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The Impact of Modern Dietary Patterns on Structural and Functional Changes in the Digestive System

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Abstract: For millions of years, the human gut evolved with fiber-rich, plant-based, and natural diets. This close relationship with unprocessed food sources helped build a strong and diverse gut microbiome that supported efficient digestion, stable metabolism, and a balanced immune system. The fibrous and complex carbohydrates present in ancestral diets made the gastrointestinal system resilient and adaptable to environmental challenges (Tannock, 2024). However, in the modern era, this evolutionary relationship has been hampered by the dominance of ultra-processed foods—high in refined sugars, saturated fats, and chemical additives, yet low in fiber and nutritional diversity. These foods have altered the internal ecosystem of the human gut, speeding up digestion and disturbing metabolic stability (Fu et al., 2022). As a result, the normal function of the gastrointestinal system is increasingly compromised, leading to a decline in microbial diversity (Moles & Otaegui, 2020). Modern dietary habits are now believed to be pushing the human gut toward a new evolutionary direction—one marked more by disease than resilience. This disruption has contributed to anatomical and physiological changes within the gut, which are closely linked to the rise of chronic disorders such as inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), obesity, type 2 diabetes, and autoimmune conditions (Oliver et al., 2021). This paper explores how the transition from traditional, fiber-rich diets to highly processed Western diets has influenced the evolution of the human gastrointestinal system. It also examines how modern food processing and nutrient composition have reshaped the gut microbiota, immune responses, and digestive health. By understanding this evolutionary and nutritional shift, the study sheds light on the importance of restoring dietary diversity and fiber intake to rebuild microbial balance, enhance gut function, and reduce the risk of modern gastrointestinal and metabolic diseases.

Keywords: Gut microbiota, Ultra processed food, Dietary evolution, Gastrointestinal health

Introduction

The human gastrointestinal system has undergone extensive evolutionary adaptation, shaped largely by long-standing dietary patterns rich in diverse plant-based foods and dietary fiber. For millennia, ancestral human diets consisted predominantly of minimally processed, fiber-dense plant matter, which played a fundamental role in establishing and maintaining a resilient and diverse gut microbiota. These microbial communities, particularly those residing in the colon, co-evolved with the host and became optimized for the fermentation of complex carbohydrates and polysaccharides (Fu et al., 2022). This symbiotic relationship enabled the efficient production of short-chain fatty acids (SCFAs), including acetate, propionate, and butyrate, which are critical for maintaining intestinal integrity, modulating immune responses, and supporting overall metabolic health (Lachmansingh et al., 2024). In contrast, contemporary dietary patterns—often characterized as Westernized diets—have diverged significantly from these ancestral norms. Modern diets are typically high in refined sugars, saturated fats, and ultra-processed foods, while being markedly deficient in dietary fiber. This nutritional transition has contributed to a measurable decline in gut microbiome diversity, a condition frequently associated with dysbiosis, defined as

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the disruption or imbalance of the normal microbial community (Hrncir, 2022). The reduced intake of fermentable substrates limits microbial fermentation processes in the colon, thereby diminishing SCFA production and impairing key physiological functions linked to gut health (Vinelli et al., 2022).

Dietary fiber plays a pivotal role in sustaining gastrointestinal function and microbial ecology. Fermentable fibers resist digestion in the upper gastrointestinal tract and reach the colon intact, where they serve as essential substrates for beneficial bacteria. Through fermentation, these fibers promote the growth of commensal microbial species and enhance metabolic activity within the gut ecosystem. Additionally, non-fermentable fibers contribute to gastrointestinal motility by increasing fecal bulk and facilitating peristalsis, thereby supporting efficient digestion and preventing metabolic disturbances such as rapid glycemic fluctuations (Slavin, 2013).

The absence or insufficiency of dietary fiber has significant implications for host health. A fiber-deficient diet deprives gut microbiota of necessary nutrients, leading to reduced microbial diversity, compromised gut barrier function, and altered immune regulation (Fu et al., 2022). These changes have been linked to an increased risk of metabolic disorders, inflammatory conditions, and other chronic diseases. Furthermore, the disruption of microbial fermentation processes may reduce the bioavailability of essential nutrients and impair host–microbe interactions that are critical for maintaining physiological homeostasis.

Given these considerations, the primary objective of dietary management in modern populations is to restore and sustain optimal gut health by promoting a diverse and resilient microbiome (Hrncir, 2022). Reintegrating fiber-rich, plant-based foods into daily dietary practices represents a key strategy in mitigating dysbiosis and enhancing gastrointestinal and systemic health. This study aims to examine the impact of dietary fiber on gut microbiota composition and function, with particular emphasis on its role in maintaining microbial diversity, supporting SCFA production, and preventing diet-related health complications.

