International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 2318-2323

Received: 11-01-2018
Accepted: 15-02-2018

Syed KA
Department of Food Chemistry and Nutrition, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Syed HM
Department of Food Chemistry and Nutrition, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Deshpande HW
Department of Food Chemistry and Nutrition, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Sawate AR
Department of Food Chemistry and Nutrition, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Correspondence
Syed KA
Department of Food Chemistry and Nutrition, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Standardization of acid concentration and solvent ratio for modification of psyllium husk (*Plantago ovata* F.)

Syed KA, Syed HM, Deshpande HW and Sawate AR

Abstract
Native psyllium husks were treated with different concentrations (0.50, 0.55 & 0.65%) of HCl in ethanol for three different psyllium husk – solvent ratios @1:2, 1:4 and 1:6 (w/v) and compared to the native & control psyllium husk sample at 37ºC temperature to reduce gel hardness and improve functional properties viz., hydration capacity, oil absorption capacity & water up-taking rate. The results highlighted that acid modification with concentration of 0.65 % HCl in the ethanol solvent for solvent ratio of 1:6 (w/v) as PSH: Solvent ratio significantly decrease the hydration capacity, oil absorption capacity & water up-taking rate of psyllium. Scanning electron microscopic (SEM) examination showed that 0.65 % HCI treatment in ethanol for ratio of 1:6 (w/v), reduce surface area of psyllium husk particle resulting in reduced water uptake capacity. Similarly the proximate composition, dietary fibre profile and textural profile analysis of the aforesaid treatment also revealed decrease in hardness and adhesiveness for gelling properties without affecting the dietary fiber and arabinoxylan contents. The results from this investigation suggests that 0.65 % HCI treatment in ethanol for ratio of 1:6 (w/v) improve functional properties of psyllium husk as required for exploration in the value addition of processed food products.

Keywords: psyllium husk, acid modification, arabinoxylan, dietary fiber, gel hardness, functional properties

Introduction

Dietary fiber is one of the valuable dietary interventions against a number of health disorders. There is no doubt that fibers, in particular viscous dietary fibers, have positive effects on human health, both in the prevention and in treatment of chronic diseases. Further, Dietary fibers from Psyllium have been used extensively both as pharmacological supplements, food ingredients; in processed food to aid weight control, to regulation of glucose control for diabetic patients and reducing serum lipid levels in hyperlipidaemias (Baljit, 2007) [1]. Fermentation and water absorption of dietary fibre components result in several beneficial health effects. Dietary fibre intake has been associated with alleviation of constipation, regulation of lipid and glucose/insulin metabolism, and carcinogenesis.

However, due to its extremely strong water-holding and gel-forming capacities, incorporation of psyllium into food products on the required amount preserving for health claim is difficult. It is a real challenge to incorporate the required amount of psyllium in one serving of a food product for example the cholesterol-lowering claim on the label, as required by Regulatory compliance. This is mainly due to the extremely strong gelling and water-absorbing abilities of psyllium. Many physical and mechanical techniques have been investigated for their effects in reducing the gelling and water-absorbing abilities of psyllium and consequently to promote its utilizations in food products (Rudin, 1985 and Wullschleger *et al*.1993) [2, 3]. These previous investigations have indicated the possibility of improving the physicochemical properties of psyllium.

Based on the previous studies, acid modification of psyllium husk presents a competitive potential of being applied in food industry due to its lower cost than enzymatic methods. In the present study an attempt has been made to improve the physico-chemical / functional properties of psyllium for incorporation in foods by acid treatment of the raw psyllium husk, so that it will serve as a source of dietary fiber without disturbing the nutritional and sensorial characteristics of the PSH incorporated processed food products.

Materials and Methodology
Psyllium Husk of indigenous variety was purchased from market of Parbhani district, Maharashtra.

Proximate composition
Proximate composition such as moisture, fat, crude protein, ash and crude fiber were determined as per A.O.A.C. (1995) [4] and carbohydrate by difference method.

