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Der Pharmacia Lettre, 2010, 2(5): 371-378
(http://scholarsresearchlibrary.com/archive.html)

Der Pharmacia Lettre
Scholars Research Library
ISSN 0975-5071
USA CODEN: DPLEB4

Soluble Dietary Fiber: Clinical Nutrition Uses

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ABSTRACT

Dietary fibers find an important role in the normal functioning of the gut, as well as in maintaining the cholesterol levels in humans. In the last two decades dietary fibers have attracted the attention of researchers and is proving a promising additive in foods as well as in nutraceuticals, but still many aspects of the dietary fibers are yet to be explored and studied. Fibers have recently been classified by the Dietary Reference Intake Committee of the Food and Nutrition Board of the Institute of Medicine of the National Academy of Sciences, Canada as total fiber, which is made up of dietary fiber and functional fiber. The importance of dietary fibers have not been realized by the authorities and so has not been separately classified so far, but has constantly been associated in short term and acute studies with serum cholesterol reduction and reduced postprandial glucose and insulin responses. Ironically, it is the insoluble cereal fiber, which is associated with protection from Coronary heart disease (CHD) and diabetes in cohort studies despite a relative absence of demonstrated metabolic effects. Soluble fibers appear to have their effect by reducing the rate of absorption from the small intestine. Similar metabolic effects have been seen with slowing the rate of absorption by other means such as sipping versus bolus ingestion of glucose, increasing meal frequency, or reducing the rate of glucose absorption by the use of low glycemic index foods. However, in this last case, benefits have also been noted in cohort studies in terms of diabetes and CHD risk reduction. Furthermore benefits also appear in relation to the incidence of certain cancers. Soluble fibers therefore have good reasons to have a range of metabolic health benefits. Their potential uses, mechanisms of action and means of incorporation into diets require further exploration. The intent of this review is to summarize the physiological significance of dietary soluble fiber.

Key words: Dietary fibers, Coronary heart disease, soluble fiber, metabolic effects

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INTRODUCTION

Hipsley in 1953 coined the term Dietary fiber (DF) as a short hand term for non-digestible food constituents dietary fibers were originally defined as "The skeletal remains of the plant cells in the diet, which are resistant to hydrolysis by the enzymes in the gut of humans" [1,2]. Most researchers are using either a physiological or a chemical definition as per the physiological definition DF is "the dietary components resistant to degradation by mammalian enzymes", while chemically it is "the sum of non-starch polysaccharides (NSP) and lignin" [3, 4]. Total fiber is the sum of dietary fiber and added fiber. Dietary fiber consists of non-digestible carbohydrates and lignin that are intrinsic and intact in plants. Added fiber consists of isolated, non-digestible carbohydrates that have beneficial physiologic effects in humans. The above said two definitions were proposed by the panel of the Food and Nutrition Board of Federal Govt. of U.S. The DF can be measured as soluble, insoluble and total DF by enzymatic gravimetric method or as soluble, insoluble and total NSP by enzymatic chemical methods and lignin by gravimetric method[3]. Soluble dietary fiber (SF) is a component that is soluble in water and includes pectin substances and hydrocolloids. Good sources of soluble fibers include fruits, vegetables, legumes, phylum seeds, oat bran, and gums. Insoluble dietary fiber (IDF) is that component which is insoluble in water and includes cellulose hemicelluloses and lignin. Whole grain is found to be rich in insoluble fiber [5- 7].

