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The impact of dietary fiber in fruits and vegetables on gut microbiota

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ABSTRACT
Fruits and vegetables are an important part of daily diet, rich in nutrients, with dietary fiber being an essential nutrient for the human body. Recently, continuous research confirmed that nutritional components of fruits and vegetables are realized through interaction with the intestinal microbiota. Dietary fiber from fruits and vegetables not only effectively promotes bowel movements and reduces the transit time of food through the intestines, but also promotes the growth and development of intestinal flora, helps maintain the diversity of intestinal flora, regulates the balance of intestinal flora, and enhances the body's immunity. In addition, dietary fiber fermented by the gut microbiota can produce important microbial metabolites, such as short-chain fatty acids, butyrate, acetate, etc., which can promote overall human health. This article focuses on analyzing the effects of fruit and vegetable dietary fiber on changing the composition of gut microbiota, maintaining gut microbiota diversity, and producing important microbial metabolites, providing insights for further rational diet and development of fruit and vegetable dietary fiber.

KEYWORDS
Fruit and Vegetable; Dietary fiber; Gut microbiota

1 Foreword

The Yellow Emperor's Inner Classic states: "Grains are for nourishment, fruits are for assistance, livestock is for benefit, vegetables are for supplementation. Combine flavors and consume them to nourish essence and enhance qi." Food is the source of life for people. The terms "five fruits" and "five vegetables" correspond to fruits and vegetables, respectively. The "five fruits" assist in supplementing nutrition, while the "five vegetables" work together to nourish the body. A balanced combination can nourish the body and enrich vitality.

Research at home and abroad has shown that dietary fiber can reduce the time food spends in the gastrointestinal tract, effectively promote bowel movements, lower blood cholesterol, blood lipids, and postprandial blood sugar levels, while enhancing the antioxidant and anti-gastrointestinal cancer abilities of animals, earning it the title of the "seventh major nutrient" [1-2]. Research on the mechanism of separation and extraction of fibers and clinical trials have shown that they have a regulatory effect on digestion and absorption in the intestines, transit time, as well as microbial effects (composition of intestinal flora and changes in fermentation metabolites), and are of great significance for gastrointestinal diseases[3].

With a better economy, dietary habits and lifestyles have undergone significant changes. The intake of coarse grains has decreased, while the intake of high-fat and high-calorie foods has increased, leading to an increasing trend in the incidence of a series of chronic diseases. Healthy eating has become a hot topic of concern for people. Fruits and vegetables are an important part of daily diet and also an effective way to promote health.

2 Concept and Classification of Dietary Fiber

The term dietary fiber first appeared in the mid-20th century, when Hipsley first put forward the explanation of it. With the deepening development of nutrition and related disciplines, the definition of dietary fiber has become more standardized. As people gradually discovered the important physiological functions of dietary fiber, in today's pursuit of a healthy and refined dietary structure, dietary fiber has become a substance of concern for the academic community and the general public.

Dietary fiber (DF) refers to the carbohydrates in plant-based foods that cannot be broken down by digestive enzymes in the human gastrointestinal tract. Dietary fiber can be divided into insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) based on water solubility. IDF refers to insoluble dietary fiber that cannot be dissolved in water and cannot be fermented by human gastrointestinal microorganisms. It is mainly derived from whole grain foods and is composed of cell walls, including cellulose, hemicellulose, lignin, etc. SDF refers to soluble dietary fiber that can be dissolved in water and digested by the human digestive system. It is commonly found in plant cell sap and intercellular substances, mainly including pectin, oligosaccharides, plant gums, etc[4].

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3 Overview of the Gut Microbiota

The gut microbiota refers to the microbial community residing in the intestines. There are a large number of microorganisms in the human intestinal tract, with about 100 trillion archaea and bacteria, belonging to over 1000 species, of which more than 90% are from the phyla Firmicutes, Bacteroidetes, and Actinobacteria. It is essential for human health by participating in metabolism, enhancing immunity, and influencing host behavior[5]. It is also a complex ecosystem. There are two main factors affecting the microecological balance: external environmental and host factors. The former affects the host's physiological function, for instance,beneficial bacterial flora, which produce antibiotics and bacteriocins, compete for nutrients and space to hold back the invasion of transient bacterial flora and keep their stability. In addition, the microbes in gut are beneficial for the human body to absorb more energy, while the imbalance of nutrients and gut microbiota can lead to various diseases, such as non-alcoholic fatty liver disease, metabolic heart disease, type 2 diabetes, and other metabolic and immune diseases.

4 Physical and Chemical Properties of Dietary Fiber

The physicochemical properties of dietary fiber mainly include hydration properties, adsorption capacity, rheological properties, ion exchange capacity, etc.

4.1 Hydration Characteristics

Dietary fiber contains many hydrophilic groups, so it has strong water absorption and swelling properties. Dietary fibers of different varieties have different compositions and characteristics, as well as varying water-holding capacities, ranging from approximately 1.5 to 25.0 times their own weight. Numerous studies have shown that increasing dietary fiber intake can improve hydration and facilitate bowel movements, helping to eliminate toxins from the body quickly[6]. In addition, the hydrating properties can increase satiety and reduce appetite, thereby achieving the goal of weight loss.