Dietary Fiber
Determination of dietary fiber was done using the method described by Prosky *et al*. (1992) [5]. The sample in duplicate was treated with buffers (40mL, pH 8.2, 24°C). Stirring of samples till uniform dispersion of samples was done on magnetic stirrer. Alpha-amylase solution (50µL) was added and sample was heated at 95-100°C for 35 min. After cooling protease solution (100µL) was added and incubation was done for 30 min at 60°C. Following the same procedure amyloglucosidase solution (200µL) was added and samples were incubated. Precipitation was done with 4 vol. of 95% ethanol and sample was filtered and dried. Then the residue was divided into two parts which were further used for protein and ash determinations. Total dietary fiber was determined by subtracting the protein and ash contents determined in dried residues. The total dietary fiber was calculated following the formula given in respective method.

Determination of Arabinoxylan (AX)
Arabinoxylan contents was determined by following the method given by Tahira *et al.* (2014) [6]. Psyllium husk sample was initially isolated followed by derivitization of sample for monosaccharides determination and subsequently calculated the arabinoxylan.

a) Isolation
In 100g husk sample, arabinoxylan was isolated by using alkali method. The sample was heated in KOH solution for two hrs. Followed by centrifugation at 6000×g for 20 min at 4°C. The supernatant was taken for precipitation and kept the precipitates overnight at refrigeration temp in absolute ethanol (final concentration of 65% v/v) and centrifuged (Cleemput *et al*., 1995) [7]. The arabinoxylan fiber thus obtained was finally dried in freeze drier for 4 hrs.

b) Derivitization of precipitates
Arabinoxylan was derivitized for monosaccharide determination (Vallance *et al*., 1998) [8]. Standard gum (1-2mg) and individual monosaccharide standard samples (1mg each) were heated in water bath at 100°C for 30 and 10 min, respectively, with triflouroacetic acid (0.1mL analytical grade, undiluted). Then samples were allowed to cool at room temperature before pyridin (0.2mL, analytical grade) was added to the vials. Hexamethyle dizilazane (0.3mL, derivitization grade) and triflouroacetic acid (5 drops, analytical grade, undiluted) were added to the samples. The samples were shaken vigorously for 30 secs and allowed to stand for 1 hr prior to analysis. Later, 0.1mm samples were removed and placed directly into vials. The material was heated for 30 min at 105°C with triflouroacetic acid (0.1mL, analytical grade, undiluted) in water bath. The samples were shaken vigorously for 30 secs and allowed to stand for 1 hr prior to analysis.

Acid modification of Psyllium husk
Acid modification of Psyllium husk was carried out as per the method described by Pei Xiaoyin (2008) [9] with certain changes in concentration of HCL in ethanol solvent. The solvent used for psyllium husks acid treatment was ethanol with 34% - 37% hydrochloric acid (HCl) at the varying concentration levels of 0.50%, 0.55% and 0.65% (w/v). The study was conducted to investigate the effect of acid concentration and psyllium – solvent ratio on physico-chemical/functional properties of the acid modified psyllium samples. At reaction temperature of 37^{o}C three different psyllium –solvent ratios (PSH:Solvent @ 1:2,1:4 and 1:6 (w/v), g/mL) were tested. Thus, 48 g of psyllium husk was divided into 4 groups having 16g PSH each, for treatments with different concentrations levels of 0.50%, 0.55% and 0.65% (w/v) of Hydrochloric acid in Ethanol solvent (Table 1). Four samples in each group were designated for three different psyllium – solvent ratios as mentioned earlier. After the addition of the solvent, samples were incubated for 48 hours at 37^{o}C temperature. Afterward, samples were vacuum filtered, rinsed with 95% ethanol and 100% for 2 times each, then dried and stored. Control group was treated with 100% ethanol, and followed the steps of preparation mentioned above.

Table 1: Acid treatment levels for psyllium husk

Concentration of HCl in Ethanol (Solvent)	Psyllium Husk (PSH): Solvent Ratio
0.50 %	1:2, 1:4 and 1:6 (w/v)
0.55 %	1:2, 1:4 and 1:6 (w/v)
0.65 %	1:2, 1:4 and 1:6 (w/v)
0.00% for Control	1:2, 1:4 and 1:6 (w/v)

Functional Properties of Native and Acid Modified Psyllium Husk
Functional properties of native and modified psyllium husk were determined in terms of hydration capacity, oil absorption capacity and water up-take rate.