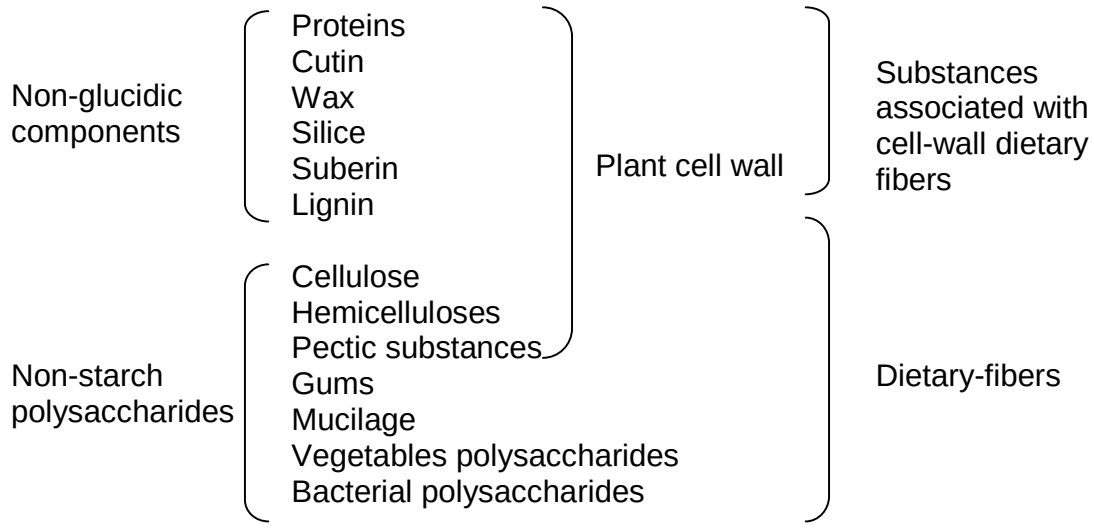
Dietary fibers are resistant to digestion by human gut enzymes. NSP contain numerous different sugar residues, but it passes through the small intestine and into the large bowel undigested. Lignin and resistant starch are also included in it. Lignin is insoluble non carbohydrate in nature. It is found in the woody component of cell wall. Many starch foods such as bread, cornflakes and boiled potatoes contain starch which is resistant to digestion by α-amylase *in-vitro* known as resistant starch [8, 9].

Gums containing 80% soluble fibers are used in food as stabilizers and thickeners by forming viscous solutions to prevent the aggregation of small particles of the dispersed phase. Gum solutions retard crystal growth in ice-cream & confectionaries. Because of their thickening and stabilizing properties, gums are used as additives in cosmetics and pharmaceuticals as emulsifiers or bases for ointments, grease-less creams, toothpastes, lotions, demulcents and emollients. Other applications include surgery film stand gauge, blood anticoagulant plasma extenders and as bacteriological culture media [10].

Soluble fiber: The soluble fiber retards intestinal transit and is partially fermented in large intestine, producing low molecular weight volatile fatty acids which are beneficial for metabolism in intestinal tissues and thought to be related to the cholesterol lowering effect of soluble fibers.

According to the *Association of Official Analytical Chemist*, the soluble fibers are the components which form alcohol precipitate fraction obtain after protease and amyloglycosidese digestion of the water extractable portion of food [11].

Composition of dietary fibers and associated substances [12]



Sources of dietary fiber:

- **Fiber supplement from food and vegetables:** Apple, Orange, Grape fruit, Pineapple, Peache, Mango, Date, Sugar Beet, Sugarcane, Olive, Potato, Carrot, Cauliflower, Cocoa hull, Chile etc. **[**12, 13]
- **Fiber supplements from legumes and seeds:** Cassia, Crotolaria, Sesbanina, and Indigofera, Peas and Beans, Peanut hull, Sunflower hull, Mesquite pod etc **[**14, 15].
- **Fiber supplements from cereals and grains:** Rice, Corn, Barley, Wheat, Oat, Psyllium etc [16-18].
- **Others-** Fiber form sea weeds and bacterial origin etc [19].

Soluble Dietary fibers and their role in prevention of metabolic disorders:

Effect on Glycemic index:

The Soluble fibers are supposed to reduce the serum glucose levels and thus often recommended to diabetic patients or patients suffering from glucose metabolism [20].

