# Fiber in Health and Disease

Subjects: Nutrition

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## Definition

The etiology of inflammatory bowel disease (IBD) is complex but is thought to be linked to an intricate interaction between the host's immune system, resident gut microbiome and environment, i.e., diet. One dietary component that has a major impact on IBD risk and disease management is fiber. Fiber also has a significant impact on beneficially shaping gut microbiota composition and functional capacity.

## 1. Inflammatory Bowel Disease

Inflammatory bowel disease (IBD) is characterized by chronic, relapsing inflammation of the gastrointestinal (GI) tract. There are two main subsets of IBD: Crohn's disease (CD), which affects any part of the GI tract but is primarily found in the terminal ileum and cecum, and ulcerative colitis (UC), which affects only the colon. The incidence and prevalence of IBD is rising in a concerning fashion, particularly in children [1].

It appears that one of the strongest determinants of IBD risk is a family history of the disease[2], although it is becoming increasingly evident that modifiable environmental factors such as diet, medication use, smoking, hygiene and breastfeeding also play a key role in disease risk [3]. The exact etiology of IBD is unknown, but the current view is that an intolerance to dysregulated gut microbiota (dysbiosis) due to environmental triggers leads to chronic gut inflammation in genetically susceptible individuals [3]. Of the environmental risk factors that have been identified, diet appears to be the most influential. Therefore, a deeper understanding of the impact diet has on the gut microbiome and subsequent development of IBD is warranted.

Presently, there is no known cure for IBD. Therefore, current therapies are directed at controlling symptoms and maintaining disease remission through the use of immunomodulatory medications that unfortunately have side effects and varying success rates. Consequently, novel therapies are in high demand, with alternative and complementary approaches, particularly dietary and gut microbiome-targeted therapeutic approaches, gaining validity and popularity [4]. More well-designed studies are needed to elucidate the true benefit these novel therapies have in treating IBD.

## 2. Fiber and Prebiotic Types

Dietary fibers (DFs) are commonly known as nondigestible carbohydrates that confer a health benefit to the host. The exact definition of fiber is still a matter of debate and is continuously evolving due to advances in the field and updates to international guidelines for food product definitions [5]. The differences in the chemical structure and physiochemical properties of DF such as water solubility and viscosity, fermentability and specific physiological benefits of each DF make specific definitions a challenge. Moreover, depending on the fiber studied, there is no consensus as to whether the positive health outcomes are restricted to intact fibers within a food matrix or whether the benefits also extend to fibers extracted from plants, i.e., fiber supplements [5].

Most countries' authorities align with the Codex Alimentarius Commission (CAC) definition established in 2009, where DFs are defined as edible carbohydrate polymers with ten or more monomeric units that are resistant to endogenous digestive enzymes and thus are neither hydrolyzed nor absorbed in the small intestine of humans [6]. The CAC definition provides flexibility to international authorities regarding polymer size; in several countries such as Australia, Brazil, Canada, China, Europe and New Zealand, nondigestible carbohydrates with greater than three monomeric units can be considered DFs [7]. According to the CAC, these edible carbohydrate polymers can be found naturally in whole foods such as fruits, vegetables, legumes and cereals as well as extracted from raw food materials by physical, enzymatic and chemical techniques. Additionally, synthetic carbohydrate polymers can also be consider DFs as long as a physiological benefit is proven [8].

DFs are subdivided into either polysaccharides, such as non-starch polysaccharides (NSP), resistant starch (RS) and resistant oligosaccharides, or into insoluble and soluble forms [8][9]. Soluble fibers are fermented in the colon and thus increase the concentration of beneficial bacterial metabolites such as short-chain fatty acids (SCFAs) [8]. Most soluble NSPs such as guar gum, β-glucans, psyllium and specific pectins are able to absorb water in the intestinal tract, forming a gel structure that improves stool consistency [8][10]. Moreover, the viscosity properties of soluble fibers can delay absorption of glucose and lipids and thus positively impact postprandial metabolism [9]. In contrast, insoluble fibers such as cellulose and hemi-cellulose are poorly fermented by the bacteria present in the colon. Instead, they confer a fecal bulking effect that helps with bowel movements by improving intestinal transit time [8][10]. Soluble and insoluble fibers are found in different proportions among several food categories such as fruits, vegetables, seeds, nuts, legumes and cereals. While common sources of soluble fiber include oatmeal; barley; and legumes such as beans, lentils and peas, insoluble fibers are present mostly in wholegrain cereals as well as in seeds and the skins of fruits and vegetables.

