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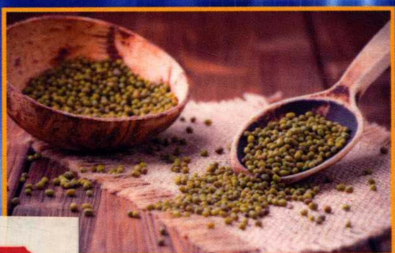
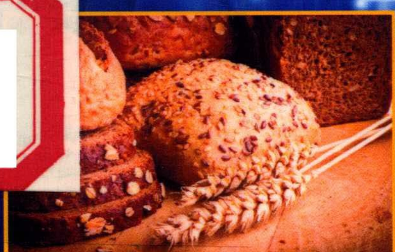
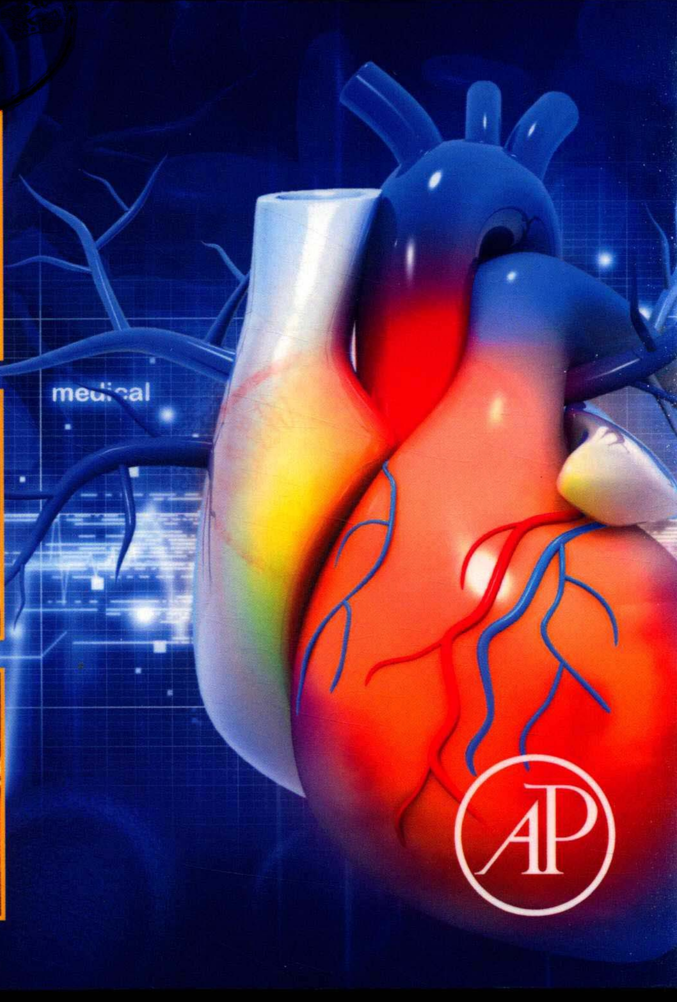
Dietary Fiber for the Prevention of Cardiovascular Disease

Fiber's Interaction Between Gut Micoflora, Sugar Metabolism, Weight Control and Cardiovascular Health







DIETARY FIBER FOR THE PREVENTION OF CARDIOVASCULAR DISEASE

Fiber's Interaction Between Gut Micoflora, Sugar Metabolism, Weight Control and Cardiovascular Health

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CHAPTER 1

Dietary Fiber and Human Health: An Introduction

Santosh K. Jha, Hare R. Singh, Pragya Prakash

1 INTRODUCTION

Fibers are the structural part of a plant and are found in all plant foods, including vegetables, fruits, grains, and legumes. Dietary fiber is a discrete group of carbohydrate found almost exclusively in plants, including non-starch polysaccharides (NSPs), such as cellulose, pectin, and lignin. It is the edible integral element of carbohydrate and lignin that is naturally found in plant food. Most dietary fibers are polysaccharides are starches, but they are not digested by humans. Starch is a long chain of glucose molecules linked together with alpha bonds. Fiber is a long chain of glucose molecules linked together with beta bonds. The human body lacks enzymes to break beta bonds, therefore fiber is not digested and absorbed. The undigested fiber passes into the lower intestine where intestinal bacteria can ferment the fibers.

