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Dietary fiber a natural barrier against alarmingly increasing metabolic disorders

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Abstract: Dietary fiber is a polysaccharide having ten or more monomeric units. Endogenous enzymes in the small intestine are unable to hydrolyze the dietary fiber. Dietary fiber is partially fermented in the colon. Alarmingly increasing chronic disorders need management strategies. Dietary fiber inclusion in daily intakes is the best option for management and prevention of these disorders. Dietary fiber has a significant role in the reduction of serum glucose levels by increasing insulin sensitivity and delaying gastric emptying. Serum cholesterol level is also controlled by its fecal egestion and by preventing bile reabsorption. Dietary fiber also reduces hypertension. An ample intake of dietary fiber is a dire need in the scenario to cope with metabolic disorders.
Key words: Dietary fiber, lipid profile, serum glucose level, hypertension

1. Introduction

Dietary fiber is a complex non-digestible polymer having an impact on, e.g., gut microlora, immunity, and gut endocrine regulation (El-Salhy, Ystad, Mazzawi, & Gundersen, 2017). Dietary fiber includes cellulose, hemicellulose, pectin, hydrocolloids, and lignin. Hydrocolloids and pectin are among the water-soluble dietary fibers. Hemicelluloses, cellulose, and lignin are among the insoluble dietary fibers, and whole grain is their good source. Insoluble dietary fiber is those components that are insoluble in water and includes cellulose, hemicellulose, and lignin(McKEE & Latner, 2000). Short-chain fatty acids are the fermentation product of dietary fiber by the intestinal microbiota, having host physiological impact such as digestion of complex macromolecules, Vitamin synthesis, and reduction and elimination of pathogenicity, and have an immunomodulatory role. (Holscher, 2017; Koh, De Vadder, Kovatcheva-Datchary, & Bäckhed, 2016). A diet with high fiber content has a positive impact on the physiological functions of the body. Dietary fiber in whole grain considered to be effective in the prevention and management of diabetes (Kaline, Bornstein, Bergmann, Hauner, & Schwarz, 2007).

Dietary fiber contributes to a number of metabolic effects, e.g., improvement in insulin sensitivity, modulation of gut hormone secretion, and effects on metabolic and inflammatory markers that are associated with the metabolic syndrome (Weickert & Pfeiffer, 2008). A high dietary fiber diet has a tendency to reduce the serum lipid profile by minimizing absorption of cholesterol in the intestinal area and increasing fecal elimination of cholesterol. LDL- Cholesterol level of the experimental group was decreased by 1 to 13 mg/100 mL (Guo, Shu, & Yang, 2016; Ramos et al., 2011). Diet with dietary fiber 11.5 g/d changed systolic and diastolic blood pressure by -1.13 mm Hg and -1.26 mm Hg, respectively (Streppel, Arends, van't Veer, Grobbee, & Geleijnse, 2005). Dietary fiber may enhance the body's defenses against oxidative stress, reduce inflammatory markers, and reduce the level of C-reactive protein, a major contributory towards cardiovascular diseases(King, Mainous III,

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Egan, Woolson, & Geesey, 2005). Dietary fiber intake has a positive impact on the immune system. Dietary fiber Fibers produce the short-chain fatty acid by fermentation of dietary fiber in the colon by colonic microbiota and have immunomodulatory roles. SCFAs are produced in the fermentation process of dietary fibers in the gastrointestinal tract and have many physiological functions, including maintenance of the epithelial barrier, tumor suppression, reduction of oxidative DNA damage, and cytokine regulation. Dietary fiber also has an anti-inflammatory effect on the regulation of immune responses (Fernstrand, Bury, Garssen, & Verster, 2017).

