and green prickly pear husk have the highest, but no significant ($p < 0.05$) differences between them. This results are similar than emulsion stability by pomegranate bagasse (90.7- 93.8 mL/100 mL) [43] and higher than guar gum 0.1-0.2 % of concentration (80-85 mL/100 mL) and mesquite seeds galactomannan 0.1-0.5 % of concentration (87-90 mL/100 mL) [53].

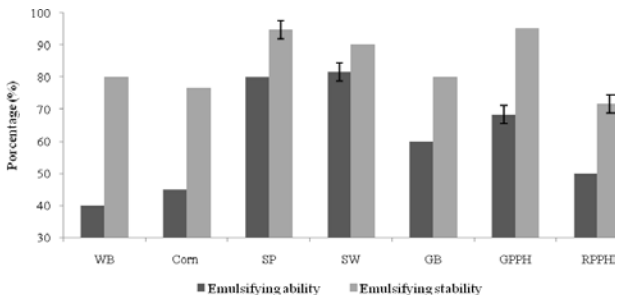

Figure 1. Emulsifying ability and Emulsifying stability of different sources of dietary fiber

But all samples are ES higher than chia (34.33- 60 mL/100 mL) [16,50], fibrous materials and residues of okara (48.81-58.79 mL/100 mL), corn cob (39.39-54.76 mL/100 mL), wheat straw (7.82-43.77 mL/100 mL and rice husk (44.62-45.83 mL/100 mL) [37]. The EA of a fibrous is indicative of its ability to adsorb biliary acids. This has potential health benefits since a fibrous component adsorbs biliary acids and increases feces excretion, consequently limiting absorption of these acids in the small intestine and therefore reducing cholesterol blood levels [16]. Consequently, incorporation of sotol pineapple, sotol wastes or green prickly pear husk into foods may have a hypocholesterolemic effect [15].

3.4. Principal Components

The 2 first components explained the 64% of variance (Figure 2). The first principal component explained the 32.5 % of total data variance, while the second component explained a 31.5 %. The green prickly pear husk, sotol pineapple, green beans and red prickly pear husk are rich in nutrients; while corn is poor in these compounds. Sotol pineapple and green beans are raws with the best nutrimental balance. Corn is rich in fats but its functional properties are very poor. The results of cluster analysis of raw materials based on their physicochemical and functional characteristics are showed in Figure 3. Three clusters were identified. A first group is composed by corn and wheat bran; these materials are characterized for low moisture and sugar content, are high in fat and have good organic molecule adsorption capacity.