Oil absorption and hydration capacity
Oil absorption and hydration capacities were determined by the method of Rosario and Flores (1981) [11]. One-gram sample was mixed with 10 ml. distilled water or 10 ml. oil (refined groundnut oil) for 30 second in a mixer. The samples were then allowed to stand for 30 min at 30^{o}C in a water bath and centrifuged at 3000 rpm for 20 min. The volume of supernatant was recorded to calculate the amount of hydration or oil absorption capacity.

Water Up-Taking Rate
According to the method described by Yu *et al.* (2003) [12], 1.0 g psyllium sample was equilibrated in 10% relative humidity (RH) desiccator for 48 h. After accurately weighing, all the samples were transferred into a 90% RH desiccator and exposed to moisture for 30 min. The moisture-absorbed samples were then accurately weighed and the weights were recorded. The amount of the absorbed water was presented as weight change of the dry matter after exposure to high RH environment. The data were reported as the average amount of water taken up by each gram of the psyllium samples per minute (mg/(g×min)).

Scanning Electron Microscopy (SEM)
Scanning electron microscopy (SEM) was performed to determine the changes of the surface structures of psyllium husk particles due to acid (HCI) treatment. SEM was carried out using the JEOL JSM-6360, Mira-3, Tescan.

Textural Profile Analysis

Texture Profile Analysis in terms of hardness and adhesiveness were analyzed using TA-*XT2 PLUS* Texture Analyzer (Stable Micro System, Surrey, UK) having 60kg load cell was used for Texture profile analysis (TPA). Measurements were performed with a pretest speed of 2.0 mm/sec, a test speed of 5.0 mm/sec, a post test speed of 5.0 mm/sec, and a distance of 6 mm. All measurements were made in triplicate. Two and one-half grams (2.5 g) of psyllium husk sample added to 50 ml. of distilled water, kept for overnight and this was used to compare the gelling properties of modified psyllium.

Results

Effect of acid modification on native psyllium husk

Raw psyllium husk was treated with an acidic aqueous solution of a solvent and an acid. The solvent being capable of dissolving the acid and may be organic, inorganic or a mixture thereof. Ethanol was a preferred organic solvent based on the studies conducted by the Yu Liangli (2000) [13]. The acid preferably hydrochloric acid a moderate to strong acid, having 34% - 37% assay. The treatment was conducted for a sufficient amount of time and at suitable processing conditions such that the resultant psyllium has the desired predetermined properties, which will vary according to the intended use of the modified psyllium product.

The acid-solvent ratios were selected after having several trials with varying concentration levels of 0.50%, 0.55%, 0.65%, 0.72 & 0.80 % (w/v). It was found the at acid-solvent concentration level of 0.72 & 0.80 % (w/v), the treated PSH was not able to form the gel even after keeping overnight 1gm of acid treated PSH in 40ml distilled water, such non gel-forming strength's PSH was not desirable for incorporation in processed food products for value addition especially for Cookies, Symbiotic *Shrikhand* & Mutton patties.

After the desired time completion of 48 hrs. for specified acid concentration and PSH & Acid solvent ratio. The acid treated psyllium product was recovered by vacuum filtration. The recovered product included the modified starting psyllium husk and also contains various reaction by products such as oligosaccharides, and possibly along with acid salts that may form by reaction of psyllium components or other reaction by products as reported by the Yu *et al*. (2001) [14]. Hence, there might be fractions of reaction by-products remaining in the solvent that may be separated when the solvent was removed. Moreover, for further applications of acid modified PSH in the value addition of processed food products, it was desirable to remove certain fractions from the final product, e.g. sugar hydrolysis products. Therefore, vacuum filtration was preferred as unwanted fractions along with the solvent. After recovery, obtained acid modified PSH was air dried at room temperature, or it may be dried by heating in an oven at a temperature required above ambient temperature till the desired water content achieved.

Effect of acid modification on functional properties of psyllium

The data pertaining to the effect of acid treatments on functional properties such as hydration capacity, oil absorption capacity and water up-taking rate of native psyllium husk were studied and obtained results are presented in Table 2.

