INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY EDUCATIONAL RESEARCH
ISSN:2277-7881; IMPACT FACTOR :6.514(2020); IC VALUE:5.16; ISI VALUE:2.286
Peer Reviewed and Refereed Journal: VOLUME:10, ISSUE:1(2), January :2021
Online Copy Available: www.ijmer.in

PHYSICAL CHARACTERISTICS OF DIETARY FIBERS FROM DIFFERENT SOURCES

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Abstract

Dietary fibers are plant based non-starch polysaccharides and lignins and are relatively resistant to digestion. The present investigation was undertaken with the aim of determining the swelling, water holding, oil holding and glucose binding capacity of various fiber sources. A total of 10 fiber sources such as wheat bran, oat bran, rice bran, cellulose powder, date fiber, carboxy methyl cellulose, guar gum, gum Arabic, isabgol and pectin were selected. The samples were subjected to different temperature treatment prior to carrying out the analysis. The results of the analysis revealed that gum Arabic and isabgol which were kept at room temperature were found to exhibit maximum swelling capacity i.e., 9.4ml/g and 7.67g/ml respectively. Glucose binding capacity indicated that almost all the fiber sources were shown to have relatively higher binding capacity. Among the samples wheat bran showed 675µg/dl and for pectin it was 618.54µg/d. With the observed results it can be concluded that the fiber sources can be utilized in a better manner for formulating specialty food products with enhanced health benefits.

Keywords: Dietary Fiber, Glucose Binding,Bulking Capacity, Cardiovascular Disease.

Introduction

The term dietary fiber can be defined as a variety of plant based non-starch polysaccharides and lignin that are considered to be resistant to digestion. It is the cell wall component of plant material which is largely indigestible[1]. Substantial experimental investigations have yielded positive results regarding the beneficial role of dietary fiber in health and nutrition since, the fiber fractions are known to play a major role in reducing the risk of certain chronic diseases like cardiovascular diseases, certain forms of cancer and constipation[2, 3]. Fiber has been categorized as soluble fraction and insoluble fraction. The insoluble fraction helps to regulate the intestinal functions. Whereas soluble fraction is largely associated with reduction in cholesterol level and absorption of glucose[4]. Hence, it has gained much popularity as a food ingredient and as a compound for obtaining health benefits[5, 6]. In the present scenario, consumers are gaining more awareness regarding the potential health benefits. This has lead to a greater interest for exploring the new dietary fiber sources[5]. This could be utilized in the formulation of health products as well as for the development of fibre enriched products like dairy products, meat or fish and wide variety of baked goods[7, 8].

There is a connection between reduced dietary fiber and the status of the colonic mucus barrier. Previous reports have correlated reduced dietary fiber with thinner colonic mucus[9-11]. Imbalances in gut microbial community is associated with several negative health outcomes including; pathogen susceptibility, inflammatory bowel disease (IBD) and colon cancer[12-14].

Western style diet low in microbiota accessible carbohydrates could lead to irreversible reduction in the microbial diversity and lead to disappearance of the specific bacterial species in the digestive system[15]. A low intake of dietary fiber and excessive consumption of fat and sugar as seen in westernized lifestyle has been suggested to contribute for the depletion of specific bacterial taxa[16]. Non-starch polysaccharides especially, the polymers with high molecular weight namely guar gum, certain pectins, β-glucan and psyllium are viscous in nature indicating that they are capable of forming gel structure in the gut that can delay the absorption of glucose and lipids hence is linked with positive influence on the postprandial metabolism[17]. It has been demonstrated in a study that when mice was fed a western diet containing very low fiber, was shown to increase the penetrability of the inner mucus layer along with lowering the growth rate and rendering the mucus highly penetrable and a concomitant increase in the susceptibility to infections[18].

The associated physiological functions of the various dietary fibers could be due to their physicochemical properties viz., water holding capacity, swelling, rheological and fat binding properties and most importantly its role in bacterial degradation of fermentation[19]. The regulation of post prandial plasma glucose concentration and lowering of cholesterol by soluble fiber fraction is mainly linked to the viscosity of the fiber. The various physic-chemical properties of dietary fiber also play a major role as functional food ingredients. The identification of new fiber sources, as well as improvement in general functional behavior has resulted in a continued interest for its utilization in food industries. This would increase the possibility of designing fiber enriched products consumption which could afford positive health benefits[20]. Hence, the present investigation was undertaken with an objective of exploring the potential functional properties of various fiber sources.