Fibers are typically known as NSPs. NSP fibers include cellulose, hemicellulose, pectin, gums, and mucilages. Dietary fibers act by changing how other nutrients and chemicals are absorbed. Some varieties of soluble fiber absorb water to become a gelatinous, viscous substance that is degraded by microbes in the digestive tract. Some types of insoluble fiber have bulking action and are not fermented. Lignin, a significant dietary insoluble fiber may alter the rate and metabolism of soluble fibers. Some other types of insoluble fiber, notably resistant starch (RS), are fully fermented. Some but not all soluble plant fibers block intestinal mucosal adherence and translocation of potentially pathogenic bacteria and may therefore modulate intestinal inflammation, an effect that has been termed contrabiotic.

The occurrence of the fiber depends on the sources and origin. For example, in vegetables, fiber is mainly concentrated on the skin, but trace amounts are found in the rind too, while in cereals it is mainly found in the bran portion, whereas in fruits it is not only present in the skin but

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Table 1.1 A classification of the unavailable carbohydrates in foods [1]

Major sources in the diet	Description	Classical nomenclature
Structural materials of the plant cell wall	Structural polysaccharides	Cellulose, some pectins, and hemicellulose
	Noncarbohydrate constituents	Lignin, minor constituents
Nonstructural materials, either found naturally or used as food additives	Polysaccharides from a variety of sources	Pectins, gums, mucilages, algal polysaccharides, chemically modified polysaccharides

also in the fruity portion named the mesocarp. Dietary fiber usually refers to the unavailable carbohydrates, and is mainly classified as soluble and insoluble. The insoluble fibers are present in fruits, vegetables, grains, legumes, and cereals. The soluble fibers include pectin, gums, certain hemicelluloses, and storage polysaccharides. Fruits, some vegetables, oat, barley, soybeans, psyllium seeds, and legumes contain more soluble fiber than other foods.

The American Association of Cereal Chemists (AACC, 2001) defined dietary fiber as: "the edible parts of plants or analogous carbohydrates that are resistant to digestion & absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fiber promotes beneficial physiological effects including laxation, blood cholesterol attenuation, and blood glucose attenuation."

These unavailable carbohydrates can be categorized into two major groups, based on the structural components as shown in Table 1.1.

2 TYPES OF DIETARY FIBER

Dietary fiber comprises cellulose, noncellulosic polysaccharides (NCPs), such as hemicelluloses, pectic substances, and a noncarbohydrate component lignin. These are mainly the structural components of the plant cell wall. Some types of plant fiber are not cell wall components, but are formed in specialized secretory plant cells including plant gums. Gums are sticky exudations formed in response to trauma. Mucilages are secreted into the endosperm of plant seeds where they act to prevent excessive dehydration and include materials with widespread industrial applications, such as guar gum.

2.1 Soluble Versus Insoluble Fiber

Chemists classify fibers depending on how promptly they dissolve in water, so these can be categorized as soluble fibers and insoluble fibers. The insoluble fibers act as a sponge within the gut by absorbing water. This will increase the softness and bulk of the stool and will thereby decrease the chance of constipation, and colon carcinoma [2]. Scientists have conjointly recommended that soluble fibers can reduce glucose levels and hence prevent diabetes [3]. Foods containing fiber often have a combination of both soluble and insoluble fibers. Diets rich in soluble fiber includes dried beans and oranges. Insoluble fibers include whole wheat (wheat bran) and rye.

The Institute of Medicine recommends that the terms soluble and insoluble fibers should no longer be used to classify dietary fibers even though they may still appear on some food labels. Both are considered to be functional fibers; nondigestable carbohydrates have beneficial physiological effects in humans. Another new term is total fiber, which is the sum of dietary fiber and functional fiber [4].

2.1.1 Common Fibers

The most common fibers are cellulose, hemicellulose, and pectic substances. A few other types of fiber include vegetable gums, inulin, beta-glucan, oligosaccharides, fructans, some RSs, and lignin. Lignin belongs to the class of the fibers that are not carbohydrates [4].

