Fibrous drugs for curing various common health problems

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ABSTRACT

In the past 50 years, dietary fiber has become an increasingly significant area of nutritional focus, debate, and research. Advances in food production practices have resulted in more refined foods being available and consumed across the world and particularly in developed nations such as the US. While refined foods are typically more palatable to consumers, the content of dietary fiber is greatly reduced. Currently, many diseases are believed to be associated with a lack of dietary fiber intake and, furthermore, significant health benefits are thought possible via increased consumption of many dietary fibers. There is no well accepted definition for dietary fiber, but most of the references mention the inability of humans to fully digest fibers; most others say about fibers being made of various monomer units of variable length and some mention plant origin. There are many raw materials/ingredients that can increase the fiber content in foods, each with its own set of functional and sensory characteristics, including acacia gum, beta-glucan, cellulose, chitin/chitosan, corn bran, corn fiber, inulin, oat bran/oat fiber, pea fiber, pectin, polydextrose, psyllium, resistant starch, rice bran, soy fibers, wheat bran, and wheat fiber. All these fibers are unique in their functional capability for treatment of number of diseases.

Key words: Dietary fiber, inulin, psyllium, soy fibers, wheat bran

INTRODUCTION

The definition of dietary fiber varies significantly depending on the source. Spiller offers the following five definitions of dietary fiber:[1]

- Plant substances not digested by human digestive enzymes, including plant cell wall substances (cellulose, hemicellulose, pectin, and lignin) as well as intracellular polysaccharides such as gum and mucilage. These are largely identical to undigested carbohydrates and lignin.
- The remnants of plant cells resistant to hydrolysis by alimentary enzymes of human.
- The sum of lignin and polysaccharides that are not hydrolyzed by the endogenous secretions of the human digestive tract.
- The sum of plant non-starch polysaccharides and lignin.
- The remnant of plant foods resistant to hydrolysis by alimentary enzymes of humans.
- There are various other definitions of dietary fiber found in the literature.
- The sum of non-digested components of a foodstuff or food product.[2]
- Substances in food (essentially from plants) that are not digested by the processes that take place in the stomach or small intestine.[3]
- Edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine.[4]

Some definitions of reference plants indirectly state that non-plant sources should not qualify as dietary fiber. Some of these definitions include resistant starch such as dietary fiber, while some do not. All definitions refer to the inability of human enzymes and processes to degrade and utilize these molecules. Much controversy exists about the definition of dietary fiber, and this debate continues with the advent of new materials that could potentially act as or be analyzed as dietary fiber. Stauffer offers the following explanation about the confusion surrounding the definition of a dietary fiber: "Definition of a dietary fiber: Insoluble dietary fiber is the insoluble residue after enzymatic

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digestion; soluble dietary fiber is the digested material that precipitates 78% ethanol; total dietary fiber is the sum of soluble and insoluble dietary fiber; physiological dietary fiber is soluble at 78% ethanol but provides beneficial effects; and some "fiber" do not fall neatly into any of these categories."[4]

From the viewpoint of physiologists and nutritionists, the definition should only include substances that produce the desired effects of dietary fiber in the body. Stauffer refers to this as physiological dietary fiber and defines it as soluble in 78% ethanol, but that have beneficial effects to the body.[4] National Academy Sciences (NAS) defines functional fiber as isolated, nondigestible carbohydrates that have beneficial physiological effects in humans.[5] Generally, functional fiber refers to the wide body of compounds that act as dietary fiber in the body but are not quantified in traditional dietary fiber analysis methods. They may or may not be of plant origin. Examples of these types of fiber include inulin and polydextrose. Most of these fibers are in use today and more are being developed and commercialized.

Common ingredients of dietary fiber: Composition, functionality

The food industry uses various different fiber-based ingredients for supplementation of fiber, physical characteristics that they give to the product or other nutritional benefits they bring to the product. Below are some of the most commonly used ingredients that are rich in fiber and pertinent information about them.

Acacia gum/Gum arabic

Acacia gum (also known as gum Arabic) is produced from the one of two species of the tree – *Acacia senegal* or *A. seyal,* grown in the sub-Saharan region of Africa.[6] This gum is a large and complex polysaccharide consisting mainly of arabinogalactans and arabinogalactan proteins, resulting in large molecules of soluble fiber, with molecular weight 300-800 kDa.