Materials and Methods

The commercial fibers included in this study were; wheat bran, oat bran, rice bran, cellulose powder, date fiber, carboxy methyl cellulose, guar gum, gum Arabic, isabgol and pectin. All the samples were procured from sigma chemicals. The samples were evaluated for various physical properties such as; swelling capacity, water holding capacity, oil holding capacity, glucose binding capacity and the preferential binding of fibers to the mixture of oil and water was also studied. All the analysis was carried out in triplicates.

a. Swelling capacity

About 500mg of the sample was taken in a graduated test tube. The initial volume was recorded. To the weighed sample 5ml of deionized water was added, mixed well and they were incubated at room temperature as well as at 37°C for 24hrs. The increase in the volume of the incubated sample was recorded after 24 hrs. The obtained results were expressed in terms of ml/g of the sample.

b. Water holding capacity

For the analysis 5ml of deionized water was introduced into each centrifugation tubes. To this 500mg of sample was also added. The tubes were kept in shaking culture bath for about 24hrs at room temperature. The tubes were centrifuged at 10000rpm for 30 minutes. The supernatant was discarded. The initial weight of the pellet was recorded. These pellets were then dried at 100°C for 4hrs to remove the moisture content. The dried samples were again weighed and the difference in weight was calculated. The analyzed results were reported as ml/g of the sample.

c. Oil holding capacity

About 3g of each sample was accurately weighed into dry centrifuge tubes and 10g of oil was added. The samples were kept at room temperature with constant agitation for about 30 minutes. The tubes were centrifuged at 2500 rpm for 30 minutes. The supernatant was decanted and was measured. The difference between the weight of the supernatant and the amount of oil was determined. The observations were reported as gram of the oil held by 1g of the sample.

d. Glucose binding capacity

The glucose binding capacity was determined by taking 0.1g of the sample in a centrifuge tube. To this 10ml of glucose solution (50mM/L) was added and mixed thoroughly. The samples were incubated at 37°C for 6hrs. The tubes were then centrifuged at 4500rpm for 30 minutes. The supernatant was collected and the amount of glucose was measured using glucose assay kit. The amount of bounded glucose was estimated by the difference in the concentration of the glucose initially taken and the concentration in the supernatant.

e. Preferential binding

About 3g of the sample was mixed with 10g of oil and 10ml of water in separate centrifuge tubes. The tubes were kept at room temperature with constant agitation for 30 minutes. The mixture was centrifuged at 2500rpm for 30 minutes. The supernatant was decanted into petridishes and were dehydrated at 100°C for about 4hrs. Similarly, the pellets were also dehydrated and their weights were recorded. The difference in the amount of oil and water added initially with the amount of oil and water left at the end will give the amount of oil as well as the amount of water adsorbed by the sample. This also explains the preferential binding of the sample with regard to oil and water.

Results and Discussion

The swelling capacity of various fiber sources is given in table 1. The swelling capacity can be defined as the bulking property of the fiber which is exhibited when it is treated with water. It is also a measure of the extent of swelling of fiber particles when treated with water. Wheat bran, rice bran, Isabgol and gum Arabic samples which were stored at room temperature had the swelling capacity of 3.8, 3.9, 7.6 and 9.4ml/g respectively. The lowest swelling capacity was observed in cellulose powder (0.4 mg/g). Among the samples which were stored at 37ºc, the highest capacity for swelling was exhibited by gum Arabic (10 ml/g). In case of rice bran and wheat bran a slight reduction in the swelling capacity was observed than compared to the samples which were stored at room temperature. On the whole it can be said that all the samples exhibited a varied swelling capacity under different storage conditions (both room temperature and at 37ºc).

In a study it has been reported that the swelling capacity of fruit pulp was found to be greater compared to dry fiber matter. In an experimental design involving citrus pulp and apple pulp it was noticed that the values were greater than 20 ml/g. This wide difference could partly be attributed to the presence of water-soluble material. At the same time, it is also important to consider the effects of processing and consequent break down of matrix structure[21]. An examination of the physico-chemical properties of commercial fibers from different sources was carried out by Rosell et al[22]. The fiber sources included in this study were divided into 4 categories namely; hydrocolloids, oligosaccharides, cereal fiber and fruit tree fiber. The four different categories consisted of a total of 11 fiber sources such as hydroxyl propyl methyl cellulose, cellulose, locust bean gum, guar gum, inulin, galacto oligosaccharides, wheat, oat 401 and 600, apple and bamboo. The fiber sources were subjected to various analysis viz., chemical characterization and color, hydration properties, particle size distribution, apparent viscosity, solvent retention capacity and scanning electron microscopy. The results indicated that, the cereal fibers were found to have greater swelling, water holding and water binding capacity. The water binding capacity ranged between, 3.5 to 6.8g per gram of dry pellet. Apple fiber also exhibited higher swelling and water holding capacity than those of cellulose and bamboo. Hydration property is considered to be of utmost important because it determines the fate of dietary fiber in regulating the colonic function, which is known to be accounted for their physiological effects[23].

