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EXPLORING THE MULTIFACETED BENEFITS OF DIETARY FIBER: A COMPREHENSIVE REVIEW

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Abstract: Dietary habits play a crucial role in the health of individuals and communities. In recent decades, dietary fiber has been recognized as a vital component of a healthy diet due to its numerous health benefits. Found in fruits, vegetables, whole grains, and legumes, dietary fiber consists of plant-based carbohydrates that resist digestion and absorption in the small intestine. These include cellulose, hemicellulose, pectin, beta-glucans, and various gums, each contributing uniquely to fiber's overall benefits.

Dietary fiber's significance extends beyond digestive health to the prevention and management of chronic diseases. High intake of dietary fiber can lower blood cholesterol levels and improve heart health, reducing the risk of cardiovascular disease. It helps maintain healthy blood sugar levels, mitigating the risk of type 2 diabetes by slowing sugar absorption and preventing glucose spikes after meals. Additionally, certain fibers protect against colorectal cancer by increasing stool bulk and reducing the contact time of potential carcinogens with the intestinal lining. Fermentable fibers further support gut health and reduce inflammation by producing short-chain fatty acids through bacterial fermentation in the colon.

As global dietary patterns shift towards processed foods, understanding the role of dietary fiber becomes increasingly important. Processed foods often lack natural fiber, contributing to deficiencies linked to higher incidences of chronic diseases. This review provides a comprehensive overview of dietary fiber types, their physiological effects, and health impacts. The review also discusses recommended intake levels by various health organizations and strategies to increase fiber consumption for better health outcomes.

By consolidating current research and offering practical dietary recommendations, this review emphasizes the critical role of dietary fiber in maintaining optimal health and preventing disease.

Key Terms **– Dietary fiber, Digestive health, Gut brain axis, Hypertension, Irritable bowel disease, Diabetes**

I. INTRODUCTION

Dietary habits are one of the most important factors affecting health of individuals and community. [1]Micronutrient deficiencies represent a public health concern in developing countries. The dietary pattern is closely related to human health. Hu et al. identified two major dietary patterns, which are the Prudent and Western diets [2]

The Prudent diet is considered healthy and is characterized by higher intake of vegetables, fruit, legumes, whole grains, fish, and poultry. Compared to the Prudent diet, the Western diet is characterized by abundant red meat, fat, and refined carbohydrates [3] The Western diet contributes to increased risk of non-communicable diseases, especially gastrointestinal diseases and metabolic diseases which are partially attributed to the deficiency of dietary fiber in the Western diet[4]

Each day huge amount of plants are consumed, thereby a lot of by-products are dumped into the ashcan directly which are rich in highly nutritious bioactive substances: dietary fiber is defined as the seventh nutrient for humans by nutritionists, has many benefits for our health, such as improve the intestinal flora, decrease the probability of obesity and cardiovascular disease, etc. [5]

Dietary fiber (DF) is believed to provide important health benefits and it has become a research hotspot. DF exists in most natural foods, including fruits, vegetables, grains consists of plant-based carbohydrates that are resistant to digestion and absorption in the human small intestine [6]

It should be noted that plant foods contain more than just dietary fiber, so any protective properties of plant-based diets may be linked to other dietary components, vitamins, minerals, or phytochemicals, and not just isolated dietary fiber. However, to study the relationship between dietary exposure and disease or health outcomes requires analytical tools to measure exposure to a nutrient or food source. Thus, since the 1970s analytical methods have been developed to measure the dietary fiber content of foods. [7]

Dietary fiber is widely recognized as a key component of a healthy diet, yet inadequate intakes are typical in many countries. A population trend away from intake of fiber-rich whole foods and toward intake of highly processed fast foods, observed in higher-income countries, is likely contributing to decreased intakes of dietary fiber, and this may have detrimental consequences for health. [8]

Changed dietary habits represent one of the most influential lifestyle factors that have changed significantly over the past few decades. Generally, Westernized diets are characterized by an increased caloric intake and changed nutrient composition. Especially, intake of plant-based fiber has declined below the recommended daily dose. [9]