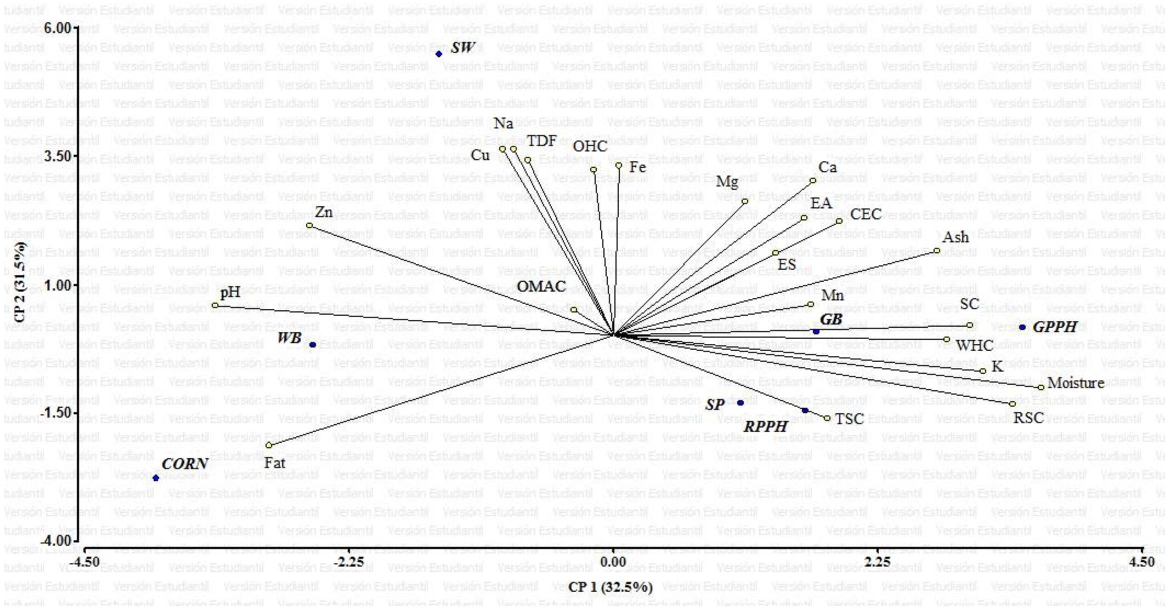

Figure 2. Principal components: chemical and functional characteristics

The results of cluster analysis of raw materials based on their physicochemical and functional characteristics are showed in Figure 3. Three clusters were identified. A first group is composed by corn and wheat bran; these materials are characterized for low moisture and sugar content, are high in fat and have good organic molecule adsorption capacity. The second group is composed for green beans, sotol pineapple, green and red prickly pear husks, and characterized by having high moisture and sugar content; low in fat content and good emulsifier and hydrant properties (SC and WHC). The main advantages of SC and WHC high values are the increase in medium viscosity, form gels, producing the effect of satiety, increased fecal bolus and therefore decreasing glucose, fat and cholesterol absorption; these properties help to improve the quality of human life prone to diabetes, obesity and cardiovascular problems. Also were observed two subgroups in this group. The first consisted in the sotol pineapple; while the second one indicated that green and red prickly pear husk are more similar to green beans, in composition and functional properties. In the third group was the sotol wastes, which are rich in dietary fiber, have a good emulsifying properties, but poor hydrant properties.

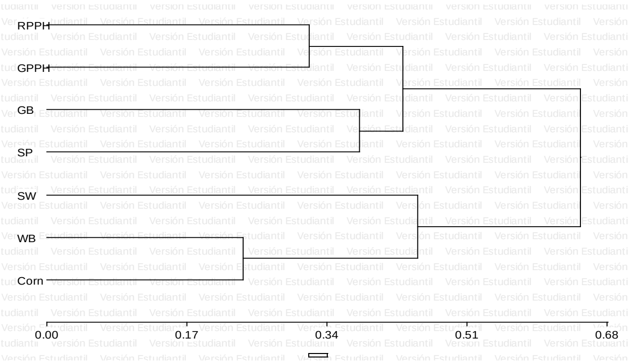

Figure 3. Dendrogram of average distances between each analyzed material, based on their characteristics

4. Conclusions

Sotol wastes, green beans and green prickly pear husk have the best functional properties, as high swelling, holding-water, cationic exchanging capacity and good emulsify and stability capacity. Besides, providing good source of potassium, calcium and iron; important elements in human nutrition. These materials were also low in fat, rich in dietary fiber and available sugar. The excellent emulsifying properties showed by sotol pineapple, sotol wastes and green prickly pear husk have also exhibited their potentials as emulsifiers in food industry. Functional properties study and their chemical composition, reveals their suitability to be a good source of food fiber for human consumption and as consequence, a functional ingredient.

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List of Abbreviations

CEC:	Cation exchange capacity
DF:	dietary fiber
EA:	emulsifying ability
ES:	emulsifying stability
GB:	green beans
GPPH:	green prickly pear husks
OHC:	oil holding capacity
OMAC:	organic molecule adsorption capacity
RPPH:	red prickly pear husks
RSC:	reductor soluble carbohydrates
SC:	swelling capacity
SP:	sotol pineapple
SW:	sotol wastes
TDF:	total dietary fiber
TSC:	total soluble carbohydrates
WB:	wheat bran
WHC:	water holding capacity

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