The water holding capacity of various dietary fiber samples has been depicted in table no. 2. The amount of water retained by a known amount of fiber under the conditions used is measured by centrifugation and is referred to either water holding or water binding capacity. The results of the analysis indicated that pectin exhibited a high-water holding capacity (3.53 ± 0.21g), followed by date fiber (1.63 ± 0.21g), carboxymethyl cellulose (0.96 ± 0.03g) and wheat bran (0.87 ± 0.01g). The least water holding capacity was observed in oat bran sample (0.73 ± 0.01g). Study by Miguel et al., (1999) has reported that the dietary fiber concentrates have high water holding capacity (15.5g water/g sample). Which is comparatively higher than the values reported for other fruit concentrates such as mango dietary fiber (11g of water/g sample). The water holding capacity of peach and orange dietary fiber ranged between 7.3-12.1g of water/g sample. In the present investigation the water holding capacity of date fiber as well as pectin was found to be comparatively higher to other dietary fiber samples. The high-water holding capacity of these fiber sources suggests that this material could be used as a functional ingredient in food which helps in preventing the occurrence of syneresis in certain formulated food products.

According to a report by Antoon and Kirsch[24] it has been suggested that the increased digestive viscosity of insoluble fibers with high water holding capacity tends to diminish nutrient absorption, because the nutrients undergo self-diffusion in the digestive lumen. Hence this can be considered as a rate limiting factor in the nutrient absorption. Both soluble as well as insoluble fibers are responsible for increasing digestive viscosity. The major factors governing the digestive viscosity are water holding capacity, particle size and level of insoluble fiber. Hence this should be taken into account when adding soluble and insoluble fiber into our diets. Using an animal model Leterme et al[25] has determined the relationship between the water holding capacity of the diets and the ileal flow of nitrogen in pigs. It was concluded that the ileal nitrogen flow was highly correlated to the dietary water holding capacity. The relationship was found to be experimental type i.e., when the water holding capacity exceeded 3g of water/g of dry matter, an increase in ileal nitrogen loss was also observed.

The oil holding capacity of selected fiber samples is given in table 3. The present study revealed that cellulose powder had the highest oil holding capacity (3.02 ± 0.10g). The oil holding capacity of isabgol, pectin, date fiber and wheat bran were found to be 2.78±0.04g, 1.45±0.11g, 1.02±0.02g, and 1.79±0.05g respectively. The oil holding capacity of gaur gum and gum Arabic was almost similar i.e., 0.86±0.05g and 0.87±0.02g, which was comparatively lower to the values reported for other fiber samples. The fiber concentrates were reported to exert a high oil holding capacity (9.7g oil/g of sample). The oil holding capacity of orange, peach and mango dietary fiber concentrate was in the range of 0.86-4.54g oil/g of sample. This property suggests that both dietary fiber as well as its concentrate could be used as an ingredient to stabilize foods having higher percentage of fat and emulsions[26, 7, 27.]

Information on the glucose binding capacity of various fiber sources have been presented in table 3. A number of studies give novel insight that might help to establish a metabolic link between insoluble dietary fiber consumption and reduced risk of diabetes[28, 29]. The beneficial effect is mainly attributed to viscous and/or gel forming properties of soluble dietary fiber. In the present study the highest glucose binding capacity was noticed in wheat bran (675.32 µg/dl), followed by rice bran (673.42 µg/dl), pectin (618.54 µg/dl) and oat bran (580.86 µg/dl) respectively.

The glucose binding capacity of all the fiber samples was found to be satisfactory. This implies that they potentially play a vital role in balancing the blood glucose level through delayed release into the blood stream during the process of digestion and absorption. The effect of fiber in maintaining blood glucose level has been investigated by various authors. In a meta-analysis involving 3, 28, 212 subjects, it was reported that there was no association with reduced risk of fruit and vegetable fiber intake[28]. Most of the studies have implicated a strong association between cereal fiber intake and reduced risk of diabetes. In a prospective cohort study involving 2, 86, 125 subjects it was revealed that about 2 serving per day of whole grain consumption was remarkably found to reduce diabetes risk by 21%[28, 29].