Based on the physiochemical characteristics of DFs it has been suggested that, even as a secondary effect, all fibers positively shift the gut microbiota composition conferring a general health benefit to the host [11]. However, some of these compounds are classified as "prebiotics" as they meet the current International Scientific Association of Probiotics and Prebiotics (ISAPP) definition of "a substrate that is selectively utilized by host microorganisms conferring a health benefit" [12]. While some researchers and clinicians still use the prebiotic and DF definitions interchangeably, it is important to note that while DFs are broadly metabolized and will therefore stimulate growth of an array of gut microorganisms, prebiotics are non-viable substrates that target human and animal-associated microbiota by serving as a nutrient source for specific beneficial microorganisms harbored by the host. Although the resident microorganisms are the predominant utilizers of prebiotics, administered probiotic strains can also benefit from these specific fermentable substrates [12]. Thus, prebiotics have the ability to create a new nutritional niche within the GI tract, providing specific microbes with nutrients allowing them to establish residence within the indigenous ecosystem [13].

Established prebiotics with the most extensively documented health benefits include inulin-type fructans (i.e., inulin, fructo-oligosaccharide (FOS) and oligofructose), galacto-oligosaccharides (GOS) and lactulose [13][14]. Other fermentable carbohydrates that have shown prebiotic potential include RS, β-glucans, arabinoxylan oligosaccharides, xylo-oligosaccharides, soy bean oligosaccharides, isomalto-oligosaccharides and pectin [13]. Prebiotics are found naturally in foods such as breads, cereals, onions, garlic and artichokes. Likewise, they are easily incorporated into processed food to increase their fiber content as well as nutritional value. They are also sold in the form of DF supplements [13][15]. Substances such as human milk oligosaccharides and plant polyphenols may also be considered prebiotics due to their ability to positively influence GI health; however, additional studies are required to demonstrate their prebiotic capacity [12].

## 3. Effect of Fiber on Health and Disease

DF intake is notably different across industrialized and unindustrialized countries around the world, with inhabitants of rural communities consuming up to seven times more fiber than typical Western countries due to increased intake of fibrous plants [7]. Western dietary patterns consist of high amounts of processed food rich in sugar and fat and generally devoid of fiber-rich foods such as fruits, vegetables, legumes and wholegrains [16]. Current recommended fiber intakes in Canadian children and adolescents aged 1–3, 4–8 and 9–18 years are 19, 25 [17] and 31 (girls) to 38 (boys) g/day[18], respectively. Current fiber intakes are well below the dietary recommendations, with children 1–3 and 4–8 years consuming only 9.9 and 13.4 g/day, respectively [17]. Meanwhile, adolescent girls and boys are reported to only consume 14 and 16.3–18.2 g of fiber per day [18], respectively, which is less than half of the recommended fiber intake. Low fiber consumption has been indicated as one of the key factors in reducing gut microbiota diversity as well as leading to subsequent increases in chronic non-communicable diseases such as obesity, type 2 diabetes, cancer and cardiovascular disease [19]. Moreover, inadequate fiber intakes are positively associated with pediatric constipation[20] and future health risks including obesity in adulthood [21].

Interestingly, several population studies and meta-analyses have demonstrated a beneficial effect of DFs in the reduction of disease risk, including cardiovascular disease, diabetes, metabolic syndrome, obesity, cancer, diverticular disease, IBD and functional intestinal disorders [22][23][24][25][26][27][28]. The mechanisms of protection in chronic conditions differ depending on the disease as well as the type and dose of the fiber administered; however, shifts in the gut microbiota and the subsequent positive effects of the metabolites they produce (i.e., SCFA) seem to play a major role in the positive outcomes [26]. Prebiotics have also been shown to enhance immune function and insulin sensitivity, which are known to lead to beneficial health effects [29]. Fiber has been reported to help minimize exposure to intestinal carcinogens by diluting fecal content and increasing intestinal transit time [29]. Furthermore, it has been shown that SCFAs produced due to the fermentation of fiber lead to an array of tumor-suppressive and anti-inflammatory effects, with butyrate having particularly compelling effects in cancer [30][31][32] and IBD model studies [33]. Interestingly, some DFs can also aid in weight management and appetite control by improving intestinal transit time, prolonging postprandial and overall satiety and stimulating satiety hormones such as cholecystokinin [34].

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**Keywords**

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