2.2 Polysaccharides

Cellulose, the foremost verdant molecule found in nature, is the beta compound of starch; it is a long (up to 10,000 sugar residues) linear compound of 1,4 joined units of glucose. Hydrogen bonding between sugar residues in adjacent chains imparts a crystalline microfibril structure; cellulose is insoluble in robust alkali. NCPs embrace an oversized variety of heteroglycans that consist of a mixture of pentoses, hexoses, and uronic acids. Among a lot of vital NCPs are hemicellulose and cellulose substances [5]. Hemicelluloses are cell wall unit polysaccharides solubilized by a binary compound alkali after the removal of water soluble and cellulose polysaccharides (Table 1.1). The hemicelluloses are subclassified on the premise of the principal monomeric sugar residue. Acidic and neutral forms differ by the content of glucuronic and galacturonic acids. Uronic acid formation involves the reaction of the terminal —CH_2OH to —COOH, and is of biological importance since the sugar residues become obtainable for methylation, amidation, and formation of ion complexes [6]. Hemicelluloses, particularly the simple sugar and uronic acid parts, are accessible to microorganism enzymes as compared to cellulose [7,8]. Pectic substances are a cluster of polysaccharides within which D-galacturonic acid is a major constituent. They are the structural part of plant cell walls and additionally act as cementing material. These substances embrace a water-insoluble parent compound protopectin, further as pectinic acids and pectin. Long chains of galacturonan are interrupted by blocks of L-rhamnose-rich units that end up in bends within the molecule. Several pectins have neutral sugars covalently joined to them as side chains, chiefly arabinose and sucrose, sugar, rhamnose, and aldohexose. It has additionally been observed that small quantities of glucuronic acid are also joined to cellulose in a facet chain [9–11]. The carboxyl groups of the galacturonic acids are partly methylated, and therefore the secondary hydroxyls are also acetylated. Pectin is extremely soluble and is metabolized by colonic bacterium [12].

2.3 Lignin

Lignin is not a sugar, but is rather a compound containing about 40 oxygenated phenylpropane units, as well as coniferyl, sinapyl, and *p*-coumaryl alcohols that have undergone a dehydrogenative polymerization process [13,14]. Lignins vary in mass and methoxyl content. As a result of strong intramolecular bonding which has carbon-to-carbon linkages, lignin is inert. Lignin displays a greater resistance to digestion than the other naturally occurring compound.

Lignin is a fiber that is not sugar, but rather a saccharide, consisting of long chains of phenolic resin alcohols connected along an oversized advanced molecule. As plants mature, their cell walls increase in lignin concentration, leading to a tough, stringy texture. This partly explains why celery and carrots get harder as they age. Boiling water does not dissolve or even soften the lignin.

3 PHYSIOLOGICAL EFFECTS OF DIETARY FIBERS

See Fig. 1.1.

3.1 Dietary Fibers Effects on Immunity

The epithelial duct is subjected to monumental and continuous foreign substance stimuli from food and microbes; it will integrate complicated interactions among diet, external pathogens, and native immunologic and

