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LITERATURE REVIEW

Unlocking the Fiber Mystery: The Secret Key to Blood Sugar Control and Diabetes Management

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Abstrak

Serat makanan adalah sekelompok karbohidrat kompleks dan lignin yang tidak dihidrolisis oleh enzim manusia dan oleh karena itu, tidak dicerna atau diserap oleh tubuh manusia.Berbagai efek dari serat makanan, termasuk peningkatan viskositas intraluminal, penurunan penyerapan makronutrien, dan penurunan sekresi insulin, berkontribusi pada pengendalian glikemia postprandial dan mengurangi risiko hipoglikemia pasca-absorptif. **Tujuan** : Memberikan pemahaman bahwa asupan serat makanan yang cukup sangat penting untuk pengendalian glikemia yang efektif dan pengelolaan diabetes. **Metode** : Artikel ini disusun berdasarkan metode tinjauan pustaka. **Hasil** : Serat makanan memainkan peran penting dalam pengendalian glukosa darah, terutama pada individu dengan pre-diabetes dan diabetes. Efek intrinsik serat makanan dalam menurunkan asupan energi dan mempromosikan penurunan berat badan juga penting dalam manajemen diabetes. Selain itu, efek koloni serat makanan, yang meningkatkan fermentasi asam lemak rantai pendek dan mengurangi produksi glukosa harian dan asam lemak bebas, dapat meningkatkan sensitivitas insulin dan mengurangi sekresi insulin. **Kesimpulan** : serat makanan memiliki manfaat untuk mengontrol glukosa darah.

Kata kunci: Diabetes, Insulin, Kontrol glukosa darah, Serat makanan

Abstract

Dietary fiber consists of complex carbohydrates and lignin that are not hydrolyzed by human enzymes and, therefore, are not digested or absorbed by the human body. Various effects of dietary fiber, including increased intraluminal viscosity, decreased macronutrient absorption, and reduced insulin secretion, contribute to the control of postprandial glycemia and reduce the risk of post-absorptive hypoglycemia. **Objective**: To provide an understanding that adequate dietary fiber intake is crucial for effective glycemic control and diabetes management. **Method:** This article is structured based on a literature review method. **Results**: Dietary fiber plays a significant role in blood glucose control, particularly in individuals with pre-diabetes and diabetes. The intrinsic effects of dietary fiber in reducing energy intake and promoting weight loss are also crucial in diabetes management. Additionally, the colon effects of dietary fiber, which increase the fermentation of short-chain fatty acids and reduce daily glucose and free fatty acid production, can enhance insulin sensitivity and reduce insulin secretion. **Conclusion**: Dietary fiber has benefits for controlling blood glucose.

Keywords: *Diabetes, Insulin, Blood glucose control, Dietary fiber*

INTRODUCTION

Diabetes mellitus, dyslipidemia, hypertension, and obesity are some examples of metabolic syndrome. Over time, significant risks of complications and even death will loom if not taken seriously. Diabetes mellitus is a group of metabolic diseases characterized by abnormalities in insulin secretion and action, resulting in increased blood glucose levels. Generally, diabetes is divided into three types: type 1 diabetes, type 2 diabetes, and gestational diabetes. In addition to medications, diabetes mellitus is managed through nutritional considerations and lifestyle modifications. Dietary fiber is essential to maintain health, control diseases, and reduce the risk of diabetes complications in the future[1–5].

The fermentation of dietary fiber has both short-term and long-term effects and is beneficial for various organs in the body, such as the liver, kidneys, and brain. The short-term effects of fiber include supporting the immune system by repairing or preventing autoimmune diseases such as arthritis, inflammatory bowel disease, allergies, and diabetes. Meanwhile, the long-term effects aim to reduce the risks associated with diseases like diabetes, obesity, hypertension, stroke, and coronary heart disease in the future. Numerous theories and evidence suggest an increase in glucose control and a decrease in diabetes risk with consuming fiber, whether soluble or insoluble, associated with short-chain fatty acids (SCFA) and insulin sensitivity. This literature review aims to identify the effects of dietary fiber on diabetes[4,6–8].