Table 2: Effect of acid modification on functional properties of psyllium

Concentration of HCl In Ethanol (Solvent)	Psyllium Husk (PSH): Solvent Ratio	Functional properties		
		Hydration capacity (ml/g)	Oil absorption capacity (ml/g)	Water up-taking Rate (mg/(g×min))
Control	1:2	2.9 ± 0.01	0.9 ± 0.05	2.1 ± 0.05
	1:4	2.8 ± 0.06	0.9 ± 0.01	2.0 ± 0.03
	1:6	2.8 ± 0.02	0.8 ± 0.07	1.9 ± 0.08
0.50 %	1:2	2.7 ± 0.02	0.8 ± 0.01	1.91± 0.03
	1:4	2.6 ± 0.08	0.7 ± 0.06	1.88 ± 0.02
	1:6	2.6 ± 0.05	0.6 ± 0.03	1.85 ± 0.04
0.55%	1:2	2.5 ± 0.04	0.6 ± 0.07	1.82 ± 0.01
	1:4	2.4 ± 0.01	0.6 ± 0.01	1.78 ± 0.03
	1:6	2.3 ± 0.02	0.5 ± 0.08	1.77 ± 0.02
0.65%	1:2	2.1 ± 0.06	0.5 ± 0.05	1.74 ± 0.04
	1:4	1.8 ± 0.07	0.5 ± 0.03	1.71 ± 0.06
	1:6	1.6 ± 0.05	0.5 ± 0.01	1.68 ± 0.07
Raw / Native Psyllium Husk		3.0 ± 0.03	1.0 ± 0.02	2.20 ± 0.03
SE ±		0.3692	0.0243	0.1682
CD @ 5%		1.1077	0.0731	0.5046

*Each value is average of three determinations.

Hydration capacity

It is revealed from the Table 2 that the hydration capacity of psyllium husk was decreased with the increased level of acid concentration used for treatment from 3.0 ± 0.03ml/g to 1.6 ± 0.05ml/g. Significant decrease in hydration capacity were observed in case of PSH sample treated with 0.65% acid concentration having lowest 1.6 ± 0.05ml/g for 1:6 - PSH: Solvent ratio followed by 1:4 PSH: Solvent ratio with 1.8 ± 0.07ml/g. Similarly, it was found that there was a substantial decrease in the hydration capacity of PSH sample treated 0.55% acid concentration for 1:6,1:4 & 1:2 - PSH: Solvent ratios with 2.3 ± 0.02, 2.4 ± 0.01 & 2.5 ± 0.04ml/g respectively in comparison with the raw PSH having 3.0 ± 0.03 ml/g and Control having 2.8 ± 0.02, 2.8 ± 0.06 & 2.9 ± 0.01ml/g respectively followed by 0.50% acid concentration with 2.6 ± 0.05, 2.6 ± 0.08 & 2.7 ± 0.02ml/g respectively. Similar trends were reported by the the Pei Xiaoyin (2008) [10] & Zhihong *et al*. (2009) [15] for the water absorbing capacity & swelling volume results respectively, for acid treated PSH at different acid concentrations, PSH: Solvent ratios and reaction temperatures.

Researchers reported the physiological effects of DF in relation to hydration characteristics and the subsequent technological aspects important in their use in modern food technology applications (Guillon & Champ, 2000; Chaplin, 2003) [16, 17]. As DFs are complex polysaccharides with differing structures and conformations it is not unsurprising that different DFs have different hydration characteristics. Conventionally these have been investigated in terms of water absorption by filtration (water holding capacity) or by centrifugation of hydrated molecules (water binding capacity/hydration capacity/ water retention capacity / free or available water). The understanding of these characteristics are crucial in developing efficient food processes which may deliver consumer acceptable food products. For instance, DFs with high water holding capacity can be used not only as DF enrichment, but also as functional ingredients to reduce calorific value, avoid syneresis and modify the viscosity and texture of the final product (Holtekjølen *et al*., 2008; Goldstein *et al*., 2010) [18, 19]. The water absorption of a DF gives an indication of substrate pore volume, and could help in understanding DF performance as it transits the gastrointestinal tract (Guillon & Champ, 2000) [16]. The faecal bulking capacity of DFs is also thought to be related to their water absorption/retention characteristics as well as their impact on microbial proliferation (Davidson & McDonald, 1998) [20].