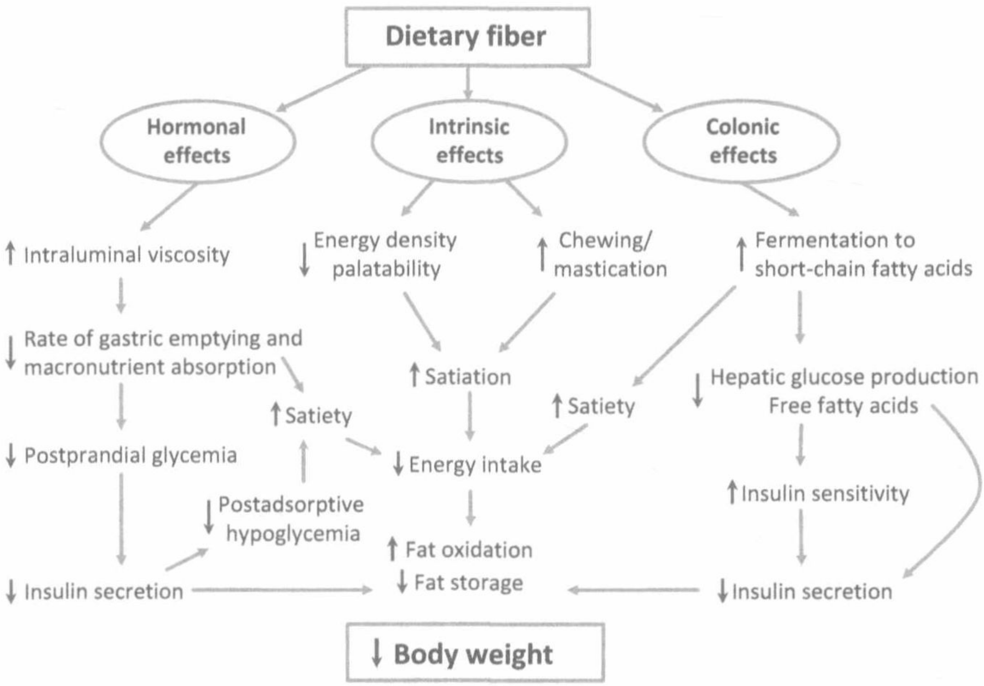

Figure 1.1 ***Physiological effects of dietary fibers [15].***

nonimmunological processes. There is an increasing proof that fermentable dietary fibers and the new delineated probiotics could modulate numerous properties of the system, as well as those of the gut-associated lymphoid tissues (GALT).

3.1.1 Proposed Mechanisms: Immunomodulating Effects of Dietary Fibers

- Direct contact of lactic acid bacteria or bacterial products (cell wall or cytoplasmic components) with immune cells in the intestine.
- Production of short-chain fatty acids from fiber fermentation.
- Modulation of mucin production.

3.1.1.1 Direct Contact of Lactic Acid Bacteria or Bacterial Products (Cell Wall or Cytoplasmic Components) With Immune Cells in the Intestine

It is typically assumed that the consumption of prebiotics, through their effects on the colonic microflora, can have an analogous impact as probiotics on the performance of the immune system. Studies have documented the effects of feeding carboxylic acid bacterium (i.e., *Lactobacilli* and *Bifido* bacteria) on varied parameters of immune function. Oral administration of probiotic bacterium resulted in the accumulation of immunoglobulins, particularly IgA, in GALT and modulated the amount and activity of Peyer's patch immune cells. There also are a variety of studies demonstrating the effects of oral probiotics on the general immune functions and immune parameters within the lungs, peritoneum, and mesenteric lymph nodes. Although there are no confirmed mechanisms as to how fiber positively influences the immune system, but one logical mechanism may well be the immune stimulation through direct contact of the colonic microflora with GALT. Smaller numbers of bacterium will cross the enteral animal tissue barrier into the Peyer's patches [16] resulting in the activation of alternative immune cells [16–19]. In vitro studies have supported this mechanism.

In one study, a phagocyte cell line accumulated its production of gas, H_2O_2, IL-6, and TNF-α when cultured with *Bifido* bacterium. Similarly, culture with *Bifido* bacterium considerably accumulated the assembly of TNF-α and IL-6 by macrophages, and therefore the production of IL-2 and IL-5 by stimulated CD4+ cells [20]. Culturing murine Peyer's patch cells with *Bifido* bacterium (*Bifidobacterium breve*) resulted in proliferation and protein production by B-lymphocytes and activated macrophage-like cells [21].

3.2 Susceptibility to Bacterial Enzyme Degradation

Fermentation could also exert a physiological impact or alter the chemical atmosphere of the cecum, thus affecting the growth or the metabolic activity of the microorganism.

The extent of fiber degradation within the colon relies on the character of the colonic microorganism flora; the condition of a given fiber to microorganism digestion relies on its physical and chemical structure. Digestion of polysaccharides varies between 30% and more than 90%. Pectin and hemicellulose are lost through the stool; cellulose is somewhat less well digestible [22–24]. Lignin, by virtue of its chemical compound cross-linked structure, is resistant against microorganism degradation and is nearly utterly recovered within the stool. Polysaccharides from extremely hard plant tissue areas are less well digestible because physical encrustation and chemical bonding to lignin occur.