Main Body

Evolutionary Mismatch: The Decline of Fiber and Its Impact on Gut Function and Microbial Ecology

From an evolutionary perspective, the human gastrointestinal system is fundamentally adapted to a diet abundant in complex plant fibers and indigestible polysaccharides. For the majority of human history, dietary intake consisted of high-residue, fiber-rich foods that were not fully digested in the upper gastrointestinal tract. Instead, these fermentable fibers reached the large intestine intact, where they served as the primary substrate for gut microbiota (Slavin, 2013). This long-standing dietary pattern fostered a mutually beneficial relationship between host and microbes, enabling efficient fermentation processes and the sustained production of short-chain fatty acids (SCFAs), particularly butyrate, which are essential for maintaining intestinal health and metabolic homeostasis (Vinelli et al., 2022).

In contrast, the modern shift toward low-residue, fiber-deficient diets represents a significant evolutionary mismatch. Unlike ancestral diets, contemporary food patterns are characterized by highly refined and rapidly digestible carbohydrates that are absorbed early in the digestive process. This results in accelerated gastric emptying and rapid glucose absorption, leading to pronounced fluctuations in blood sugar levels and increased risk of insulin resistance. Furthermore, the absence of indigestible plant components—such as seeds, skins, and structural fibers—reduces the bulk of intestinal contents. This diminishes mechanical stimulation of the gut wall, weakens peristaltic activity, and contributes to gastrointestinal disturbances such as constipation, bloating, and increased intraluminal pressure within the colon (Liang et al., 2023).

The evolutionary consequences extend beyond mechanical digestion to the ecological stability of the gut microbiome (Gomez et al., 2019). Fiber-rich diets historically provided a continuous supply of fermentable substrates necessary for sustaining diverse microbial populations. In the absence of dietary fiber, beneficial gut bacteria are deprived of their primary energy source, leading to reduced microbial diversity and functional capacity. This decline disrupts the fermentation of complex carbohydrates and significantly lowers the production of SCFAs. As a result, colonocytes—cells lining the colon that depend on SCFAs for energy—experience nutritional deprivation, compromising the integrity of the gut barrier (Fu et al., 2022).

The reduction in SCFA availability has profound physiological implications. A weakened gut barrier increases intestinal permeability, often referred to as “leaky gut,” allowing toxins and microbial components to translocate into the bloodstream. This process can trigger systemic inflammation and has been associated with the development of metabolic and inflammatory disorders, including obesity, type 2 diabetes, and colorectal diseases.

Additionally, the diminished fermentation activity reduces the microbiota's ability to enhance nutrient bioavailability and regulate immune function, further exacerbating health risks (Desai et al., 2016).

Thus, the transition from an ancestral, fiber-rich diet to a modern low-residue dietary pattern not only impairs digestive efficiency but also destabilizes the intricate host–microbe ecosystem that has evolved over millennia. The loss of dietary fiber effectively initiates a cascade of mechanical, biochemical, and microbial dysfunctions, highlighting the critical role of fiber in maintaining both gut integrity and overall health (Desai et al., 2016).

Due to the reduction in dietary fiber, there is a significant overgrowth of harmful and opportunistic bacteria within the gut. As beneficial bacteria decline from lack of fermentable substrates, opportunistic species—often inflammatory in nature—begin to expand and dominate the microbial environment. These microbes adapt by feeding on readily available energy sources such as simple sugars, dietary fats, and even the mucus lining of the gut wall. In the process, some of these bacteria produce harmful compounds, including endotoxins such as lipopolysaccharides, which can trigger inflammatory responses (Fu et al., 2022). This microbial imbalance is referred to as dysbiosis, characterized by a disrupted and unhealthy gut ecosystem. Furthermore, in the absence of dietary fiber, bacteria increasingly turn to the gut's protective mucus layer as an alternative nutrient source, leading to its gradual erosion. As this mucus barrier thins, the integrity of the gut lining is compromised, resulting in increased intestinal permeability, commonly known as leaky gut. Consequently, harmful substances, toxins, and microbial components are able to cross into the bloodstream, promoting systemic inflammation and contributing to the development of various chronic diseases (Martinez et al., 2017).