This review aims to highlight a comprehensive overview of the types of dietary fiber, their physiological effects, and their impact on health outcomes. It will explore the biochemical properties of different types of fiber, including their solubility, viscosity, and fermentability, and how these properties influence their function in the body. Additionally, it will discuss the recommended dietary fiber intake levels established by various health organizations and the strategies for incorporating more fiber into the diet to enhance overall health and well-being. By consolidating current research and providing practical dietary recommendations, this review seeks to emphasize the critical role of dietary fiber in maintaining optimal health and preventing disease

DIETARY FIBER –

The component of food that comes from plants that human gastrointestinal enzymes lack the capacity to fully break down is known as dietary fiber or roughage[10].Whereas Hispley coined the phrase "dietary fiber" in 1953, it has since undergone revisions, and people have long recognized the health advantages of eating foods high in fiber. Regarding contrast to refined wheat, Hippocrates reported about 430 BC the laxative properties of coarse wheat. During the 1920s, J. H. Kellogg wrote a lot regarding the benefits of bran, saying it made stools heavier, encouraged loose stool, and shielded against illness. The 1930s saw research on dietary fiber, which was subsequently neglected until the 1970s. The Irish surgeon and physician Denis Burkitt is generally recognized for having revived the notion that dietary fiber guards against the onset of Western diseases such

as obesity, diabetes, colon cancer, and cardiovascular disease. Research on defining, measuring, and other aspects of fiber has persisted since then. [11]

The complicated class of fiber known as dietary fiber is separated into many forms based on variables including solubility, viscosity, and fermentability. Fibers that can dissolve in water, like mucilage, gums, and pectin, create thick gels that help manage blood sugar levels and reduce cholesterol. Even though cellulose, hemicellulose, and lignin are types of insoluble fibers that do not dissolve in water, they still play a role in promoting regular bowel movements and producing soft stool. Fermentable fibers additionally offer colonic bacteria a growing medium for synthesis of short-chain fatty acids (SCFAs), which have several health benefits, such as enhanced gut barrier effectiveness and anti-inflammatory properties.

The definition of Dietary Fiber was released by CODEX alimentarius in 2009 (Codex alimentarius, 2010). As per the statement, dietary fiber refers to carbohydrate polymers that have ten or more monomeric units, are not broken down by the body's own enzymes in the small intestine, and fall into the following groups: The three types of carbohydrate polymers that are considered edible are: (1) naturally occurring edible polymers found in food; (2) carbohydrate polymers obtained from food raw materials by means of physical, enzymatic, or chemical means; and (3) synthetic carbohydrate polymers that have been shown to have a physiological effect that is beneficial to health and have been proven to do so by generally accepted scientific evidence to competent authorities.[12]

Water solubility is an additional characteristic that determines how dietary fiber is categorized. Dietary fiber mostly comes in two varieties: soluble and insoluble. Soluble fiber is mainly discovered in fruits and vegetables. On the other hand, whole-grain goods and cereals are excellent sources of insoluble fiber. But soluble and insoluble fibers are present in varying proportions in the majority of naturally occurring high-fibre diets. Even though the majority of dietary fiber is partially fermented in the gastrointestinal system due to the activity of the gut microbiota, soluble fiber generally ferments more quickly than insoluble cereal fiber [13].

Soluble fiber additionally referred to as fermentable fiber or prebiotic fiber dissolves in water and is often fermented in the colon to produce gasses and physiologically active byproducts like short-chain fatty acids, which are made by gut bacteria in the colon. Beta-glucans found in oats, barley, and mushrooms, as well as raw guar gum, are two examples. One bulking fiber that helps with defecation is psyllium, a soluble, viscous, non-fermented fiber that hangs onto water as it passes through the digestive tract. In addition to its viscous nature and ability to postpone stomach emptying, soluble fiber can cause an extended sensation of fullness in people [14]

II. DIETARY FIBER INTAKE RECOMMENDATIONS

Contrasting the amounts that various health groups advice regarding the dietary fiber-