It is assumed that the cause of this moderation in glycemic response is due to the soluble Acacia gum thickening the food matrix in the stomach and intestine, thus reducing the ability of the digestive system to act upon the food. Salovarra describes Acacia gum as having very little ability to increase the viscosity of the food matrix, even at high usage levels, perhaps eluding that there may be some other factors at work here. In addition to moderating glycemic response, Acacia gum is believed to have significant health benefits. Among these are probiotic effects leading to greater gut health and comfort, reduction of diarrhea, and improved cardiovascular health.[6]

Beta-glucan

Beta-glucans are linear polysaccharides made up of D-glucopyranosyl units connected mostly by (1→4) beta linkages, with occasional (1→3) beta linkages.[7] Often there are three or four (1→4) linkages between each (1→3) linkage. Cereal beta-glucans function as soluble and insoluble fibers, as they are only partially soluble in water.[7]

Beta-glucan is a component of cell wall in fungi, algae, oats, barley, rye, and wheat.[5,7] The location of beta-glucan within the cereal grain varies. In some cases, it is found throughout the grain, while in others it concentrates in a particular area. For example, in wheat, the majority is found in the bran of the grain.[7] When further fractionating wheat bran, beta-glucans are found in greater concentrations in the aleurone fraction of wheat bran than in the pericarp fraction (refer to wheat bran for more information on these fractions).[8] Because of this variability, processing techniques can greatly alter the beta-glucan content of various cereal products.

Beta-glucans are associated with reduction in blood cholesterol and regulation of blood glucose levels (functions associated with soluble fiber). NAS states that beta-glucans minimally increase fecal bulk, and thus lack the ability to relieve constipation, somewhat contradicting the concept that they function as both soluble and insoluble fiber.[5]

Cellulose

Cellulose is beta (1→4) glucan. For those less familiar with this terminology, these are glucose molecules that are linked C1 (carbon 1) to C4, using the beta orientation. This linkage is in contrast with the alpha linkage of traditional starches; in fact, it is the only major structural difference when comparing the two molecules. The enzymes of the human digestive system are not capable of breaking this beta linkage. However, certain enzymes are capable of this conversion. In laboratory settings, cellulose can by hydrolyzed by heating in the presence of a strong acid. Cellulose is a major structural component for almost all plants and is believed to be the most abundant organic substance in the world.[9]

Cellulose varies in its morphology depending on its source, thus allowing a trained microscopist to be able to determine the plant of origin.[9] Scientists recommend using cellulose as a fiber source because it is cheap, abundant, almost 100% dietary fiber, has low flavor impact, good storage stability, low or no microbe counts, and is a virgin product.[9] Others would likely note its lack of functional viscosity (insoluble fiber) and its tendency to produce undesirable textural changes as reasons not to use cellulose.

Cellulose can also be modified by various further processing steps in order to change its structure, and thus its functionality. One form of processing is to treat cellulose (sometimes referred to as alpha-cellulose) with acid to remove the amorphous paracrystalline regions.[10] This is sometimes referred to as cellulose gel or microcrystalline cellulose. This ingredient comes in many forms and is mostly used for its thickening properties and sometimes as a carrier or bulking agent for various other ingredient or flavor delivery systems.

Cellulose can be chemically modified into methylcellulose, carboxymethyl cellulose, or hydroxypropyl methylcellulose.[10] These molecules have a variety of substitutions that impact the molecules' solubility and other physical properties.

Cellulose is known to significantly increase fecal bulk (and thus presumably laxation), decrease transit time, and increase wet stool weight.[5] There is little, if any, effect of cellulose on blood lipid concentration or blood glucose responses, and is thus often used as a control or placebo in these types of studies.[5]

Chitin/chitosan

Chitin and chitosan are beta (1→4) linked insoluble polysaccharides found in arthropods (crabs, lobster, etc) and some fungi and yeasts and is the second most abundant polymer in nature (second to cellulose).[5,10] Chitosan is simply a deacylated version of chitin.[10]

Chitin and chitosan have been shown to affect blood glucose concentrations in animal studies, although the results have not translated to human trials that convincingly.[5] NAS states that there are no known reports demonstrating that either of these fibers can affect blood glucose response or fat absorption in humans.[5]