The possible mechanism by which dietary fibers have been involved in lowering the glycemic level in serum is by (i) increasing the growth and function of the upper gastrointestinal tract as well as the plasma levels of the intestinotrophic factor, glucagons like peptides, (ii) Lowering the insulin response, and (iii) Delayed glucose absorption through an effect on gastric emptying and or entrapment of materials in the viscous digesta [21-23].

Soluble dietary fibers slow down the rate of diffusion of glucose along with the delayed absorption and digestion of carbohydrates, resulting in lowered post prandial serum blood glucose level [22- 25].

Entrapment of digestive enzymes (α-amylase) as well as food substrate (starch) in the viscous digestible is likely to reduce the hydrolysis of starch to glucose [14, 26].

Effect on lipid metabolism:

The majority of evidences point to soluble fibers having the potential to decrease the total cholesterol and low density lipoprotein cholesterol level (LDL) in the serum [27].

It was proposed that the absorption of bile salts by dietary fibers would result in changes in cholesterol metabolism, leading to loss of cholesterol from the body. Firstly, increased bile excretion would require increased synthesis of bile acids from cholesterol. Second, the unavailability of bile salts in the intestine for micelle formation would also inhibit lipid and cholesterol absorption. Dietary fibers such as barley and sugar beet have been shown to increase buccal bulk and thereby dilute bile acids in the lower intestinal tract [28, 29].

Treatment of diarrhea:
In the irritable bowel syndrome the soluble fiber is more beneficial than total dietary fiber and insoluble dietary fiber. The clinical use of soluble dietary fiber is examined by measuring the serum diamine oxidase activity, which is an index of the morphological change in small intestinal mucosa, fecal features (Feces, Fecal pH, and Fecal short chain fatty acid), and the frequency of bowel movements.

The serum diamine oxidase acts as an index of morphological changes in the small intestinal villous tissues. It has been found that water content is increased significantly, fecal feature is improved, and the frequency of bowel movement is decreased. Therefore, the fiber may have some preventive effect on mucosal epithelial atrophy in the intestine. Most soluble dietary fibers are used as an energy source of bacteria and converted to various substances. When the intestinal flora was investigated, the soluble dietary fiber administered was found to decrease significantly the number of aerobic bacteria, thus making anaerobic bacteria predominant in the intestinal flora. In general, aerobic bacteria are thought to play a protective role in intestinal flora. Therefore, the administration of the fiber may help to normalize the intestinal flora [30, 31].

Effect on colon:
The soluble fiber make a major role in the large intestine ,it increases the fermentation activity, especially production of butyric acid enhances growth and colonization of some probiotic bacterial strains, increases production of microbial mass and thereby aids the removal of nitrogen via feces. it also increases wet weight of stool, thereby alleviating constipation ,short chain fatty acids formed enhances cell proliferation of the colonic mucosa. According to this view it reduces the risk of colon cancer [32-35, 37].

The dietary fiber reduces intestinal transit times allowing intestinal epithelium. Fibers as fermentative substances can also modify the activity of digestive microflora which leads to a modification or reduction in the production of mutagens [32].
When entering the large bowel, fiber increases stool weight, reduces transit time, dilutes colonic contents, and stimulates bacterial anaerobic fermentation. This process reduces contact between the intestinal contents and mucosa and leads to production of short chain fatty acids and the conversion of primary to secondary bile acids [36].

Butyrate is a major source of energy for the distal colon, and in cell lines it reduces cell proliferation and induces apoptosis that are associated with inhibition of the transformation of the colonic epithelium to carcinoma. A possible mechanism for the protective effect of fibers against breast cancer in that high fiber intakes result in increased faecal losses of estrogens which are associated with an increased risk of breast cancer [37, 38].