METHOD

In this study, researchers utilize a literature review approach.

RESULT AND DISCUSSION

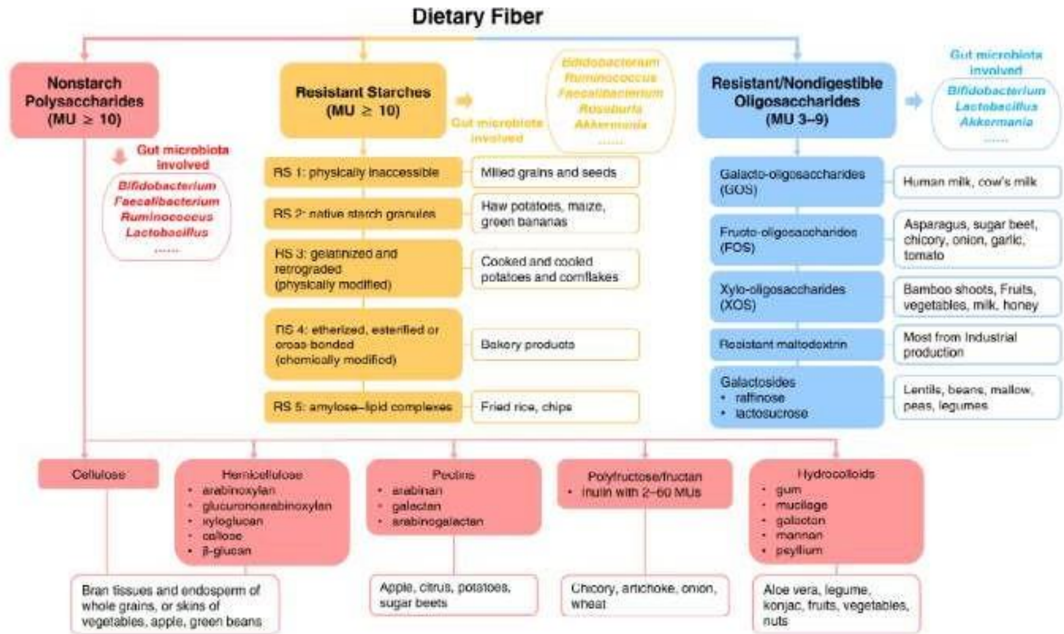
FIBER CLASSIFICATION

Fiber is difficult to define because there is a substance similar to fiber but not physiological, so fiber is described as carbohydrates that pass through the small intestine and can be partially or entirely fermented in the large intestine. The Codex Alimentarius Commission 2009 defined dietary fiber as carbohydrate polymers with 10 monomer units not hydrolyzed by endogenous enzymes in the human small intestine. Dietary fiber consists of two types: soluble fiber and insoluble fiber. Soluble fiber is edible plant material that produces a sticky gel in the large intestine, which colon bacteria can partially or entirely ferment into gas and short-chain fatty acids in the large intestine. This soluble fiber forms a colloid solution in the intestines, slowing digestion and nutrient absorption, resulting in prolonged satiety effects and decreased appetite, reducing the food's glycemic index. Soluble fiber includes pectin (polysaccharide), beta-glucans (polysaccharide), hydrocolloids (polysaccharide), mucilages, gums, and oligosaccharides, with fruits and vegetables as the primary sources. Additionally, it is found in foods such as oats, legumes, seeds, fruits, flaxseeds, chia seeds, and others [1,8–14].

Insoluble fiber passes through the digestive system intact, accelerating intestinal transit and playing a crucial role in the body's detoxification process. Additionally, insoluble fiber acts as a laxative due to its bulking effect, which can increase stool mass because the water trapped within the fiber matrix enhances digestive regularity, making it one of the therapy options for constipation. Insoluble fiber includes cellulose, hemicellulose, lignin, resistant starch, and resistant dextrin from wheat, vegetables, kale, broccoli, beans, seeds, and others[8,12,15,16].