The World Health Organization, or WHO, advises adults to take at least 25 grams of fiber per day due to research showing a link between higher fiber consumption and a decreased risk of cardiovascular ailments, type 2 diabetes, and colon cancer. In contrast, the United Nations Food and Agriculture Organization (FAO) [15] recommend that people take in 25 grams per day. This is in line with global health guidelines that emphasize the benefits of fiber in preventing chronic illnesses. The Food and Drug Administration of the United States (FDA) [16] recommends 28 grams of dietary fiber per day, based on a 2,000-calorie diet. The Daily Value (DV) is used in nutrition labeling to help customers make informed dietary decisions. According to the Dietary Guidelines for Americans, 14 grams of fiber are required (DGA). [17]

Organization	Recommendation	Rationale
World Health Organization	≥ 25 grams/day	Prevent chronic diseases (CVD, diabetes, cancer)
Food And Agricultural Organization	≥ 25 grams/day	Aligns with global health guidelines
Food And Drug Administration	28 grams/day	based on a diet of 2,000 calories
Dietary Guidelines For Americans	14 grams/1,000 calories	Promote health and reduce chronic disease risk
Institutes Of Medicine	25-38 grams/day (age and sex-specific)	Health benefits and average intake levels
European Food Safety Authority	≥ 25 grams/day	Improve bowel function and overall health
British Nutrition Foundation	30 grams/day	Improve digestive health as well as reduce chronic disease risk
Health Canada	21-38 grams/day (age and sex-specific)	Maintain health and prevent diseases

Table 1: Recommendation of dietary fiber amount by different organizations

III. ROLE OF DIETARY FIBER IN DISEASE

Dietary fiber (DF) is a micronutrient that is necessary for the body to perform various important functions. It is believed to have anti-inflammatory disease-modifying effects through DF-related gut microbiota degradation products called short chain fatty acids. Research to date has shown the strongest correlations between dietary fiber intake and risk reduction in obesity, improved weight loss outcomes, and risk reduction of cardiovascular disease (CVD). There is weak evidence linking dietary fiber intake to the risk of inflammatory bowel disease (IBD), IBD remission, and reduced risk of Crohn's disease (CD) flare-ups, and no evidence of any benefit for ulcerative colitis (UC).Lack of randomization or control over the types and sources of fiber hampered the studies. Counseling patients to increase their consumption of DF could be a cost-effective way to reduce the burden of chronic illness, given the benefits of DF that are currently being shown for managing obesity and cardiovascular disease. [18]

In order to lower the risk of chronic diseases like obesity, type 2 diabetes, and cardiovascular disease, the 2010 Dietary Guidelines for Americans advise consuming at least half of the 6–11 daily servings (1 ounce equivalent per serving) of grains as whole grains. Nutrients found in whole grains include n-3 fatty acids, dietary fiber, minerals (zinc, manganese, copper, selenium, phosphorus, calcium, sodium, and potassium), vitamins (E, thiamin, niacin, pantothenic acid, biotin, pyridoxine, and folate), and phytochemicals. [19]

1. DIETARY FIBER AND GUT BRAIN AXIS

Consistent investigations, Dietary fiber's molecular properties affect the gut microbiota; dietary fiber from fruits and vegetables is 75–90% more readily digested by microbes than fiber from grains, which is only approximately 30%. The ability of different microbiota species to break down polysaccharides varies; generalists can break down a wide range of polysaccharides, whilst specialists can only break down a particular type.