Impact of Westernized Diets on Gut Microbiome and Intestinal Integrity

The Westernized diet, characterized by low dietary fiber and high consumption of refined carbohydrates, saturated fats, and processed foods, has led to a marked regression in gut microbiome diversity and function. The shift from fiber-rich to fiber-depleted diets has significantly altered microbial metabolism, reducing the production of short-chain fatty acids (SCFAs) and favoring the generation of long-chain fatty acids. SCFAs, such as butyrate, serve as a vital energy source for colonocytes and help maintain the structural integrity of the intestinal epithelium. Their depletion results in reduced energy availability to gut lining cells, leading to thinning of the epithelial barrier and increased intestinal permeability, commonly known as “leaky gut.” (Kang et al., 2022). This compromised barrier permits translocation of microbial components such as lipopolysaccharides (LPS) and other toxins into the bloodstream, triggering systemic inflammation. Chronic low-grade inflammation resulting from this process is strongly associated with the development of metabolic and inflammatory diseases, including obesity, insulin resistance, type 2 diabetes, and colorectal cancer (Martinez et al., 2017).

Furthermore, low-residue diets—those deficient in indigestible plant materials such as seeds, skins, and structural fibers—reduce the mechanical stimulation necessary for normal gut motility. As a consequence, gastrointestinal transit becomes sluggish, leading to constipation, bloating, and increased intraluminal pressure. Fiber normally slows glucose absorption and moderates postprandial glycemic responses. However, in the absence of sufficient fiber, food is absorbed rapidly, resulting in sharp glucose spikes and increased insulin secretion. Chronic exposure to these metabolic fluctuations contributes to insulin resistance and, over time, the onset of obesity and type 2 diabetes (Oliver et al., 2021).

Mechanically, a low-residue diet weakens intestinal muscle tone; biologically, it decreases microbial diversity and metabolic activity; and chemically, it limits the synthesis of beneficial SCFAs. The absence of fermentable fibers effectively starves beneficial gut bacteria, which depend on complex plant polysaccharides as their primary energy source. When deprived of these substrates, beneficial bacteria die off within days or weeks, leading to a significant reduction in microbial diversity. This imbalance facilitates the overgrowth of opportunistic or pathogenic species that thrive on simple sugars, fats, and even host-derived mucus. These harmful microbes can release inflammatory compounds, including endotoxins and LPS, which further exacerbate gut inflammation and promote dysbiosis—a state of microbial imbalance within the intestinal ecosystem (Oliver et al., 2021).

In the absence of adequate dietary fiber, gut microbes seek alternative nutrient sources, often degrading the protective mucus layer that lines the intestinal wall. This erosion of the mucus barrier exacerbates gut permeability and increases exposure of epithelial cells to harmful substances. The resulting condition, commonly termed “leaky gut syndrome,” allows antigens, toxins, and bacteria to cross into systemic circulation, intensifying immune activation (Usuda et al., 2021).

The gut microbiome also plays a critical role in training and modulating the host immune system. A reduction in microbial diversity and the dominance of pathogenic species can lead to immune dysregulation, where immune cells become hyperreactive and prone to misidentifying self-tissues as threats (Sun et al., 2021). This dysregulated immune response contributes to chronic low-grade inflammation and has been linked to a range of disorders, including irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), obesity, type 2 diabetes, and various autoimmune and allergic conditions (Liang et al., 2023).

In summary, the Westernized, low-fiber diet profoundly disrupts gut microbial ecology and intestinal physiology. The resulting loss of beneficial microbes, depletion of SCFAs, and erosion of the mucosal barrier collectively contribute to metabolic, inflammatory, and immune-mediated diseases. Preservation of gut health thus requires restoring dietary fiber intake to support microbial diversity, maintain epithelial integrity, and promote systemic metabolic balance (Vinelli et al., 2022).

From Foraging to Processing: How Food Diversity Reshaped the Human Gut

In recent years, modern nutritional science has increasingly emphasized not only the quantity of food intake but also the diversity and quality of foods consumed as critical determinants of gastrointestinal health. From an evolutionary standpoint, the human digestive system developed in response to a wide variety of natural, minimally processed foods. This diversity required the gastrointestinal tract to function as a highly adaptable system, capable of handling different physical structures, chemical compositions, and nutrient profiles. Consequently, both the physiological processes and anatomical features of the gut were shaped by the need to efficiently digest and extract nutrients from a broad spectrum of dietary sources (Carmody et al., 2021).

However, with the advent of modern food processing techniques—such as cooking, juicing, refining, and preservation—the physical and chemical properties of food have been significantly altered. These processes often reduce structural complexity, modify nutrient composition, and, in some cases, decrease fiber content. As a result, the digestive demands placed on the gastrointestinal system have changed. Processed foods are generally easier and faster to digest, requiring less mechanical breakdown and enzymatic activity compared to whole, unprocessed foods. Over time, such dietary shifts may influence gut motility, enzyme secretion, and even the structural and functional dynamics of the gastrointestinal tract (Vadatchkoria & Narayan, 2025).