The results pertaining to preferential behaviour of various fiber sources with oil and water have been presented in table no 4. The results indicated that almost all fibers exhibited a greater affinity to water than compared to oil. Among the various fiber sources, gum Arabic, guar gum and carboxymethyl cellulose showed comparatively higher water absorption (4.28, 4.52, and 4.87ml/g respectively). Cellulose powder was shown to absorb more oil than water (2.01Vs 1.87 ml/g). This analysis revealed that fibers can very efficiently bind water rather than any other material. This particular property is very beneficial for preventing disorders like constipation.

Conclusion

In recent years there has been an increasing trend towards the use of healthy foods and is known to act as a stimulating factor for food industry sector to develop enriched food products. The use of high fiber additives as supplements for food has become very common. It is a well-established fact that dietary fiber has a vital role in the prevention and management of life style related diseases such as cardiovascular disease, obesity and diabetes mellitus. Certain properties of fiber such as water holding and oil holding capacity could be adopted in a better way in food industry sector to make them suitable for product formulation. But yet, food companies need to establish and develop the newer ways of incorporating fiber into normal diets. Extensive well controlled clinical trials are needed before being arriving at any conclusion regarding the beneficial role of dietary fiber in the maintenance of health.

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Online Copy Available: www.ijmer.in

Table 1: Swelling capacity of various fiber sources under different temperatures

SAMPLE USED	SWELLING CAPACITY	
	At room temperature (ml/g)	At 37°C(ml/g)
Wheat bran	3.8 ± 0.16	3.47 ± 0.09
Oat bran	3.53 ± 0.09	3.67 ± 0.09
Rice bran	3.93 ± 0.09	1.87 ± 0.09
Cellulose powder	0.4 ± 0.09	0.27 ± 0.09
Date fiber	0.67 ± 0.09	0.47 ± 0.09
Carboxymethylcellulose (CMC)	3.93 ± 0.19	3.93 ± 0.09
Guar gum	0.80 ± 0.16	0.93 ± 0.19
Gum Arabic	9.40 ± 0.16	10.00 ± 0.28
Isabgol	7.67 ± 0.25	5.80 ± 1.84
Pectin	1.53 ± 1.6	0.14 ± 0.08

Table 2: Water and oil holding capacity of various fiber sources.

SAMPLE USED	**WATER HOLDING CAPACITY (ml/g)**	**OIL HOLDING CAPACITY (ml/g)**
Wheat bran	0.87 ± 0.01	1.79 ± 0.05
Oat bran	0.73 ± 0.01	0.99 ± 0.03
Rice bran	0.77 ± 0.04	1.39 ± 0.01
Cellulose powder	0.97 ± 0.02	3.02 ± 0.10
Date fiber	1.63 ± 0.21	1.02 ± 0.02
Carboxymethyl cellulose (CMC)	0.96 ± 0.03	1.02 ± 0.09
Guar gum	0.75 ± 0.02	0.86 ± 0.05
Gum Arabic	0.84 ± 0.03	0.87 ± 0.02
Isabgol	0.82 ± 0.07	2.78 ± 0.04
Pectin	3.53 ± 0.12	1.45 ± 0.11

Table 3: Glucose binding capacity of various fiber sources

SAMPLE USED	**GLUCOSE BINDING CAPACITY (ml/g)**
Wheat bran	675.32 ± 2.47
Oat bran	580.86 ± 3.36
Rice bran	673.42 ± 2.39
Cellulose powder	543.19 ± 3.71
Date fiber	547.38 ± 3.85
Carboxymethyl cellulose (CMC)	554.27 ± 3.02
Guar gum	551.71 ± 4.29
Gum Arabic	555.64 ± 4.69
Isabgol	557.65 ± 10.19
Pectin	618.54 ± 2.47

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Table 4: Preferential test

SAMPLE USED	AMOUNT OF OIL ABSORBED (g)	AMOUNT OF WATER ABSORBED (g)
Wheat bran	1.79 ± 0.02	3.75 ± 0.01
Oat bran	1.19 ± 0.02	1.03 ± 0.03
Rice bran	1.86 ± 0.02	3.37 ± 0.03
Cellulose powder	2.01 ± 0.03	1.87 ± 0.01
Date fiber	1.94 ± 0.03	2.08 ± 0.02
Carboxymethyl cellulose (CMC)	2.71 ± 0.01	4.52 ± 0.01
Guar gum	4.24 ± 0.03	4.87 ± 0.01
Gum Arabic	2.22 ± 0.03	4.28 ± 0.02
Isabgol	2.46 ± 0.0	2.40 ± 0.01
Pectin	0.87 ± 0.11	1.68 ± 0.01