Nonetheless, repeated studies show that a high-fiber diet is typically associated with a "healthy" microbiome, which is characterized by a greater diversity of microorganisms. A high dietary fiber intake is often associated with increases in beneficial microbes such as lactobacilli and bifidobacteria, though the specific changes may vary depending on the type of fiber consumed. For example, Bifidobacterium, Eubacterium, and Faecalibacterium grow more readily when resistant starch is present. However, certain microbes, such as Ruminococcus and Fibrobacter, break down insoluble fibers like cellulose. [20]

In microbial fermentation, dietary fiber serves as the primary substrate. This fermentation process influences the synthesis of microbial metabolites, particularly short-chain fatty acids (SCFAs) like butyrate, propionate, and acetate. Specialized bacteria create certain metabolites, and in addition to basic changes, microbes feeding on other microbes can cause secondary changes in the metabolism of the microbiota. It is important to highlight the intricate relationships that exist within the microbiome since recent research in pigs has shown that fiber that is accessible to the bacteria can trigger both direct and secondary metabolic alterations. [21]

Insoluble fibers can affect microbial enzymatic pathways and the creation of metabolites over time, while being more difficult to digest. These pathways include those associated with branched-chain amino acids (valine, leucine, and isoleucine), glycerophospholipids, nicotinate, nicotinamide, linoleic acid, and glutathione.

Not with standing these general trends, there is a significant amount of interindividual variability in the microbiota's responses to dietary fiber. This variability can be ascribed to a number of variables, such as the host's genetic composition, dietary practices, and preexisting microbiota. For instance, a baseline microbiome rich in fiber-digesting enzymes (Prevotella, for example) would suggest a stronger response to fiber intake. Those with lower habitual intakes of fiber may benefit the most from increased consumption. [22]

The impacts of nutrition, particularly fibers, which are broken down by specific bacteria to form a spectrum of health-promoting compounds, are communicated to the brain through the microbiota-gut-brain axis, which has grown in importance. The fundamental processes of the microbiota brain cross talk have been proposed to include the immune system, gut hormones, the kynurenine pathway, these metabolites (including short chain fatty acids), and the vagus nerve.[23]

Although dietary fiber typically promotes a better microbiome with more beneficial microbes and variety, individual responses to it might vary significantly. To more precisely predict and optimize dietary fiber therapy, additional research is needed to understand the specific factors that influence these reactions, such as hereditary features and pre-existing microbiota compositions.

2. DIETARY FIBER AND MENTAL HEALTH –

Depression is a highly frequent mental disorder that has a major impact on community public health. The World Health Organization (WHO) reports that 4.4% of people worldwide suffer from depression. Symptoms of anxiety and sadness are two of the psychological issues that are spreading around the world.

About 300 million people are affected by depressing all around the world and it is also seen that it cause consequences such as disability that is mainly seen in young adults and adolescents. Numerous studies have shown that eating a balanced diet reduces the likelihood of getting depression as well as the symptoms of depression. For example, studies have connected a high consumption of fruits and vegetables to better mental health and a decreased risk of depression. [24] It has also been demonstrated in intervention trials that consuming more of some food groups high in dietary fiber, such as fruits, vegetables, and whole grains, can lower the severity of depressive symptoms. Despite dietary fiber's widespread recognition as a benefit of a balanced diet, there is a dearth of research on the potential link between its consumption and mental health

consequences[25] According to a cross-sectional study, a reduced prevalence of depression symptoms in both men and women is linked to a higher intake of soluble, vegetable, and soya DF.[26]. Two systematic reviews [27, 28] and one meta-analysis [29] revealed that eating a healthy diet high in fruits, vegetables, and whole grains was linked to a lower risk of developing depression.

A high-fiber diet can lower inflammation by changing the permeability and pH of the gut. The consequent reduction in inflammatory chemicals may alter neurotransmitter concentrations, perhaps mitigating depression symptoms. [30]

A substantial inverse association has been found between an adult's total dietary fiber consumption and psychological distress, specifically anxiety, according to a study that employed data from the Iranian population. Higher dietary fiber consumption was also associated with lower odds of depression in women. To validate the reported findings, more prospective investigations are needed. [31]

3. DIETARY FIBER AND HYPERTENSION –

Numerous cardiovascular illnesses and disorders have been linked to fiber consumption as a preventive measure. The primary soluble fiber found in oat grains, β-glucan, was first connected to a decrease in plasma cholesterol. Subsequent research has demonstrated that dietary fiber may also help with weight loss, insulin resistance, and glycaemia.[32] Research suggested that consuming more fiber enhanced the levels of triglycerides and low-density lipoproteins.[33]