Oil absorption capacity (OAC)

Oil absorption capacity, the amount of oil absorbed by sample, is an important characteristic in food formulations since they improve the satiety, flavour and mouth feel of foods (Omosulis *et al*., 2011) [21]. It can be observed from the Table 2 that the Oil absorption capacity of 0.65 % acid treated psyllium husk for the PSH: solvent ratio @ 1:6 was found to be lowest as 0.5 ± 0.01 ml/g. The data from the Table 2 indicates that the OAC of treated psyllium husk decreased with the increased level of acid concentration from 1.0 ± 0.02ml/g to 0.5 ± 0.01 ml/g. Significant decrease in OAC were observed in case of control PSH sample treated with 1:6 - PSH: Solvent ratio compared to 1:2 - PSH: Solvent ratio with 0.9 ± 0.05ml/g OAC for 1:2 & 0.8 ± 0.07ml/g for the PSH: solvent ratio @ 1:6 respectively. Similar trend was found in case of 0.50 & 0.55% acid concentration. Moreover, significant difference was observed for 0.55% acid concentration treatments for various PSH: Solvent ratios (1:2, 1:4 & 1:6) having OAC 0.6 ± 0.07, 0.6 ± 0.01 & 0.5 ± 0.08 ml/g respectively. However no significant difference was observed for 0.65% acid concentration treatments for various PSH: Solvent ratios (1:2,1:4 & 1:6). According to Oladele and Aina (2007) [22], the major chemical component affecting OAC is protein, which is composed of both hydrophilic and hydrophobic parts. Higher OAC might be due to the partial denaturation of proteins with exposition of high hydrophobic proteins which show superior binding to hydrocarbon chains of lipids.

Water up-taking rate

The data from the Table 2 indicates that water up-taking rate was found lowest for 0.65 % acid treated psyllium husk for the PSH: solvent ratio @ 1:6 sample as 1.68 ± 0.07mg/(g×min). Moreover, significant water up-take rate reduction was observed between the raw psyllium husk sample and PSH treated with 0.65 % acid concentration for PSH: solvent ratio @ 1:6 as 2.20 ± 0.03 mg/(g×min) and 1.68 ± 0.07 mg/(g×min) respectively. The data for the water up-taking rate showed that acid treatment of PSH at various PSH: solvent ratios highly affects the water up-taking rate, particularly it helps in reduction of water up-taking rate of the psyllium husk. The results for the water up-taking rate are in good agreement with the results found by the Pei Xiaoyin (2008) [10] & Zhihong *et al*. (2009) [15] for water up-taking rate for acid treated PSH. Water up-taking rate plays an important role in deciding the physico-chemical and sensorial characteristics of processed food products fortified with psyllium husk as a source of dietary fiber especially dairy based as well as baked and fried products.

Based on the results of acid modifications on functional properties of psyllium husk, acid modification concentration of 0.65 % HCl in the ethanol solvent for solvent ratio of 1:6 as PSH: Solvent ratio, had been selected considering previous reported studies for further studies on its surface structure by SEM, proximate composition, dietary fibre profile and textural profile analysis.

Scanning Electron Microscopy (SEM)

Sincere efforts had been made to better understand the reduction in water absorbing capacity and gel hardnes of the acid modified psyllium, SEM was conducted to compare surface structures of HCL acid modified psyllium with those of original psyllium husks.