Corn bran

Corn bran can be separated via wet or dry corn milling, separating the bran, germ, and endosperm components of the corn grain. The typical composition of the corn kernel is 80-85% endosperm, 10-12% germ, and 5-6% bran.[10] A variety of products are made from this process including grits, meal, flour, and bran.[11] Refined corn bran typically has a nutritional profile similar to the following: 4% moisture, 3.8% protein, 1% oil, 1% ash, and 88% total dietary fiber. The 88% fiber breaks out as 18% cellulose, 67% hemicelluloses, <2% lignin, <1% pectins, <1% gums, and thus is largely an insoluble fiber.[11] Corn bran is natural, minimally processed, low calorie, exhibits high water binding capacity, available in many grind sizes (to alter textural attributes), and is readily available. Burge and Duensing also cite studies indicating that corn bran helps reduce serum cholesterol (even without much soluble fiber) and the ability to absorb fecal mutagens, potentially protecting the body against them.[11]

Corn fiber

Corn fiber is the seed coat and residual endosperm from grain processing, often the byproduct of wet milling used in the production of ethanol.[12] Research is ongoing to make this industrial byproduct available for use as a biofuel.[12]

Inulin

Inulin is a soluble fiber and classified as a fructan. Inulin is composed of a linear chain of fructose molecules ending with a glucose molecule. This chain is made up of beta 2→1 linked fructose molecules and the chain length varies between approximately 2 and 60 units.[6]

The physical properties of inulin change slightly on the basis of chain length. Inulin is present in more than 36,000 plants and vegetables.[10] It acts as the energy storage system (instead of starch) for these plant species and is found in leek, onion, garlic, asparagus, Jerusalem artichokes, dahlia, yacon, and chicory.[13,14] Chicory roots are the most widely used source as this plant has a very high content of inulin, up to 80% of the dry matter.[15]

In practice, inulin is usually sold as a finely ground white powder. It is essentially odorless. In solution, inulin imparts some viscosity, slight opacity, and potentially a slight sweetness that is approximately 10% as sweet as sugar.[13] There are actually two types of inulin sold: standard and high performance or long chain. High-performance inulin has the shorter chains removed, and thus has less sweetness and results in greater viscosity in solution.

Inulin is used in a wide variety of products and for various reasons. Most common of these is fiber fortification, but it is also used to mimic fat, provide viscosity, stabilize gels/foams/emulsions, provide body/mouthfeel, freeze-thaw stability and provide synergy with other sweeteners, moisture retention and also as a probiotic.[13] Inulin is known to work synergistically with high-potency sweeteners to enhance their sweetness, reduce bitter flavors, and enhance fruity aromas.[15] Inulin can also be viewed as a probiotic, as it is consumed by healthy microflora in the small intestine, resulting in growth of those microflora, and leading to a healthier bowel.[16]

Inulin and other fructo-oligosaccharides have been shown to increase fecal bulk and reduce transit time while promoting the growth of bifidobacteria.[5] Bifidobacteria are believed to promote health in animals, although the effect on humans it still unclear. The effect of inulin and other fructo-oligosaccharides is somewhat conflicted in the areas of blood lipid concentration and blood glucose response.[5]

In the industry, it is widely understood that inulin has the tendency to cause increased flatulence in some people. Due to this, the amount used in products must be at reasonable levels and people who are significantly affected by this are advised to read labels carefully for inulin or chicory root fiber.

Oat bran/Oat fiber

When processing oats, the hulls are removed from the grain and separated via air classification and/or sifting. What remains (oat bran, germ, and endosperm) is commonly called a groat. The hulls can be ground to produce oat fiber or they can be further processed to increase the fiber content and remove any unwanted fractions such as the color.[10]

Groat can be further processed to yield oat bran and oat endosperm. Oat bran is composed of the bran and endosperm because it is difficult to remove the endosperm from the bran as compared to other cereal grains, likely due in part to the high lipid content.[10,17] Oats are a significant source of beta glucan, which is predominantly a cell wall component of the oat endosperm.[17]

Oat products are associated with a host of beneficial effects in humans, many directly related to the beta-glucan present. Insoluble fiber from oats can help with fecal bulk and transit time, while the soluble fiber (including beta-glucan) is believed to promote bacterial growth in the large intestine through fermentation, lower blood lipids, and reduce glucose response, although some conflicting research is also available.[5]

Pea fiber

Pea fiber is made from the shells of peas. In practice, the powder can be white to green, depending on pea source and any purification that is done.[10] Nelson states that pea fiber is typically 75-82% fiber, 77% of which is insoluble. Pea fiber from the inner cell walls can be used to alter the sensory properties of reduced fat beef patties.[18] This fiber contains approximately 48% fiber, 44% starch, and 7% protein. This study determined that patties with pea fiber had higher yield and improved tenderness, similar juiciness, but slightly less beef flavor and more browned flour flavor.