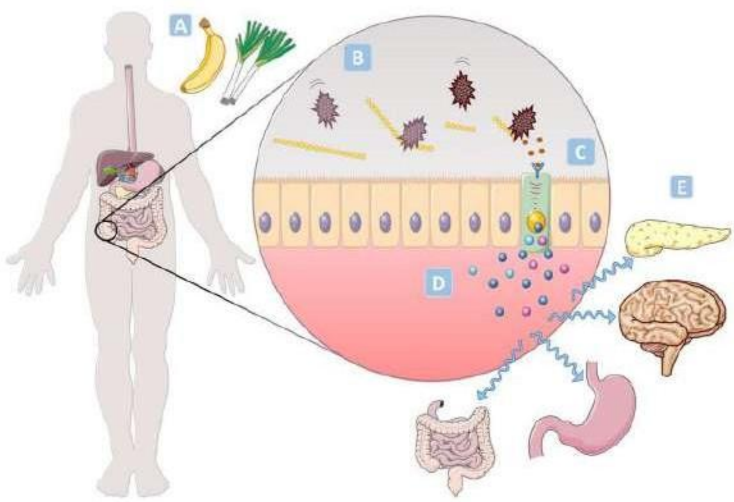
Cellulose is the most dominant carbohydrate in nature, contributing a quarter of the dietary fiber in grains and fruits. Cellulose has the benefit of reducing constipation and aiding in weight loss. Hemicellulose is a group of polysaccharides found in plant cell walls, with cereals being a good source of hemicellulose. Lignin is a polysaccharide found in almost all raw materials in the food industry and is an insoluble dietary fiber that helps prevent the formation of gallstones and reduces cholesterol. Cellulose, hemicellulose, and lignin form lignin-carbohydrate complexes (LCC) that comprise the plant cell wall[8].

Dietary fiber is also classified into three types based on the physiological properties of polymerization monomeric units: non-starch polysaccharides (NSPs) (MU≥10), resistant starches (RS) (MU≥10), resistant/nondigestible oligosaccharides (ROS) (MU 3-9). Non-starch polysaccharides comprise cellulose, hemicellulose, pectin, polyfructose, and hydrocolloids. Resistant starches include RS1 to RS5, while ROS comprises galacto-oligosaccharides (GOS), fructo-oligosaccharides (FOS), xylo-oligosaccharides (XOS), resistant maltodextrin, and galactoside[10,16,17].



Picture 1 Classification of dietary fiber based on monomeric units [1]

Furthermore, dietary fiber can be classified based on its solubility and fermentability:



Picture 2. The effects of dietary fiber on glucose control and appetite [2]

1. Short-chain, soluble fiber is highly fermentable, resulting in a weak laxative effect. It is not influenced by intestinal transit time despite producing significant gas. Examples of this type of fiber include oligosaccharides such as fructo-oligosaccharides (FOS) and galacto-oligosaccharides (GOS).
2. Long-chain soluble fiber is highly fermentable and readily soluble. Like short-chain, soluble fiber, this fiber has a weak laxative effect and is not influenced by intestinal

transit time. However, it produces moderate gas and can stimulate bacterial growth.

3. Moderately fermentable and partially soluble fiber. Unlike others, this fiber has an excellent laxative effect, accelerates intestinal transit, produces moderate gas, and stimulates bacterial growth.
4. Slowly fermentable insoluble fiber that has an excellent laxative effect and stimulates bacterial growth but produces a moderate amount of gas.
5. Non-fermentable insoluble fiber that has an excellent laxative effect accelerates intestinal transit but only stimulates the growth of certain bacteria such as Xylanibacter and Prevotella[1,18]

INTAKE OF FIBER

Recommendations according to the Dietary Reference Intake (DRI) for males aged 19-50 are 39g/day; for those aged >51 years, it is 31g/day, while for females aged 19-50, it is 25g/day, and for those aged >50 years it is 21g/day. The recommended intake for boys aged 9-13 years is 31g/day; for ages 14-18, it is 38g/day. For girls aged 9-18 years, the recommended intake is 26g/day. The American Diabetes Association (ADA) recommends that patients with diabetes mellitus consume 14g of fiber for every 1000 calories consumed daily[6,9].

