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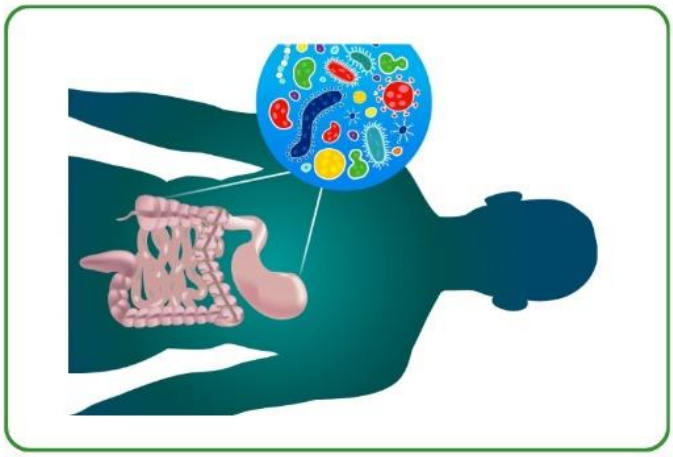

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The Role of Diet in Shaping Human Gut Microbiota: A Review of Vegetarian Diets

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Abstract

The human gut microbiota plays a pivotal role in health and disease, being influenced by various factors, with diet being a primary modulator. This review explores how specific dietary components particularly dairy products, vegetarian diets, and pulses affect the diversity, composition, and functionality of the gut microbiota. The paper summarizes findings from various research studies and provides insight into how these dietary patterns can promote gut health, modulate inflammation, and influence metabolic outcomes. It is increasingly understood that fermented foods can also have enhanced nutritional and functional properties due to transformation of substrates and formation of bioactive or bioavailable end-products. Many fermented foods also contain living microorganisms of which some are genetically similar to strains used as probiotics. Although only a limited number of clinical studies on fermented foods have been performed, there is evidence that these foods provide health benefits well-beyond the starting food materials.

Keywords- Gut microbiota, human microbiome, diet and gut health, probiotics, vegetarian diet, plant-based nutrition.

1. Introduction

The human gut is generally inhabited by more than trillion microbes of diverse groups, which may be considered as a metabolic organ as a result of their immense impact on human health, as well as host metabolism, physiology, nutrition and immune. It plays an essential role in digestion, immunity, vitamin synthesis, and protection against pathogens. Diet has emerged as one of the most important factors shaping the gut microbiota's structure and function. This review focuses on three dietary components: milk and dairy products, vegetarian diets, and pulses, evaluating their individual and cumulative effects on gut microbial composition and health outcomes. Dairy and dairy-derived products are a common component of many diets and influence physiological functions. [1-4] Dairy products, including milk, yogurt and cheese, are generally considered nutrient-dense foods that contain proteins, calcium, and other essential nutrients such as magnesium, potassium, phosphorus, zinc, and B vitamins and their intake is associated with higher diet quality. These microbes comprise diverse groups of symbiotic, commensal organisms as well as opportunistic . One study classified the inhabitants of a microbiome by using an advanced molecular technique, metagenomic analysis, to provide a larger scope and provide a deep view into

hundreds of microbial communities concurrently as those previously identified by . This classification revealed that the human gut microbiome is mostly composedof four main bacteria

Phyla, Firmicutes, Bacteroidetes, Actinobacteria and Proteobacteria; the rest, however, is remarkably diverse. Bacteroidetes, which are mostly represented in the healthy human gut (beneficial genera, or symbionts), are Gram-negative bacteria involved in complex carbohydrate digestion and immune system modulation; they export antibacterial proteins to target competing bacteria. Proteobacteria and some Firmicutes are Gram-positive bacteria that also digest carbohydrates; however, some of them are highly pathogenic opportunistic pathogens.

2. Role of Short-Chain Fatty Acids (SCFAs)

SCFAs, such as acetate, propionate, and butyrate, are key metabolites produced during the fermentation of dietary fiber by gut bacteria [5]. These SCFAs have numerous beneficial effects on gut health and overall physiology.