Pectin

Pectin is formed from linear chains of galacturonic acid with some rhamnose units included in the chain. Pectin does not have a significant effect on fecal bulking, wet stool weight, or transit time, but is believed to reduce blood glucose response (as other viscous fibers do).[5] NAS also states that most studies indicate that pectin provides a lowering effect on blood lipid concentrations, particularly to Low-Density Lipoprotein (LDL, or "bad") cholesterol.[5]

Polydextrose

Polydextrose is a polymer of randomly ordered glucose and sorbitol units.[5] This molecule is not sweet and considered a resistant oligosaccharide or polysaccharide.[10] The structural complexity and tightness is the reason it resists the action of enzymes, although some of it is available to the enzymes, resulting in approximately 1 kcal per gram energy as compared to 4 kcal per gram for a fully available starch.[19] It is often used as a bulking agent and a source of dietary fiber in many food products. According to Nelson, it has a neutral flavor, is stable, and very water soluble. Polydextrose can be used by food industry professionals to supplement fiber, replace fat, or replace sugar.[10]

Polydextrose is believed to have several physiological effects related to laxation. Increased fecal mass has been shown, although the effect on transit time and fecal bacteria production are not well agreed upon as studies conflict.[5] Polydextrose lowers the pH of the intestinal contents, resulting in the promotion of beneficial bacteria (probiotic effect) and inhibiting pathogenic bacteria.[19]

Psyllium

Psyllium (or psyllium husk/*ispaghula* husk) is a soluble fiber derived from the husk of psyllium seeds.[5] This fiber source is about 70% soluble fibers and is a polymer of arabinose, galactose, galacturonic acid, and rhamnose.[10]

Psyllium's role in laxation is well known as it is commonly used in laxatives and has been shown to increase stool water content and water weight, total stool output, bowel movement frequency, and thus reduce the issues of constipation.[5] Psyllium has been shown to reduce blood lipid concentration, most often more so on total and LDL cholesterol and less on High-Density Lipoprotein (HDL) and blood glucose responses in a wide variety of studies.[5]

Resistant starch

Resistant starch comprises starch molecules that are unavailable for degradation for a variety of reasons and are classified as RS1 through RS4. Although the physiological effects of resistant starch varies by its type, generally, resistant starch is believed to slightly increase fecal bulk, reduce blood glucose response, and have little effect on blood lipid concentration.[5] After passing through the small intestine, this starch is fermented in the large intestine, thus producing short chain fatty acids.

Contrary to the contentions of the NAS, Leszczyński describes the short chain fatty acid production as having several beneficial effects in the colon.[5,20] These effects include reduction of blood lipids and cholesterol, promotion of favorable intestinal microflora, and prevention of gut cancer.

Rice bran

Rice bran is obtained when making white rice. Once the hull is removed, the rice bran is obtained by further processing and abrasion (called polishing) to separate the bran and germ portions from the endosperm.[10] The total dietary fiber content of rice bran varies based on whether it is obtained from standard whole grain rice or from parboiled rice. Generally, rice bran contains 20-33% dietary fiber, the majority of which is insoluble.

