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# Plant-Based Diet – Modulation of the Gut Microbiome and Metabolic Consequences

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**ABSTRACT**
Plant-based diets have gained prominence due to their environmental benefits and protective effects against metabolic disorders, including obesity, type 2 diabetes, and cardiovascular disease. The gut microbiome acts as a key metabolic organ mediating the interaction between diet and host physiology, primarily through microbiota-accessible carbohydrates (MACs) and polyphenols found abundantly in plant foods. A comprehensive literature review demonstrates that plant-based diets promote favourable shifts in microbiota composition, increasing beneficial bacteria populations such as *Lachnospiraceae*, *Ruminococcaceae*, and *Bifidobacterium spp*., while reducing pathobionts including *Enterobacteriaceae* and *Bilophila wadsworthia*. These compositional changes enhance production of short-chain fatty acids, particularly butyrate, which strengthen intestinal barrier function and activate signalling pathways regulating satiety hormones (GLP-1, PYY) and glucose homeostasis. Plant-derived tryptophan metabolites and urolithin A further support intestinal integrity through aryl hydrocarbon receptor and Nrf2 pathway activation. The resulting microbiome alterations correlate with improved postprandial glycemic response, reduced cholesterol levels, decreased inflammatory markers, and lower risk of non-alcoholic fatty liver disease. However, the protective effects depend critically on consuming whole foods rich in fiber and polyphenols rather than processed plant-based alternatives. Long-term randomized controlled trials and personalized approaches considering individual microbiome variation are necessary to fully elucidate these mechanisms and optimize dietary recommendations across diverse populations.
**Keywords:** plant-based diet, gut microbiome, short-chain fatty acids, microbiota-accessible carbohydrates, metabolic health, polyphenols, intestinal barrier function

## 1. INTRODUCTION

A plant-based diet is a model of nutrition that involves consuming minimally processed plant products such as fruits, vegetables, whole grains, legumes, nuts, and seeds, while completely excluding foods of animal origin, including red meat, poultry, fish, eggs, and dairy products[1]. However, not all types of this diet are so restrictive. There is a spectrum of these diets: from strict veganism, through vegetarianism, to flexitarian diets. Plant-based diets have become increasingly popular due to their positive impact on global environmental change compared to animal-based foods through their impact on climate, land and water use, and biodiversity[2]. The type of diet also has a major impact on health. Epidemiological studies consistently show that plant-based dietary patterns are associated with a reduced risk of metabolic disorders, including obesity, type 2 diabetes, and cardiovascular diseases[3]. The gut microbiome is considered a key metabolic organ that mediates the interaction between diet and host status[4]. This interaction is largely driven by the high content of microbiota-accessible carbohydrates (MACs) such as dietary fiber, resistant starch, inulin, pectins, and beta-glucans in plant foods, which serve as primary substrates for bacterial fermentation, shaping the composition and function of the intestinal ecosystem[5].

The aim of this study is to analyse the mechanisms through which a plant-based diet modulates the gut ecosystem and to assess the clinical effects of these changes on metabolic health.

## 2. PLANT-BASED DIET COMPONENTS AND THE GUT MICROBIOME

The main factor modulating the gut ecosystem in a plant-based diet are microbiota-accessible carbohydrates (MACs), which include various dietary fiber fractions such as resistant starch, inulin, and beta-glucans. These compounds, which are resistant to enzymatic digestion in the small intestine, are the primary substrate for certain species of gut microbiota in the colon[6]. Recent studies indicate that the effect of fiber on the microbiota is not uniform, but depends on its complex structure, including its degree of crystallinity, porosity, particle size, and viscosity, as well as on the initial state of the host's microbiome, particularly the balance between dysbiotic and eubiotic states, which determines the rate of fermentation and metabolic profile[7,8]. The fermentation of dietary fiber leads to the production of metabolites, primarily short-chain fatty acids (SCFA), but also modulates levels of branched-chain amino acids and neuroactive chemicals. These compounds act as paracrine or endocrine signalling molecules, affecting colonocyte metabolism and systemic signalling pathways[9].

Another key component found in a plant-based diet is polyphenols (e.g., flavonoids, phenolic acids), which work synergistically with dietary fiber. This study demonstrated that the simultaneous consumption of fibre and polyphenol mixtures produces a stronger additive effect than either component alone. This combination leads to the selective growth of key bacterial taxa (such as *Ruminococcus bromii* and *Bifidobacterium spp*.), while inhibiting pathobionts like *Enterobacteriaceae*. This mechanism involves not only growth stimulation, but also modulation of bacterial metabolic pathways, which translates into increased synthesis of anti-inflammatory SCFAs[10].