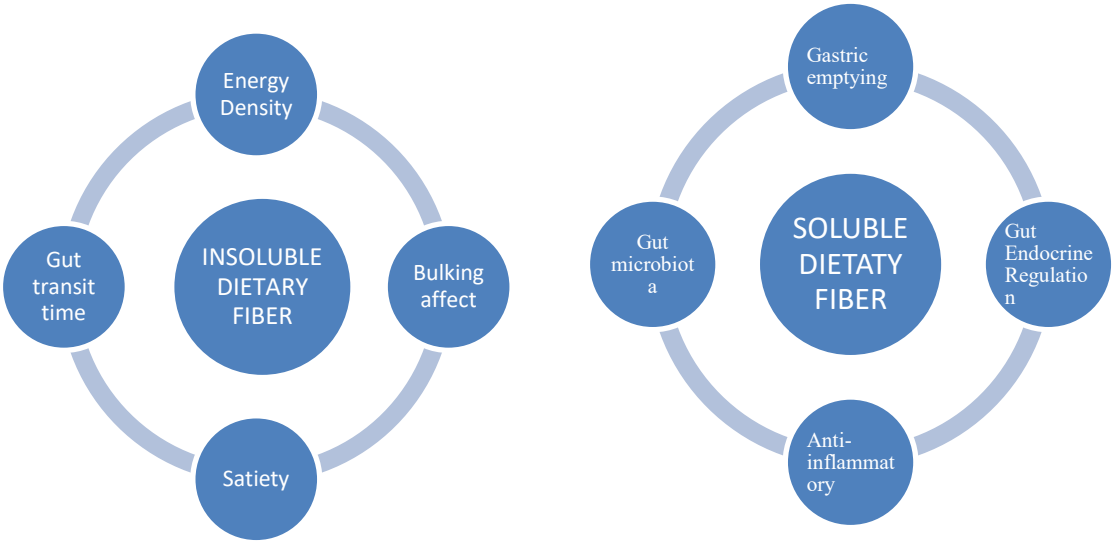

Figure 1. The role of soluble and insoluble dietary fiber

1.1. Health Benefits of Dietary Fiber

1.2. Effect of Dietary Fiber on Serum Glucose Level

Dietary fiber intake can reduce fasting glucose levels by 0.85 mmol. Type 2 diabetes can be managed by dietary fiber intake (Post, Mainous, King, & Simpson, 2012). Dietary fiber plays a therapeutic role. Dietary fiber incorporation in daily intake can reduce the incidence of disease and can save millions of lives and economic losses incurred on mediation (Ismaiel, Yang, & Min, 2016). A higher proportion of fiber in daily intake, soluble dietary fiber, decreases hyperinsulinemia and has a hypolipidemic effect in diabetic patients (Chandalia et al., 2000; Tiberius, Carmen, & Evelin, 2017). Cereal grains are the most economical and richest source of insoluble dietary fibers and have a potential role in the prevention and management of diabetes (Kaline et al., 2007). Dietary fiber was efficient in decreasing glucose levels of diabetic patients.

Consistent intake in the daily diet has significant efficacy against these metabolic disorders (Andrade et al., 2015). Type 2 diabetes is one of the metabolic syndrome having highest economic and social impact, and also has a detrimental effect on the quality of life. Prevention and management of these metabolic disorders should be focused rather than on cure. High dietary fiber affects satiety level, delays gastric emptying, and hence promotes blood glucose control (Velázquez-López et al., 2016). Dietary fiber, when taken as a dietary supplement, improves various physiological functions, including absorption, gut viscosity, and regulates endocrine hormones. Due to changes in dietary behavior of the masses, dietary fiber should be incorporated in the diet to fetch its physiological merits. This will not only improve the individual's life but also contribute towards decreasing the health treatment burden of the developing countries (Lattimer & Haub, 2010). Diabetes increases mortality by almost 2-fold and increases mortality from cardiovascular disease by 2-to 3-fold. The diet rich in fiber reduces the glycemic index of the food and is used as nutritional therapy against diabetes mellitus (Post et al., 2012). Dietary fiber has no significant impact on the physiological function of pancreatic islets of Langerhans (C. Chen et al., 2016). High fiber diets with soluble fiber have an impact on weight management, carbohydrate metabolism, total cholesterol, and LDL. It also plays an important role in the improvement of

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insulin sensitivity, modulation of the secretion of certain gut hormones, and improvement of various metabolic and inflammatory markers associated with the metabolic syndrome, thus reducing the risk of cardio-metabolic diseases (Mogoș, Dondoi, & Iacobini, 2017). Among the dietary fibers, water-soluble dietary fiber has the potential to reduce postprandial blood glucose and insulin more than insoluble fiber (Tabatabai & Li, 2000).