Butyrate serves as a primary energy source for colonocytes, promoting the health and function of the large intestine [5]. Acetate and Propionate: Can reach the liver and other tissues, influencing glucose metabolism, lipid synthesis, and overall energy balance [5]. The digestion and metabolism of dietary fiber plays a crucial role in gut health [5]. SCFAs also play a role in modulating inflammation and immune responses in the gut. For example, they can enhance gut barrier integrity, reduce intestinal inflammation, and promote effective intestinal immune [2,9]. SCFAs contribute to maintaining colonic pH, which inhibits the growth of pathogenic bacteria and favors beneficial microbes such as Bifidobacterium and Lactobacillus [10]. Butyrate also promotes mucin production and tight junction protein expression, thereby strengthening the intestinal epithelial barrier 11]. Acetate, the most abundant SCFA, crosses the blood-brain barrier and may play a role in appetite regulation and neuroimmune signaling [12]. SCFAs regulate gene expression through inhibition of histone deacetylases (HDACs), thereby influencing inflammation, cell proliferation, and apoptosis [13]. Propionate has been shown to activate intestinal gluconeogenesis, which can contribute to improved glucose homeostasis and insulin sensitivity [14]. In addition to energy provision, SCFAs act as signaling molecules through G-protein-coupled receptors (GPCRs), including GPR41 and GPR43, to modulate immune responses and lipid metabolism [15].

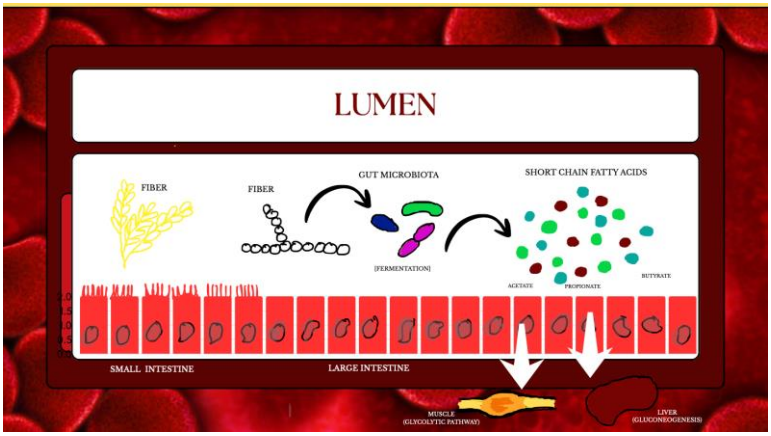

Fig 1. Production of SCFAs from dietary fiber by gut microbiota

3. Impact on Gut Barrier Function

A healthy gut barrier is essential for preventing the translocation of harmful substances, such as toxins and pathogens, from the gut lumen into the bloodstream [10]. Vegetarian diets, by promoting a diverse and balanced gut microbiota and increasing SCFA production, can help maintain gut barrier integrity [11]. Increased microbial diversity associated with vegetarian eating supports the expression of tight junction proteins like occludin and claudin1, reducing gut permeability and limiting systemic exposure to endotoxins.

Plant-based fiber intake encourages the proliferation of fiber-fermenting microbes that generate signaling molecules activating GPR109A and GPR43 receptors on epithelial cells; this signaling promotes an antiinflammatory environment and strengthens epithelial defenses. In human feeding trials, individuals on high-vegetable diets exhibit reduced markers of intestinal inflammation (e.g., calprotectin) and lower levels of circulating lipopolysaccharide, indicating improved barrier function.

Nutrients in vegetarian foods—such as polyphenols and resistant starch—can act in synergy with microbial metabolites to support epithelial regeneration, reduce oxidative stress, and maintain barrier coherence after injury or infection. Intervention studies have shown that vegetarian diets lead to increased abundances of butyrate-producing bacteria—such as Ruminococcaceae, Roseburia, and Coprococcus—which are directly linked to improvements in gut barrier metrics. However, certain components of vegetarian diets, such as fructose, can disrupt the gut barrier if consumed in excess [11]. Therefore, a balanced and varied vegetarian diet is crucial for optimal gut health.