Rice hulls are about 25% of the initial rice grain and contain mainly cellulose and lignin.[21] Rice bran is mostly used as animal feed as the high lipid content (as well as protein, vitamins, and minerals) leads to rancidity, and thus off odors and flavors.[10,21] Rice bran, therefore, finds limited commercial use in foods, although it can be found in rice flours and breakfast cereals.[21]

Soy fibers

Soy can be processed into three fiber ingredients- soy bran made from hulls, soy fiber made from endosperm called cotyledon, or soy protein concentrate/isolate made from cotyledon.[10,22] Soybean cell walls are made of approximately 30% pectin, 50% hemicelluloses, and 20% cellulose.[22]

Soy bran is made from the soybean hull and is typically 65-95% total dietary fiber and is mainly insoluble. Hulls are further refined to accomplish this level of purity, involving lipid extraction and the product of that is ground to various sizes.[10]

The process of making soy protein concentrates results in the generation of the other two fiber sources. This process involves taking the de-hulled soybeans and further processing them by rolling, lipid extraction, drying, and finally protein extraction.[22] The protein extraction involves a solubilization step at alkaline pH that removes most of the protein and some soluble fiber; this fraction will become soy protein concentrate. The nonsolubilized portion will become soy fiber. Both products are somewhat purified and then dried.

Soy fiber is typically a total dietary fiber with a content of 75-80%, which is a mix of insoluble and soluble dietary fiber, and contains much less cellulose derived than the bran fraction.[10] Soy protein concentrate is typically about 20% dietary fiber and 70% protein.[10] Soy bran and fiber ingredients are used in all types of products that are currently in the market. These products include many nutritional beverages (such as those used in hospitals), muffins, cookies, crackers, pudding, cake, noodles, breakfast cereals, snack foods, and more. Soy fiber can be used from 5-20% of the flour weight in multigrain breads or up to 10% in bakery products.[22]

Soy fibers provide many of the typical health benefits of other soluble and insoluble fibers. These fibers have been shown to have many positive effects on bowel function, including increased fecal bulk, decreased transit time, increased stool consistency, and increased frequency of bowl movements.[22,23] Riaz also contends that soy fibers have been shown to reduce serum cholesterol, lower insulin and glucose responses and reduce mineral absorption to a lesser extent than other fibers (this is a significant concern in some populations, not too often in healthy people consuming a well balanced diet).[23]

Wheat bran

Wheat bran is a byproduct of wheat milling containing the outer layers of the wheat grain.[8] It typically contains about 45% total dietary fiber, other components being protein, starch (contamination from milling process), moisture, ash and various other low level fractions.[8,24] Wheat bran can be separated into two main fractions; the pericarp fraction which contains a greater proportion of the outer wall of the grain and the aleurone fraction that contains a greater proportion of the inner wall.[8] Consumption of wheat bran is associated with a wide variety of health benefits including relieving constipation and prevention of colorectal cancer.[8]

Wheat fiber

Wheat fiber is essentially a further refinement of wheat bran. It is primarily cellulose and hemicellulose with very low levels of lignin.[24] This fiber has a light color, neutral taste/odor, high fiber content (~98%), thus low caloric value, high water-binding capacity, dispersing effect, good storage stability, and a clean label. Bollinger describes wheat fiber's unique property of binding water compared to simple surface association, called the capillary affect, resulting in lower vapor pressure and positive product characteristics unique to this fiber, particularly in the case of wafer production. Wonderful baking properties of this fiber are described without undesirable sticking or discoloration.

SUMMARY

Currently, dietary fiber is a topic of considerable interest and debate. Unlike many other components of foods, the importance of dietary fiber was not well established until sometime in the 20th century. Most definitions of reference dietary fibers include being indigestible by human enzymes and metabolic processes; many refer to polysaccharides, and some state that fiber must come from plant sources. Dietary fibers can be divided into several groups of compounds: pectin, cellulose, hemicellulose, lignin, hydrocolloid, mucilage, and resistant starches. A significant part of the complexity in defining dietary fiber is trying to account for the wide variety of compounds that act as dietary fiber. More generally, fiber is often grouped into soluble and insoluble portions, although functional fiber has recently been added to these groups, as many compounds thought of as dietary fiber do not analyze as soluble or insoluble fiber based on traditional methods. Lack of dietary fiber consumption is associated with the development of many common diseases through epidemiological and human/animal intervention studies. These diseases include bowel disease/Crohn's disease, colon cancer, constipation, diabetes, diverticulosis/itis, gallstone, heart disease, high cholesterol, hyperlipidemia, and obesity. While very strong epidemiological evidence exists, cause and effect conclusions cannot be made based on these studies alone. Epidemiological studies cannot determine whether the presence of dietary fiber is the reason for the health effect or whether foods high in fiber are generally more nutritious than those low in fiber and that is the reason for the health benefits. Thus, there is still a great need for research correlating specific fiber types to reduction in disease risk.

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