Furthermore, the source of dietary protein plays a critical role in shaping the gut ecosystem. Animal proteins are rich in sulfur-containing amino acids, which promote the growth of proteolytic bacteria and the production of potentially toxic metabolites such as hydrogen sulfide (H2S), ammonia, and branched-chain fatty acids (BCFAs), which can weaken the intestinal barrier and cause inflammation. On the other hand, the inclusion of plant-based proteins in the diet has been shown to alleviate intestinal dysbiosis and reduce the risk of disease[11].

## 3. CHANGES IN THE GUT MICROBIOME CAUSED BY A PLANT-BASED DIET

A plant-based diet causes characteristic and beneficial changes in the composition and function of the gut microbiome. A diet based on plant products promotes microbial diversity, the growth of beneficial bacteria populations, and the production of metabolites that support metabolism and have anti-inflammatory effects[12]. One study observed a significant increase in the number of *Lachnospiraceae*, *Ruminococcaceae*, *Monoglobaceae*, *Eggerthellaceae*, *Christensenellaceae*, *Butyricicoccaceae*, and *Erysipelatoclostridiaceae* in individuals following a plant-based diet for six days. In contrast, the number of *Barnesiellaceae*, *Sutterellaceae*, *Marinifilaceae*, *Tannerellaceae*, *Rikenellaceae*, and *Acidaminococcaceae* decreased significantly during this period . These changes are associated with beneficial effects of plant-based diets on gut microbiota composition and overall health[13]. Another study observed specific changes in the composition of the microbiome in people who included plant-based meat alternatives (PBMA) in their diet. The key change was an increase in the number of butyrate-producing bacteria, including members of the *Lachnospiraceae* and *Ruminococcaceae* families. In addition, the group consuming plant-based products (PBMA) saw a decrease in the number of *Tenericutes* bacteria, which are often associated with metabolic disorders, while in the control group consuming traditional meat, their levels increased[14]. Researchers have shown that a diet based on animal products leads to a rapid increase in the number of *Bilophila wadsworthia* pathobionts, which are associated with inflammatory bowel disease (IBD), representing the microbiome's response to increased bile acid concentrations. In contrast to this dietary model, a plant-based diet does not stimulate the growth of these bile-tolerant microorganisms, but promotes the maintenance of fiber-fermenting bacteria populations[15]. Another article showed that long-term consumption of a plant-based diet rich in fiber and complex carbohydrates promotes the formation of an enterotype based on *Prevotella* bacteria, which has an excellent ability to hydrolyze cellulose and xylan. This contrasts with the Western diet, which promotes the formation of an enterotype dominated by *Bacteroides* bacteria, adapted to metabolize animal proteins and fats. The study emphasizes that the gut microbiota evolves with diet, maximizing energy extraction from plant polysaccharides through specific enzymatic pathways that are not present in the microbiome of people on a low-fiber diet[16]. Collectively, these studies show that shifting to a plant-based diet effectively supports a healthier gut microbiome by boosting fiber fermentation, lowering the number of harmful bacteria, and improving metabolic health.

## 4. MICROBIOME METABOLITES AS MEDIATORS OF HEALTH EFFECT

The gut microbiota converts dietary components into a wide range of biologically active metabolites. These compounds act as key mediators between the food consumed and the physiology of the host. A plant-based diet, by providing specific substrates such as fiber and polyphenols, promotes the synthesis of protective metabolites while limiting the formation of toxic compounds. A well-documented protective mechanism is the production of short-chain fatty acids (SCFA), such as butyrate, acetate, and propionate, in the process of dietary fiber fermentation. The authors of the study point out that SCFAs function not only as a source of energy, but primarily as signalling molecules. They activate G protein-coupled receptors (GPR41 and GPR43), which stimulates the secretion of the intestinal hormones GLP-1 and PYY, responsible for regulating satiety and glucose homeostasis. In addition, butyrate is a key metabolite that seals the intestinal barrier[17]. Plant-derived tryptophan metabolites also play an important role in maintaining immune protection. The study showed that gut bacteria convert tryptophan into indole derivatives, which act as ligands for the aryl hydrocarbon receptor (AhR). Activation of this pathway strengthens the integrity of the intestinal epithelium and suppresses inflammation[18]. Other authors have shown that urolithin A, produced in the intestines from ellagitannins contained in certain plant products, acts as a signal activating the Nrf2 defense pathway. This activation results in a direct increase in the production of proteins such as claudin-4 and occludin, which play a role in binding epithelial cells together. Interestingly, a plant-based diet enriched in polyphenols is not enough on its own, as the microbiota's ability to transform these compounds into active metabolites is critical for the protective effect[19].