SEM results showed that the native psyllium husk had a smoother surface than that treated with 0.65% HCl acid treated psyllium husk for 1:6 @ PSH: Acid solvent ratio. The changes in morphology of the acid modified psyllium husk particles in comparison with native psyllium husk are as shown in Plate 1. The acid modified psyllium husk degraded on the external surface structure might be due to hydrolysis occurred by exocorrosion, and was almost uniform for all particles/granules of acid modified PSH with some variations due to structural characteristics of each husk fragments. Acid treatment cause alteration on the surface and degrade the external part by exocorrosion. In other words, scanning electron microscopic (SEM) analysis showed that HCI treatment reduce surface area of psyllium particle resulting in reduced water uptake capacity. The reduction of particle/fragment surface area provides a reasonable explanation for the suppressed water-absorbing rates of the modified psyllium preparations. Similar observations were made by Zhihong *et al*. (2009) [15] for SEM of HCl acid treated PSH that the HCI treatment might reduce surface area of psyllium particle, which might contribute to their reduced water uptake capacity. Moreover, Yu L. and Perret, J. (2003) [23] reported the SEM results which indicated that the enzymatic modification decreased the total surface area contributing to the reduced water-absorbing ability of the modified psyllium. The results from this study indicated that the low concentration acid treatment in ethanol may improve psyllium functionality.

Proximate composition of selected acid modified psyllium husk

It can be observed from Table 3 that moisture content increased from 7.19 to 7.36 per cent upon acid modification. Fat content decreased after acid modification from 1.84 to 0.65 per cent while protein content decreased from 2.95 to 1.22 per cent. Similarly, ash and crude fiber decreased from 2.95 to 1.22 and 3.13 to 2.69 per cent respectively. The decrease in fat, protein, ash and crude fiber content resulted due to the partial degradation of the psyllium gel hardness because of acid modification. Further, carbohydrate content increased from 85.38 to 88.50 per cent and energy value decreased from 370 to 365 Kcal/100g.

Table 3: Effect of acid modification on proximate composition of psyllium husk

Particulars (g/100g)	Native Psyllium Husk PSH (N)	Modified Psyllium Husk PSH (M)
Moisture	7.19	7.36
Fat	1.84	0.65
Protein	2.95	1.22
Ash	2.62	2.25
Carbohydrate	85.38	88.50
Crude Fiber	3.13	2.69
a) Dietary fiber	77.66 ± 1.28	79.67 ± 0.89
b) Arabinoxylan	47.60 ± 0.65	48.73 ± 0.78
Energy Value	370 Kcal/100g	365 Kcal/100g

* Each value is average of three determinations.

Dietary fiber and Arabinoxylan

The results from the Table 3 also indicates that Dietary fiber and Arabinoxylan contents as 77.66 ± 0.28 and 47.60 ± 0.33% for native psyllium husk while for acid modified psyllium 79.67 ± 0.89 and 48.73 ± 0.78% respectively. Slight increase in dietary fiber might be due to marginal increase in the total carbohydrate content resulting from the sugar hydrolysis giving by products such as oligosaccharides, and possibly along with acid salts that may form by reaction of psyllium components or other reaction by products as reported by the Yu Liangli (2000) [13]. The acid modified psyllium husk degraded on the external surface structure only due to hydrolysis occurred by exocorrosion, that's why dietary fiber did not affected by the acid treatment. Considering psyllium husk as source of dietary fiber some researchers inferred that arabinoxylan as the active fraction helpful to manage various physiological ailments (Fischer *et al*., 2004; Saghir *et al*., 2008; Van-Craeyveld *et al*., 2009) [24, 25, 26]. The current results for arabinoxylan content in acid modified psyllium husk ranged between 45 to 60% further indicated that the major fractions are arabinose and xylose whilst minor fractions include some other sugars and uronic acid (Guo *et al*. 2008) [27].

Effect of acid modification on hardness and adhesiveness of selected acid modified psyllium husk

Hardness and adhesiveness are the maximum force (g) measured on for peaks of the "texture profile" graph provided according to analytical testing with a texture analyzer. These properties correspond to the first positive peak and the first negative peak. Comparative data of hardness and adhesiveness from Table 4 & Graph No.1 indicates that there was a substantial decrease in hardness and adhesiveness of the acid modified psyllium husk.

Table 4: Hardness and adhesiveness of psyllium husk

Particulars	Hardness (g)	Adhesiveness (-g)
PSH(Native)	90.0 ± 1.4	11.6 ± 0.95
PSH(Modified)	55.5 ± 2.6	9.1 ± 0.22

Conclusion

In conclusion, the present study suggests that 0.65 % HCI treatment in ethanol for ratio of 1:6 (w/v) as PSH: Solvent containing 0.65 % HCl, improves functional properties of psyllium husk without affecting the dietary fiber and arabinoxylan contents without affecting the dietary fiber and arabinoxylan contents as required for exploration of psyllium husk as a source of dietary fiber in the value addition of processed food products.