Both normotensive and hypertensive people appear to benefit from dietary fiber intake, according to observational and experimental research on blood pressure (BP). Vegetarian diet consumers typically have a decreased risk of hypertension.[34,35]

Consuming dietary fiber lowers blood glucose levels by slowing the passage of food through the digestive system as well as the digestion and absorption of carbohydrates. Increased dietary fiber consumption lowers blood pressure, serum cholesterol, heart disease risk, and weight control. It improves gastrointestinal health and glycemic control also. [36]

The DASH study was the first large-scale randomized controlled trial to assess how a diet high in plants affected blood pressure. "Have the blood pressure-lowering benefits of a vegetarian diet, yet contain enough animal products to make them palatable to nonvegetarians" is how the "DASH" diet was developed. [37]

Research has shown that those who consume large amounts of dietary fiber had a lower risk of developing hypertension and its related conditions, like coronary artery disease and stroke. When fruits and vegetables are raw, they can offer fiber and nutrients, but when they are fried or cooked, they can also significantly increase the amount of fat and sodium in the diet. However, the fiber psyllium makes the digestion more viscous, which slows down the gastrointestinal tract's absorption of nutrients and glucose. This mechanism enhances systemic insulin resistance and modulates the release of glucose into the bloodstream. If unchecked, insulin resistance contributes to endothelial dysfunction, which causes hypertension. [38]

Pharmacies sell psyllium fiber, a great dietary fiber that has been shown to lower hypertensive people's systolic and diastolic blood pressure. Fibers provide a number of advantages, including reducing low-density lipoproteins, improving insulin resistance, lowering blood pressure, and having little to no negative side effects. [39]

4. DIETARY FIBER AND IBS –

Bowel discomfort Constant stomach pain during bowel movements and deviations from regular fecal evacuation patterns are symptoms of irritable bowel syndrome. The diagnosis is made using a set of clinical criteria and symptoms known as the Rome IV criteria. Biochemical and imagistic studies are only used by clinicians under specific circumstances, such as when alarm signs are present or to aid in differential diagnosis. [40].IBS has a complicated and poorly known etiology, and several theories have been put out to try to explain the symptoms, including: modifications to the gut flora, mental health issues, and intestinal disruptions-axis of the brain. [41]

In the literature, since 1978, there has been considerable interest in dietary fibers as a therapeutic option in IBD but its role is unclear, with conflicting findings [42]

The conclusion drawn from systematic reviews on the effectiveness of fiber was that the kind of fiber, daily consumption, and IBS subtype all play a significant role in how well it works for IBS. Fibers and carbohydrates that are acceptable to eat but are not impacted by digestion or absorbed by the colon are referred to as edible fibers. In the colon, such fibers participate in fermentation activities in varying amounts. Plants supply them, and some of them are processed. it is seen that in comparison with general population in IBS patient protein energy malnutrition is more common. They struggle to put on weight, and those with CD in particular may be deficient in micronutrients like iron, vitamin B12, and vitamin D. [43]

Ispaghula husk, a product containing soluble fiber, is a good first line therapy for IBS patients with symptoms, according to an expert evaluation of gastroenterology and hepatology. Its ability to hold onto water and thus create a mass that aids in colonic peristalsis and the slow, partial fermentation by bacterial enzymes that determines the prolonged formation of significant amounts of short-chain fatty acids throughout the colon are most likely the main causes of its therapeutic efficacy. [44]

The involvement of fermentable carbohydrates, commonly known as FODMAPs (oligosaccharides, disaccharides, monosaccharides, and fermentable polyols), in IBS must also be discussed. Due to their ability to recall partially or wholly indigestible water and gas in the intestinal lumen, FODMAPs have an osmotic and fermentative activity. When someone has Irritable Bowel Syndrome (IBS), which is characterized by symptoms including diarrhea, constipation, bloating, meteorism, or abdominal pain, a low-FODMAP diet is typically advised. [45]