4. Considerations and Potential Challenges

While vegetarian diets generally promote gut health, potential challenges and considerations exist:

Nutrient Deficiencies: Vegetarian diets may lack certain nutrients which can impact gut health indirectly. Vegetarian diets are associated with significant health benefits, including reduced risks of chronic diseases such as heart disease, type 2 diabetes, and obesity, largely due to their high content of fiber, antioxidants, and healthy fats. Additionally, vegetarians tend to have lower BMI and improved cholesterol and blood pressure levels. However, unbalanced vegetarian diets may lead to deficiencies in essential nutrients such as protein, vitamin B12, iron, zinc, and omega-3 fatty acids, which can impact overall health [1]. Supplementation and careful meal planning are necessary to address these deficiencies.

Individual Variability: The response to vegetarian diets can vary significantly depending on individual factors, such as genetics, physiological condition, and pre-existing gut microbiota composition. The physiological condition of host contributes more significantly to the composition of gut microbiome than diet, which means that the composition of gut microbiome is more significantly affected by a host factor than diet. This work also would provide a new theoretical basis why physical exercises is more health-beneficial than vegetarian diets [14].

Diet Composition: A plant-based diet is thought to benefit host health by contributing to establish a diverse and stable microbiome. In addition, microbe-derived metabolites of specific nutrients known to be abundant in vegetarian diets (such as indigestible carbohydrates, arginine, and others) are important to promote effective intestinal immune responses, maintain intestinal barrier function, and protect against pathogens. Simply following a vegetarian diet does not guarantee optimal gut health. The specific types of plant-based foods consumed, the balance of macronutrients, and the inclusion of fermented foods all play a role [2].

5. Conclusion

A well-structured vegetarian diet, high in fiber and varied plant foods, can favorably modulate gut health by enhancing a stable and diverse gut microbiome, enhancing SCFA production, and sustaining gut barrier function. These alterations lead to enhanced metabolic and neurological health. Nevertheless, careful consideration of nutrient adequacy, individual variation, and composition of the diet must be taken to ensure maximizing the benefits of a vegetarian diet on gut health. Though vegetarian diets have shown numerous benefits, difficulties such as possible nutrient deficiencies, variation in the response of individuals, and the need for well-balanced diet structure should be taken into account.

Further studies should aim to determine how personal gut microbiota profiles react to various vegetarian diets to maximize individualized nutrition approaches. Long-term (longitudinal) studies are also important to evaluate the long-term effects of these diets on gut well-being and global well-being. A greater understanding of the mechanisms through which components of certain diets affect gut microbiota and host physiology will allow for more effective, tailored dietary therapy.

In summary, when constructed thoughtfully, vegetarian diets offer a promising strategy for gut and overall health, though their implementation should be tailored, evidence-based, and well-supported further.

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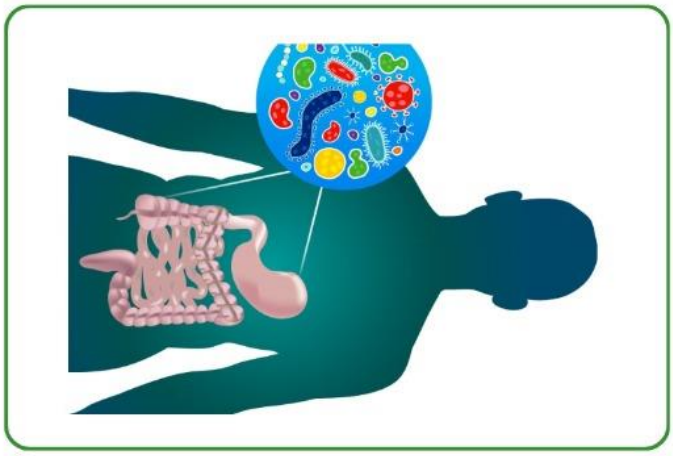

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