3.3 WaterRetention Capability of Dietary Fiber

The water retention capability of dietary fiber has necessary physiological effects in each of the small and large intestines.

The initial event upon exposure of fiber to an aqueous medium is surface adsorption of water molecules. Particle size may additionally influence the water retention capability of fiber [25–27]. Robertson and Eastwood have demonstrated that the fiber preparation alters the water retention capabilities. This implies that the physical structure of fiber is the most significant determinant of hydratability.

3.4 Adsorption of Organic Materials

Adsorption of digestive fluid acids has been best documented and relies on the composition of the fiber, the chemistry of the steroid, and therefore the pH and osmolality of the encompassing medium [28,29]. Lignin is the most potent steroid adsorbent, and binding is seemingly influenced by mass, pH, and therefore the presence of methoxyl and α-carbonyl groups on the lignin molecule [30]. Eastwood and Hamilton [31] demonstrated that methylation of polymer accumulated steroid sorption. These authors conjointly reported that adsorption was greatest at low pH. Each condition would either block or suppress ionization of carboxyl groups and hydroxyl groups on lignin's phenyl propane units, suggesting a hydrophobic bonding mechanism. These studies predict that interaction with lignin is greater for bacterially changed digestive fluid acids shaped within the colon. Saponins conjointly bind bile acids in vitro [32] and in vivo [33], and they may be responsible for sterol adsorption related to fiber. However, bran and alfalfa showed no diminution of adsorbent capability following removal of associated saponins [34].

3.5 Cation Exchange Properties

The useful capability of dietary fiber for ion exchange is well established. The impact is expounded to the amount of free carboxyl teams on the sugar residues [35,36]. Calcium binding is foretold on the premise of uronic acid content of fiber residues [37]. Formation of ion complexes with acidic polysaccharides is mirrored in their effects on mineral balance, solution absorption, and significant metal toxicity.

3.5.1 Quantifying Fiber Content

Several completely different laboratory strategies are used to measure the quantity of fiber in foods. The older technique consisted of treating a food with robust acid to simulate the surroundings of the abdomen, so treating it with a base to parallel the experience within the small intestine. The remaining weight of undigested fiber was measured as "crude fiber" and was listed in most food composition tables as "fiber." This rather inaccurate technique has been for the most part replaced by associate analytical technique approved by the Association of Official Analytical Chemists International (AOAC) that measures dietary fiber. For each 1 g of crude fiber, there are 2–3 g of dietary fiber.

4 DIETARY FIBER SUBSTANCES

4.1 Inulin

This polysaccharide consists of continuous repetitive units of fruit sugar with associate finish molecule of glucose. Although this fiber happens naturally in over 30,000 plants, it is most typically found in asparagus, artichoke, and garlic. Food processors extract polysaccharide from the chicory root [31], and this soluble fiber is used by the industry to impart a creamy texture to frozen farm merchandise like no-fat or no-sugar frozen dessert, improve the textures of spread spreads, and develop no-fat icings, fillings, and whipped toppings (Table 1.2).

5 RECOMMENDED FIBER INTAKE

Fiber is a carbohydrate that is not digested or absorbed, so it contributes few, if any, calories. The Institute of Medicine recommends that healthy adults consume:

- 25 g of daily fiber for women
- 38 g of daily fiber for men

Fiber recommendations for children and elderly are 14 g of fiber for every 1000 calories (kcal) consumed. The average US intake of only 15 g of dietary fiber per day falls short of these goals. One of the ways to increase

Table 1.2 Dietary fibers and their prebiotic effects

Fibers	Prebiotic effects
Wheat dextrin	Increase bacteroides, reduce clostridium
Inulin	Bifidogenic
Galactooligosaccharide	Bifidogenic
Acacia gum	Bifidogenic
Psyllium	Prebiotic potential
Polydextrose	Bifidogenic
Whole grain	Prebiotic potential
Banana	Fecal microbiota