## 5. METABOLIC CONSEQUENCES OF CHANGES IN THE GUT MICROBIOME

A plant-based diet affects the composition and functionality of the gut microbiome, which influences the signalling pathways that regulate the host's metabolism. These mechanisms go beyond a simple reduction in calorie intake, encompassing the production of bacterial metabolites, modulation of gut hormones, and tightening of the intestinal barrier. One of the well-documented mechanisms linking a plant-based diet to weight control is its effect on the secretion of satiety hormones. The study showed that a plant-based meal stimulates the secretion of intestinal hormones much more strongly than a meat-based meal. Study participants (both healthy, obese, and type 2 diabetic individuals) showed higher concentrations of glucagon-like peptide-1 (GLP-1) and peptide YY (PYY) after consuming a plant-based meal. An increase in their concentration leads to a longer period of postprandial satiety[20]. Modulation of the microbiome in a plant-based diet is also associated with an improved glycemic profile. In a large cohort study, researchers showed that people who ate a plant-rich diet had higher numbers of *Prevotella copri* and *Blastocystis bacteria*. These species were associated with a favourable postprandial glycemic response and insulin sensitivity. The researchers emphasize that these beneficial metabolic effects result from the role of the microbiome in modulating circulating metabolites, which translates into a lower risk of type 2 diabetes[21]. A plant-based diet also has a positive effect on the cardiovascular system. In a prospective cohort study, researchers showed that following a plant-based diet is associated with a significant reduction in total cholesterol and LDL cholesterol levels. These metabolic improvements were accompanied by specific microbiome alterations, including a reduction in *Peptostreptococcus* abundance. The researchers found that the decrease in this genus was significantly correlated with lower inflammatory markers (CRP) and higher levels of HDL cholesterol[22]. A recent study has shown that following a plant-based diet, particularly one rich in healthy plant foods such as vegetables, fruits, nuts, and legumes, is associated with a significant reduction in the risk of liver fibrosis in people with non-alcoholic fatty liver disease (NAFLD). A plant-based diet high in fructose, particularly from fruit juices, may increase the risk of hepatic steatosis. However, consuming fructose along with whole fruits, which contain fiber and polyphenols, can have a neutral or even positive effect. The most important factor for the beneficial effects of a plant-based diet on the liver is to ensure high-quality plant products and avoid fructose-dense products[23].

## 6. CONCLUSIONS

Plant-based diets exert profound effects on the gut microbiome, driving shifts in microbial composition and function that are closely linked to metabolic health. The high content of microbiota-accessible carbohydrates (MACs) and polyphenols in plant foods promotes the growth of beneficial bacterial taxa and enhances the production of protective metabolites, such as short-chain fatty acids (SCFAs), which mediate anti-inflammatory and metabolic effects. These changes are associated with improved regulation of body weight, enhanced insulin sensitivity, favourable lipid profiles, and reduced systemic inflammation. Moreover, the quality of plant-based foods plays a crucial role: diets rich in whole foods, fiber, and polyphenols offer the greatest benefits, while excessive intake of processed foods and fructose-dense products may attenuate or negate these positive effects. The gut microbiome thus acts as a key mediator, translating dietary patterns into metabolic outcomes. Despite the growing body of evidence, the field of plant-based nutrition and gut microbiome interactions remains highly complex and dynamic. Many of the reported effects are based on observational or short-term interventional studies, and there is a need for more large-scale, long-term, and randomized controlled trials to fully elucidate the mechanisms and clinical relevance of these findings. Future research should also focus on personalized approaches, considering individual differences in baseline microbiome composition, dietary habits, and genetic factors. Such efforts will be essential to optimize dietary recommendations and maximize the health benefits of plant-based diets in diverse populations.

## DISCLOSURE

### Author's contribution

Conceptualization: B.Wróbel; methodology: B.Wróbel; check: J.Klonowska; formal analysis: L.Wójcik; investigation: M.Filipski; resources: M.Filipski; data curation: S.Kosek; writing - rough preparation: B.Wróbel; writing - review and editing: J.Klonowska; visualization: L.Wójcik; supervision: S.Kosek; project administration: J.Klonowska; receiving funding- no specific funding.

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In preparing this work, the authors used Perplexity for the purpose of checking language accuracy. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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