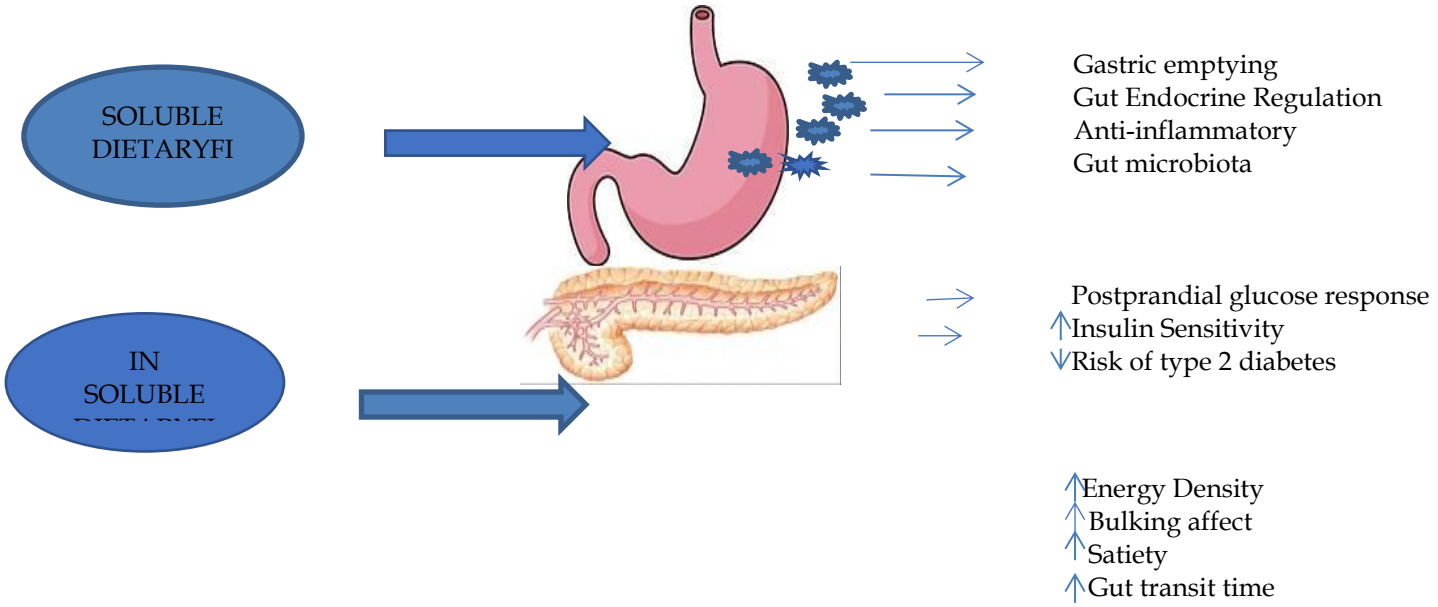

Figure 2. Therapeutic effect of Dietary fiber

Dietary fiber reduces the prevalence of abdominal obesity, hypertension, and metabolic syndrome. Dietary fiber intake lowers the occurrence of albuminuria, lowers the glomerular filtration rate, and reduces uremia (Fujii et al., 2013). Primarily, dietary fiber was considered due to its gastrointestinal effects, but presently it is also known as having an effect on glycaemia and lipidemia. Dietary fiber is s associated with substantial improvements in glycemic control and reductions in the use of oral medication and insulin doses (Anderson et al., 2009). The functional role of dietary fiber is well documented in the prevention and management of diabetes, attenuates insulin sensitivity, decreases weight gain, and reduces CVDs (Li & Uppal, 2010). Apricot pulp SDF was investigated in diabetic rats. SDF fiber from apricot significantly ($p < 0.01$) changed blood glucose level and body weight after intragastric administration for 28 days (Cui, Gu, Zhang, Ou, & Wang, 2015). (Kimmel, Michel, Hess, & Ward, 2000) investigated the effect of a low fiber, high insoluble fiber diet and a high soluble fiber diet on diabetic dogs, and concluded that the blood glucose level of the dogs is affected significantly by the high insoluble dietary fiber intake.

Table 1. Mechanism of serum glucose lowering

Mechanism	Reference
Inhibit macronutrient absorption, reduce postprandial glucose response, improve glucose sensitivity, modulate gut hormones, and affect metabolic and inflammatory markers	(Weickert & Pfeiffer, 2008)
Prolonged feeling of satiety	(de Leeuw, Jongbloed, & Verstegen, 2004)
Attenuates glycemic index, alters insulin sensitivity, and has hypolipidemia affect	(Chandalia et al., 2000)
Alter the small intestine juice viscosity	(Ou, Kwok, Li, & Fu, 2001)