Fermentation by Human Fecal Bacteria:
The microflora of the large bowel is composed of a diverse community of bacteria with significant roles in the physiology and nutrition of the human host. An effect of fermentation on the colon is stimulation of bacterial growth**.** Short-chain fatty acids produced during colonic fiber fermentation (acetate, proplonate, and butyrate) are absorbed from the colonic lumen and metabolized by various body tissues. Butyrate is preferentially metabolized by colonocytes thus; butyrate level in portal blood is diminished relative to acetate and propionate. Propionate is nearly quantitatively cleared by the liver and may modulate hepatic carbohydrate and lipid metabolism. Acetate largely escapes colonic and hepatic metabolism and serve primarily as a fuel for peripheral tissues. Fiber that escapes colonic degradation, bacterial cells arising from fermentation, and water associated with these components all serve to increase fecal bulk which may be important in reducing the incidence of conditions such as colon cancer and irritable bowel syndrome [39].

Mineral bio-availability:
The soluble dietary fiber improves the mineral absorption. Although, dietary fiber have traditionally been thought to decreases absorption of minerals, but most soluble fermentable fiber sources do not appear to bind minerals and limit their absorption. In fact, some researches have supported the idea that fermentable carbohydrates enhance the absorption of minerals.

A possible mechanism whereby soluble fiber would improve calcium absorption at the gastrointestinal level, is soluble fiber passing through the small intestine and reaching the cecum and colon where fermentation takes place. This fermentation results into production of short chain fatty acids and a decrease in gut pH that may improve calcium abruption in the gut [40].

Antioxidant Activity:
Free radicals attack the saturated fatty acids in the bio-membrane. They cause lipid preoxidation, decrease protein membrane damage resulting in cellular inactivation. DNA is also subjected to mutations, which leads to cancer. An important correlation of cancer prevention, anti-mutation and antioxidant properties exits. Antioxidants act as breaker of chain reaction caused by free radicals [40].
Soluble fiber show1 antioxidant activity largely preventing the bleaching of β-carotene which indicates a good capacity for reduction of the radicals generated by the oxidation of linoleic acid [41-45].

Other function of food fibers:
By controlling metabolic rate the food fibers can help in reducing body weight. Besides energy supply to the colon region via Short-chain fatty acid the food fibers maintain water and electrolyte balance of the intestine. This help in smooth bowl motion and prevents diarrhea and constipation [45-49].

Possible industrial use of soluble fibers [46-52]:
Function:
- Stabilizes emulsion

- Impart creamy consistency
- Enhances mouth feel
- Imparts viscosity
- Stabilizes pulp in beverages
- Controls sedimentation
- Controls crystallization
- Increases the baking volume
- Provides temperature and pH
- Provides retarded drug release in pharmaceuticals
- Extends contact time.

Application:
Food: Dairy, sauces, ketchups and soup, dressing mayonnaise and desert bakery [50-53].

Pharmaceuticals/cosmetics:
Disintegrating and binding agent in compressed tablets, thickeners in liquid suspensions, lotions and creams and some time also used in ophthalmic and skin infection preparations, sustain release formulation as bio-adhesives and emulsion stabilizer.

Other important applications of soluble fiber are in feed products such as liquid animal feed, alternative for calf milk & carpet printing pastes, water based paints and ink etc [47-55].

CONCLUSION

Fiber-rich ingredients are available in different forms and from different botanical origins. Different fibers exhibit different structural and chemical compositions, resulting in a range of nutritional and technological properties. Some of the commercially available highly purified DF (pea and oat fibers) are rich in total DF content of approx. 90%, whereas others contain only 30–70% dietary fibers and are naturally associated with additional food components (e.g. proteins, starches, lipids) that can also play a sensory or technological role.

The use of fibers from newer origin are not fully explored (e.g. from bacteria masses, sea weeds, fruits and vegetables) till date, which may prove to be highly promising. The possibility of modifying the fibers, (by chemical enzymatic or physical treatment) combining them with other components and enhancing their nutritional and sensory characteristics, will probably widen the field of application of dietary fibers.

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