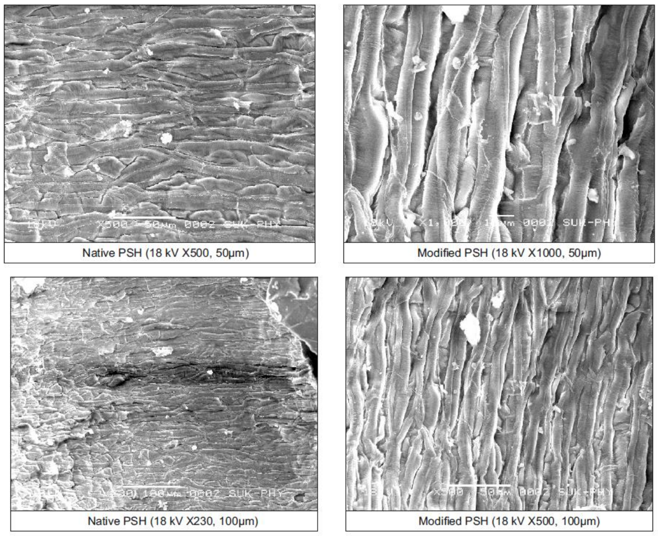
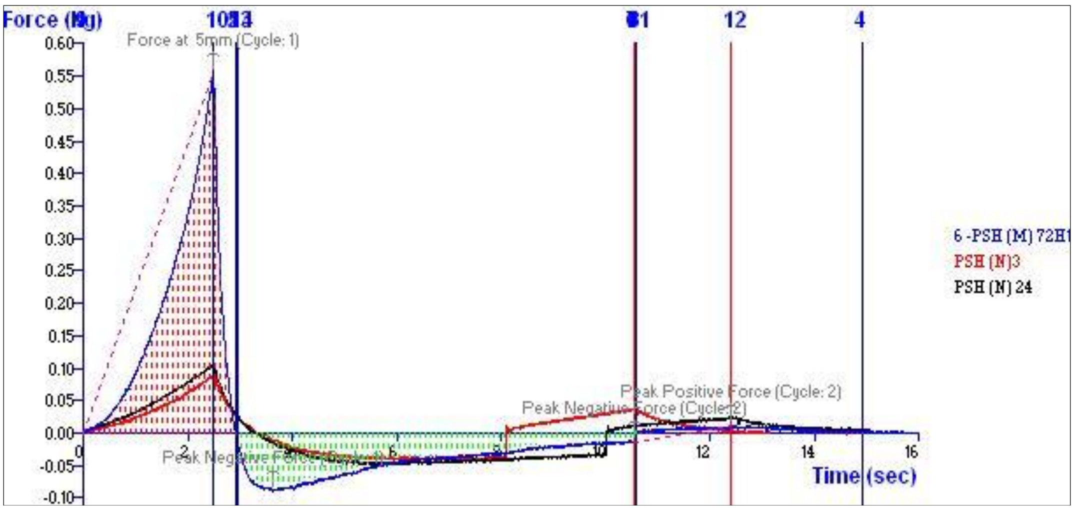


Fig 1: SEM (Scanning Electronic Microscope) Images for the comparison of surface structures of acid modified psyllium husk particle / fragment sample with native psyllium husk under different resolutions



Note: PSH(M) – Acid modified Psyllium Husk, PSH(N)- Native Psyllium Husk

Fig 2: Texture profile of acid modified and native psyllium husk.