Binding of available glucose	
Inhibitory effect on α-amylase	
Increase insulin concentration	(Díez et al., 2013)
Body Weight Management	(Rohajatien, Estiasih, & Sriwahyuni, 2018; Russell et al., 2016)
Regulating insulin levels and body weight management	(Jiang et al., 2012)
Production of SCFA	((Zhao et al., 2018)
Regulation of pancreatic insulin release	
Regulation of glycogen breakdown	
Venous and capillary postprandial blood glucose reduction	(Stewart & Zimmer, 2018)
Reduction in postprandial insulin concentration	
Reduction of microinflammation	(Cai, Wang, Wang, & Liu, 2017)
Intestinal flora improvement	
Delayed gastric emptying, reduction of the pH of the digestive medium	(Alexander, 2012; Asif, 2011; Hyman, 2010; Scazzina, Siebenhandl-Ehn, & Pellegrini, 2013)
Abrogation of obesity	(Han et al., 2015; McRorie Jr, 2015)
Mediating glucose metabolism(Costa, Guimarães, & Sampaio, 2012)	(Abutair, Naser, & Hamed, 2016; Costa et al., 2012)
Obesity Management, insulin resistance, and altering endocrine and cytokine production by the adipose tissue	(Galisteo, Duarte, & Zarzuelo, 2008)
Fermentation and altering the viscosity of the GI	(Dahl & Stewart, 2015)

1.3. Effect on Serum Lipid Profile

A diet with high fiber supplementation decreased the serum cholesterol level. It was observed that there was a decrease of 1 to 15 mg/100 ml in the experimental group. The change in the LDL- Cholesterol value was significant at both the 5 percent and 1 percent levels of supplementation (Khogare, 2012). Soluble fiber and soy protein improved the serum lipid profile of the hypercholesterolemia subjects significantly low-density lipoprotein (LDL) cholesterol fraction was significantly reduced (8.5% ± 3.3%, P = .020). Cholesterol-rich diets are responsible for Hypercholesterolemia and hypertriglyceridemia. Cocoa fiber showed a significant effect in hypercholesterolemia animals. The hypocholesterolemic effect was also patent, reducing LDL and total cholesterol (Guo et al., 2016; Lecumberri et al., 2007). Dietary fiber increased the fecal discharge of cholesterol by binding cholesterol in the gastrointestinal tract. Dietary fiber has lipid-binding ability and inhibits lipid peroxidation. Dietary fiber has a potential role in the prevention and management of CVDs. A higher content of dietary fiber in the diet reduces HbA1c, triglycerides, and improves HDL levels. Higher fiber consumption ensures lower calorie consumption and manages body weight to maintain a healthy serum lipid profile.(Velázquez-López et al., 2016). Greater dietary fiber intake lower risk of both cardiovascular disease and coronary heart disease. It is recommended to increase fiber intake (Threapleton et al., 2013).

Table 2. Mechanism of the serum cholesterol-lowering effect of dietary fiber

Mechanism	References
Reduced glycemic response	(Gunness & Gidley, 2010)
Prevention of bile salt reabsorption	
Excess fecal bile salt excretion	
Fiber binds bile salt micelles	
Reduction in endogenous cholesterol synthesis	(Ramos et al., 2011)
Regulation of alpha-hydroxylase activity	(Babio, Balanza, Basulto, Bulló, & Salas-Salvadó, 2010; Fernandez, 1995)
Reduction in cholesterol absorption	
Production of SCFA	(Queenan et al., 2007)
Reduction in hepatic cholesterol synthesis	(Gallaher et al., 2002; Pereira & Gibson, 2002)

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Deconjugating bile salts	
Secretion of 7-α-hydroxy-4-cholesten-3-one	(Bazzano, 2008; Moreyra, Wilson, & Koraym, 2005)
(Bile acid)increases	
Depleting cholesterol from the liver	
Lipid emulsification	(Sánchez-Muniz, 2012)
Lipolysis	
Postprandial lipemia	
inhibition of bile acid reabsorption	(Moreyra et al., 2005)
Glucose oxidation	(Zunft et al., 2003)
Insulin clearance	
Free fatty acids	
Cholesterol homeostasis	(Z.-Y. Chen, Ma, Liang, Peng, & Zuo, 2011)