4.2 Ion Exchange and Adsorption

Dietary fiber structures contain important side chain groups such as carboxyl, hydroxyl, and amino groups, which can exhibit similar weakly acidic cation exchange properties as ion exchange resins. These side chain groups can undergo reversible exchange with cations, especially organic cations. In addition, the ion exchange of dietary fiber can not only reduce the absorption of ions by binding, but also change the instantaneous concentration of ions, prolong the conversion time of ions by diluting the ion concentration, and affect the pH value, osmotic pressure, and redox potential of the digestive tract, creating a buffering environment to facilitate digestion and absorption[6]. Dietary fiber can adsorb cholesterol, bile acids, carcinogens, organic substances, and heavy metal ions. The adsorption of organic substances by dietary fiber belongs to physical adsorption, while the adsorption of heavy metal ions belongs to chemical adsorption. Organic substances that are adsorbed by dietary fiber cannot be absorbed by the terminal ileum and will eventually be excreted from the body along with dietary fiber in the feces, reducing the absorption of these organic substances and promoting health. At the same time, dietary fiber can form water-insoluble complexes with mineral ions, so it can adsorb mineral ions [7].

4.3 Rheological Effects

Research shows that different dietary fibers have significant differences in their rheological effects due to their differences in water solubility. There are various processes for extracting dietary fiber, and the ratio of soluble dietary fiber (SDF) to insoluble dietary fiber (IDF) varies, resulting in different nutritional value and metabolic characteristics of dietary fiber. Therefore, methods that can alter the physicochemical properties of dietary fiber during production are adopted to enhance its application in food [8].

5 The role of dietary fiber

Dietary fiber is a type of polysaccharide that cannot produce energy or be digested by the intestines. It plays an important nutritional and health role, closely related to human health, and is also of great significance for the development of intestinal health in the human body. In addition, dietary fiber may affect the quantity, type, and consistency of gut microbiota[9].

5.1 Changing the composition of gut microbiota

Because specific gene clusters in bacterial genomes determine the types of carbohydrate enzymes produced by bacteria, the composition of dietary fiber packs a powerful punch: the constitution and metabolism of the intestinal micro flora[10]. Research shows that the gut microbiota is involved in human metabolism and closely related to human health. Fruit and vegetable dietary fiber can alter the composition of gut microbiota, selectively stimulate bacteria in the intestines, and promote human health[11]. Using metagenomic sequencing technology to conduct molecular ecological analysis of fecal microbiota, it was found that the intake of inulin significantly improved the composition and structure of the intestinal microbiota of KO mice[12]. In addition, It was well established that vegetarianism is the antetype of healthy eating associated with gut flora. A plant-based diet involves its components influencing the constitution of the intestinal flora by adding beneficial microorganisms[13]. Therefore, we can consider that the intake of a plant-based diet can alter the composition of the gut microbiota, which is beneficial for host health.

5.2 Maintaining diversity of gut microbiota

Research has shown that long-term dietary patterns can alter the diversity and function of gut microbiota[13]. Dietary fiber can promote the growth of beneficial bacteria in the intestines, inhibit the growth of harmful bacteria such as Clostridium and Escherichia coli, and maintain the ecological diversity of intestinal flora[14]. In vitro fermentation experiments have shown that the dietary fibers of Hericium erinaceus, Agaricus bisporus, and Shiitake mushrooms promote the growth of beneficial bacteria, maintain the diversity of intestinal flora, and promote intestinal health[15]. Researchers Lappi, Duncan, Brinkworth, and others, who formed three research groups habitually consuming dietary fiber, have experimentally demonstrated that increasing dietary fiber contributes to the diversity of bacteria in the gut microbiota, while decreasing it reduces diversity. In addition, daily intake of complete cereal fiber helps to promote a prebiotic effect on the composition and biological activity of the gut microbiota, while also benefiting a diverse bacterial population. So far, through a large number of experimental studies, all results seem to indicate that promoting the diversity of gut microbiota through long-term dietary interventions may play an important role in maintaining long-term health [16].

5.3 Generation of important metabolites

Dietary fiber not only affects the ecology of gut microbiota but also promotes the production of important microbial metabolites, thus promoting our overall health through direct interaction with gut microbiota[17]. Fermented dietary fiber has been proven to be a product of gut microbiota metabolism. The main metabolites of dietary fiber after fermentation by intestinal microbiota are short-chain fatty acids (SCFAs), especially including acetate and propionate (used as substrates for lipid, glucose, and cholesterol metabolism) and butyrate (playing important roles in immune regulation and maintaining tissue barrier function)[13]. Dietary fiber in the colon is anaerobic fermentation by bacteria, generating SCFAs as metabolic byproducts, which help maintain gut microbiota balance and intestinal health[18]. Short-chain fatty acids (SCFAs), as the main metabolites of the gut microbiota, play a significant role in shaping the composition of the gut microbiota in the body, as well as in improving gut function and lipid metabolism-related diseases[1].

6 Outlook

With the development of economic life, unhealthy diet and lifestyle have led to an increase in the intake of fats, sugars, proteins, and other nutrients, resulting in a higher incidence of chronic diseases and a range of health issues. As a major agricultural country, China has abundant dietary fiber resources. Many studies have shown that the intake of dietary fiber plays a promoting role in human health and development. Based on the huge consumer demand for health and abundant dietary fiber resources in China, the prospects for the development of dietary fiber are promising. The interaction and influence of dietary fiber, intestinal flora and human health still need further research and exploration. However, it has raised awareness that increasing dietary fiber intake in daily life, supplementing necessary nutrients, and maintaining a diverse, dynamic, and healthy gut microbiota are important for promoting human health and preventing diseases. This article focuses on analyzing the effects of fruit and vegetable dietary fiber on changing the composition of intestinal microbiota, maintaining intestinal microbiota diversity, and producing important microbial metabolites. It is hoped to provide insights for a balanced diet and the development of fruit and vegetable dietary fiber, as well as to contribute to the development and utilization of dietary fiber.

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