References

1. Baljit S. Psyllium as therapeutic and drug delivery agent. Int. J Pharmaceutics. 2007; 334:1-14.
2. Rudin R. Easily dispersible dietary fiber product and method for producing the same. US Patent, 1985, 4551331.
3. Wullschleger RD. Heat treatment for decreasing the allergenicity of psyllium seed husk products. US Patent, 1993, 5271936.
4. AOAC. Official methods of analysis. Association of Official Analytical Chemists Washington, DC, 1995.
5. Prosky L, Asp N, Schweizer T, Devries J, Furda I. Determination of insoluble and soluble dietary fiber in foods and food-products - collaborative study. Journal of AOAC International. 1992; 75(2):360-367.
6. Tahira Batool Qaisrani, Masood Sadiq Butt, Safdar Hussain, Muhammad Ibrahim. Characterization and utilization of psyllium for the preparation of dietetic cookies. International Journal of Modern Agriculture. 2014; 3(3):81-91.
7. Cleemput G, Oort MV, Hessing M, Bergmansl MEF, Gruppen H, Grobet PJ *et al*. Variation in degree of D-xylose substitute in arabinoxylans extracted from European wheat flour. J Cereal. Sci. 1995; 22:73-84.
8. Vallance SL, Singer BW, Hitchen SM, Toe JH. The development and initial application of chromatographic method for the character media. JAIC. 1998; 37:294-311.
9. Pei, Xiaoyin. Acid modification of Psyllium. Theses and Dissertations. DRUM University of Maryland, 2008. https://drum.lib.umd.edu/handle/1903/3.
10. Rosario DRR, Flores DM. Functional properties of flour types of milling bean flour. J Food Sci. Agric. 1981; 32:175-180.
11. Yu L, Perret J, Parker T, Allen KGD. Enzymatic modification to improve the water-absorbing and gelling properties of psyllium. Food Chemistry. 2003; 82:243-248.
12. Yu Liangli. Acid and solvent modification of psyllium. Patentee O1999062342A9, 2000.
13. Yu L, De Vay GE, Lai GH, Simmons CT, Neilsen SR. Enzymatic modification of psyllium. United States Patent, 2001; 6:248-373.
14. Zhihong Cheng, Jessica Blackford, Qin Wang, Liangli (Lucy) Yu. Acid treatment to improve psyllium functionality. Journal of Functional Foods. 2009; 1(1):44-49.
15. Guillon F, Champ M. Structural and physical properties of dietary fibres, and consequences of processing on human physiology. Food Research International. 2000; 33(3-4):233-245.
16. Chaplin MF. Fibre and water binding. Proceedings of the Nutrition Society, 2003; 62(01):223-227.
17. Holtekjølen A, Olsen H, Færgestad E, Uhlen A, Knutsen S. Variations in water absorption capacity and baking performance of barley varieties with different polysaccharide content and composition. LWT - Food Science and Technology. 2008; 41(10):2085-2091.
18. Goldstein A, Ashrafi L, Seetharaman K. Effects of cellulosic fibre on physical and rheological properties of starch, gluten and wheat flour. International Journal of Food Science & Technology. 2010; 45(8):1641-1646.
19. Davidson M, McDonald A. Fiber: forms and functions. Nutrition Research. 1998; 18(4):617-624.
20. Omosulis V, Ibrahim TA, Oloye DA, Aladekoyi G, Ogundowole O. Functional properties of roasted and defatted cashew nut (*Anarcadium occidentale*) flour. Electronic Journal of Environmental, Agricultural and Food Chemistry. 2011; 10(4):2135-2138.
21. Oladele A, Aina J. Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*). African Journal of Biotechnology. 2007; 6(21):2473-2476.
22. Yu L, Perret J. Effects of solid-state enzyme treatments on the water absorbing and gelling properties of psyllium. LWT-Food Science and Technology. 2003; 36:203-208.
23. Fischer MH, Yu N, Gray GR, Ralph J, Anderson L, Marlett JA. The gel-forming polysaccharide of psyllium husk (*Plantago ovata* Forsk). Carb. Res. 2004; 339:2009-2017.
24. Saghir S, Iqbal MS, Hussain MA, Koschella A, Heinze T. Structure characterization and carboxymethylation of arabinoxylan isolated from Ispaghula (*Plantago ovata*) seed husk. Carbohyd. Poly. 2008; 74:309-317.
25. Van-Craeyveld VV, Delcour JA, Courtin CM. Extractability and chemical and enzymic degradation of psyllium (*Plantago ovata* Forsk) seed husk arabinoxylans. Food Chem. 2009; 112:812-819.