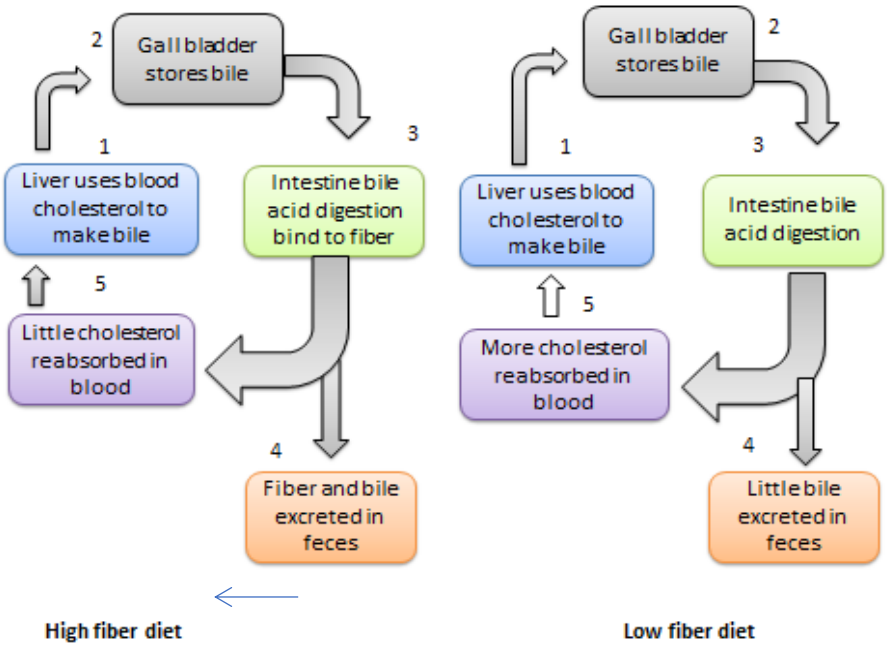

Figure 2. Cholesterol reabsorption pathway

1.3.1. Dietary Fiber Role in Hypertension

Dietary fiber is the natural mediator of metabolic disorders (Whelton et al., 2005). Studies revealed that oral intake of dietary fiber plays a potential role in the reduction of systolic and diastolic blood pressure(Aleixandre & Miguel, 2016) by 1.13 mm Hg and 1.26 mm Hg, respectively (Streppel et al., 2005). Dietary fiber intake reduced systolic blood pressure by 2.9 mmHg and diastolic by 1.5mmHg (Evans et al., 2015). Studies revealed that linear polysaccharides present in oats have a significant effect on blood pressure reduction among hypertensive patients. These mainly contribute to the arterial blood pressure reduction (Aleixandre & Miguel, 2008; Daou & Zhang, 2012).

Study revealed that dietary fiber lowered the systolic pressure by −5.95 mmHg and diastolic blood pressure and lowered systolic pressure −4.20 mmHg, respectively, after eight weeks of intervention (Whelton et al., 2005).11.5 g /day dietary fiber intake systolic BP by –1.13 mm Hg and diastolic BP by –1.26 respectively. The reduction was more significantly observed among the hypertensive patients above the age of 40 (Streppel et al., 2005). Dietary fiber has a significant effect on the reduction of hypertension (Ötles & Ozgoz, 2014).

1.3.2. Immuno-Modulatory Role of Dietary Fiber

Soluble fiber from oats has stimulated macrophages and monocytes, thus increasing immunoglobulin quantity, NK cells, and killer T-cells. Immunomodulation provides a natural barrier against parasitic infection and cancerous cells (Daou & Zhang, 2012). Fermentable dietary fiber has an immune-modulatory effect. The mechanism by which this effect is modulation of gut-associated lymphoid tissues, secondary lymphoid tissues, and peripheral circulation (Schley & Field, 2002)The mechanism of immunomodulation includes effects on f lactic acid-producing bacteria, bacterial constituents on immune cells, production of short-chain fatty acids, and binding of these fatty acid receptors on leucocytes (Kelly-Quagliana, Nelson, & Buddington, 2003; Seifert & Watzl, 2007; Watzl, Girrbach, & Roller, 2005). Studies revealed that dietary fiber has an immunomodulatory role in both animals and plants (Delgado, Tamashiro, & Pastore, 2010). The immunomodulatory role of cereal beta-glucan is due to its physical structure. Polymer ratio affects its solubility and aggregation. Fibers having low solubility and more aggregation properties increase the immune response (Mikkelsen, Jespersen, Mehlsen, Engelsen, & Frøkiær, 2014).

2. Conclusion

Chronic disorders not only affect individuals but also threat to the developing economies. These increasing disorders can only be wiped out by preventive and management strategies. Dietary fiber is a natural barrier against these disorders. Unfortunately, we are not consuming the recommended intake, which is why we are not reaping its benefits. Massive public awareness can play a vital role in the introduction of the health effects of dietary fiber at gross root level, especially the illiterate population of developing countries. This can be the only way to reduce the public health burden around the globe.

Abbreviation

SCFA: Short Chain Fatty acid	LDL: Low-density lipoprotein
HDL: High-density lipoprotein	SDF: Soluble dietary fiber
IDF: insoluble dietary fiber	CVD,s: Cardiovascular diseases

CRediT authorship contribution statement

Muhammad Suhail Ibrahim and Ishtiaq Hassan, Experiment and analyze data, Muhammad Nadeem and Ahmad Mujtaba, Data analysis, writing original draft, Amer Mumtaz and Abdus Samee, editing, proofreading.

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Declaration of competing interest

The authors declare no conflict of interest.

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