The mechanism of dietary fiber in controlling glucose

Fiber has numerous health benefits, such as lowering postprandial glucose, intestinal homeostasis, preventing obesity, and accumulating visceral fat. Dietary fiber is fermented by gut microbiota, producing short-chain fatty acids (SCFA) and lower luminal pH. SCFA are transported across epithelial cells by noncarbohydrate transporter (MCT), absorbed in the large intestine, and metabolized in the second-colonic epithelium, liver cells, and muscle cells. Dietary fiber enhances intestinal homeostasis by improving the integrity of the gut barrier and repairing the local immune system. Three mechanisms of gut barrier include: whole dietary fiber stimulates goblet cells to produce mucus, dietary fiber supports fiber-degrading bacteria, suppressing the growth of mucin-degrading bacteria that damage the mucus layer, and finally, SCFA enhances epithelial integrity by providing energy and modulating its activity, including increasing protein expression and activating anti-inflammatory pathways [1,19].

SCFA primarily consists of acetate, propionate, butyrate, formate and lactate. Butyrate is the primary energy source for the cecocolonic epithelium, which helps maintain energy-producing pathways and protects the mucosal layer. Propionate is helpful for gluconeogenesis and anti-inflammatory purposes. Acetate and butyrate can also enhance mucus synthesis and secretion by increasing goblet cell differentiation and mucin gene expression in the host gastrointestinal tract[1,8,14,20–22].

SCFA binds to paired receptors such as GPR 41 and GPR 43 in L enteroendocrine cells and GPR109A receptors. As a result, there is an increase in the release of intestinal peptide hormones (PYY) such as glucagon-like peptide 1 (GLP-1) and glucagon-like peptide 2 (GLP-2) after meals. GLP-1 protects beta cells, improves glucose regulation by increasing insulin release, and suppresses glucagon release from the pancreas. GLP-1, leptin, and PYY increase satiety by influencing the brain and digestive system, while GLP-2 maintains the intestinal barrier and prevents systemic inflammation[16,20,23].

Other literature explains that a decrease in dietary fiber intake will reduce the production of SCFA, especially butyrate, leading to increased permeability and consequent elevation of lipopolysaccharides (LPS). The increase in LPS triggers systemic inflammation, causing an imbalance in cytokines, antibodies, and innate immunity, reducing T-cell regulation, disrupting antimicrobial function, and increasing autoimmunity. This increases the incidence of metabolic syndrome such as diabetes [24–26].

European Food Safety Authority (EFSA) states that dietary fiber, including beta-glucans and pectin, can reduce postprandial glucose when consumed in food [1,6,20]. Psyllium works by thickening the luminal contents of the intestine, delaying nutrient degradation and absorption, thereby decreasing total glucose. A high-fiber diet slows down carbohydrate absorption and digestion by reducing postprandial hyperglycemia. Studies show that this increases satiety, leading to weight [5,6,8].

Many studies support that dietary fiber affects glucose control in pre-diabetes and diabetes. Three effects resulting from dietary fiber are hormonal effects that increase intraluminal viscosity, reduce macronutrient absorption, lower postprandial glycemia, and reduce insulin secretion, lowering post-absorptive hypoglycemia. Additionally, intrinsic effects decrease energy intake, leading to weight loss. Finally, colony effects increase SCFA fermentation and reduce daily glucose and FFA production, thus increasing insulin sensitivity and decreasing insulin [10,13,27].

CONCLUSION

Based on the above information, it can be concluded that dietary fiber plays a significant role in controlling blood glucose, especially in individuals with pre-diabetes and diabetes. Various effects of dietary fiber, such as increased intraluminal viscosity, reduced macronutrient absorption, and decreased insulin secretion, contribute to the control of postprandial glycemia and reduce the risk of post-absorptive hypoglycemia. Additionally, the intrinsic effects of dietary fiber in reducing energy intake and causing weight loss also play a role in diabetes management. The colony effects of dietary fiber, which increase SCFA fermentation and reduce daily glucose and FFA production, can also enhance insulin sensitivity and decrease insulin secretion. Therefore, adequate dietary fiber intake can be essential in glycemic management and diabetes control.

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CONFLICT OF INTEREST (If Any)

None

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