Though no single food is thought to be the cause of the illness, nutrition is a major factor in treating IBS. As a result, it is recommended that patients with IBD consume a diversified diet that satisfies their needs for minerals and energy, including dietary fiber. It is evident from the literature that people with IBS typically consume less fiber than healthy controls. According to studies, fiber supplements by themselves are unlikely to help IBS patients' microbiome return to a healthy state. [46]

5. DIETARY FIBER AND DIABETES –

It is commonly acknowledged that controlling the plasma glucose levels in diabetics can be facilitated by eating a diet high in fiber, especially soluble fiber. This is one of the reasons that a number of national diabetes groups advise people with diabetes to consume a diet rich in foods high in fiberS. [47]

According to a comprehensive epidemiological study including 42,000 males, dietary fiber from fruits and vegetables had no impact on the risk of developing diabetes.[48] On the other hand, dietary fiber derived from whole cereal grains significantly reduced the incidence of diabetes.

Supporting evidence that a high consumption of dietary fiber is related with better insulin sensitivity, a cross-sectional analysis has shown that the dietary intake of total as well as insoluble and soluble fiber is associated with good result in insulin resistance. Soluble dietary fiber is associated to reduce postprandial glucose levels and to improve insulin sensitivity in both diabetic and non diabetic persons. [49]

The conventional wisdom that the chain length—that is, the difference between "simple" and "complex" carbohydrates—determines the overall metabolic importance of the rate of carbohydrate digestion, or the postprandial blood glucose response, has been called into question. The glycemic index (GI) was developed as a result of these inquiries, and it was proposed that slowly digesting carbohydrates may have metabolic advantages in relation to diabetes and a lower risk of coronary heart disease. This idea is an extension of the dietary fiber hypothesis initially put forth by Burkitt and Trowell. [50]

In summary, individuals with type 2 diabetes mellitus who increased their consumption of dietary fiber—mainly soluble fiber—saw improvements in glycemic control and a reduction in hyperinsulinemia, in addition to the anticipated lowering of plasma lipid concentrations. Therefore, rather than recommending the use of fiber supplements, dietary guidelines for people with diabetes should emphasize an overall increase in dietary fiber through the use of unfortified foods. [51]

IV. CONCLUSION –

One essential part of a balanced diet is dietary fiber, which has numerous advantages that go well beyond digestive health. The evaluation of a large body of evidence indicates that dietary fiber plays an important role in the management and prevention of a number of chronic conditions, including as type 2 diabetes, cardiovascular disease, colorectal cancer, and mental health issues like anxiety and depression.

When soluble fibers, such those in fruits, vegetables, and cereals, dissolve in water, they generate viscous gels that lower the absorption of cholesterol and help control blood sugar levels. Constipation can be avoided and regular bowel movements are facilitated by insoluble fibers, which are found in whole grains and cereals.

As a substrate for gut bacteria, fermentable fibers encourage the synthesis of short-chain fatty acids, which improve gut health and lower inflammation. Dietary fiber's role in preserving general health is further highlighted by its connection to the gut-brain axis. A varied and beneficial micro biome is linked to high-fiber diets, and this micro biome influences mental health by regulating the synthesis of neurotransmitters and other neuroactive compounds. Despite the well-established advantages, a huge number of people globally do not consume the required amount of dietary fiber each day, partly because processed foods, which are low in natural fiber, are becoming more and more popular. Increased fiber consumption is continuously emphasized in public health campaigns and dietary recommendations as a way to lower the risk of chronic illnesses and improve general health.

Future studies should carry out more investigation into the precise processes via which various forms of fiber benefit health, as well as the individual differences in dietary fiber response. Based on genetic composition and current microbiota compositions, personalized nutrition strategies may optimize fiber consumption recommendations.

To sum up, increasing dietary fiber consumption is an easy yet effective way to enhance health outcomes. It is recommended that health practitioners promote diets high in dietary fiber from natural sources in order to counteract the increasing incidence of chronic illnesses and improve the health of people everywhere.

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