Moreover, the variety of foods consumed plays a crucial role in shaping digestive mechanisms and microbial diversity. Different types of food substrates interact uniquely with the gastrointestinal system, influencing not only digestion and absorption but also the composition and metabolic activity of the gut microbiota. A diverse diet supports a wider range of microbial species, enhancing the overall functional capacity of the gut ecosystem. In contrast, limited dietary variation may reduce microbial diversity and restrict the adaptive potential of the gastrointestinal system (Vadatchkoria & Narayan, 2025).

To better understand how different dietary patterns influence gut function and microbial composition, modern research utilizes experimental approaches such as fecal inoculum models. These methods allow scientists to study the interactions between diet, microbiota, and host physiology under controlled conditions. Through such approaches, it becomes possible to investigate how variations in food type, processing, and diversity can modulate digestive processes and contribute to both the evolution and the ongoing adaptation of the human gastrointestinal system (McBurney & Thompson, 1987).

Diversity Lost: The Dietary Roots of Gut Disorders

Dietary diversity has long been recognized as a key factor in shaping the structural and anatomical integrity of the gastrointestinal system. A varied, fiber-rich diet supports optimal gut function by maintaining stool bulk, promoting efficient motility, and sustaining a balanced microbial ecosystem. However, a significant regression in dietary diversity—largely driven by the increased consumption of low-residue, fiber-deficient foods—has been associated with a wide spectrum of gastrointestinal disorders (Fu et al., 2022).

At the functional level, reduced fiber intake leads to decreased stool bulk and impaired intestinal motility, resulting in harder stools and increased straining during defecation (Oliver et al., 2021). This contributes to the development of common conditions such as constipation and hemorrhoids. Over time, chronic mechanical stress and elevated intraluminal pressure within the colon may lead to structural abnormalities, including diverticulosis, characterized

by the formation of outpouchings or herniations in the colonic wall. These conditions reflect not only functional impairment but also long-term anatomical consequences of inadequate dietary patterns (Martinez et al., 2017).

Beyond mechanical effects, the decline in dietary diversity significantly impacts the gut microbiome and its interaction with the host immune system. The gut microbiota plays a crucial role in training and regulating immune responses. When dietary diversity decreases and fiber intake is insufficient, beneficial microbial populations decline, allowing harmful or opportunistic bacteria to dominate. This imbalance can lead to immune dysregulation, where immune cells become overactive or improperly regulated (Desai et al., 2016).

Such immune disturbances often manifest as chronic low-grade inflammation, a key underlying factor in a range of diseases. These include gastrointestinal conditions such as irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD), as well as systemic disorders like obesity, type 2 diabetes, and various autoimmune and allergic conditions. Thus, the shift away from diverse, fiber-rich diets not only compromises gastrointestinal structure and function but also disrupts immune homeostasis, highlighting the far-reaching health consequences of modern dietary patterns (Heiman & Greenway, 2016). A low-fiber diet is strongly linked to a range of gastrointestinal disorders because fiber plays a central role in stool formation, bowel movement, and overall gut health.

When dietary fiber is low, the body produces smaller, harder stools. This leads to slower transit through the colon and increased pressure inside the intestinal walls. Over time, this repeated strain becomes a key factor in conditions like constipation and hemorrhoids. Hard stools require more force to pass, which can cause swollen veins around the rectum (hemorrhoids) and difficulty in regular bowel emptying (Heiman & Greenway, 2016). One of the most important conditions connected to low fiber intake is **Diverticulosis**. In a fiber-deficient diet, stools become compact and difficult to pass, increasing internal pressure within the colon. This pressure can cause weak points in the colon wall to bulge outward, forming small pouches called diverticula. These outpouchings are essentially structural changes caused by long-term strain and pressure from hard, low-volume stools. When these pouches become inflamed or infected, the condition can progress to **Diverticulitis**, which is more serious. In addition, low fiber intake disrupts normal bowel motility, which can contribute to disorders like **Irritable Bowel Syndrome** and worsen symptoms in other gastrointestinal conditions. A lack of fiber also reduces stool bulk, which slows intestinal movement and increases toxin exposure time within the colon (Liang et al., 2023).

Decoding Your Gut: How Science Tailors the Perfect Diet

An in vitro human gut microbiota fermentation model is a powerful laboratory system used to study how the human gut microbiome breaks down and ferments dietary components—especially fiber—outside the human body. These models replicate the conditions of the human colon, including an anaerobic (oxygen-free) environment, controlled temperature, regulated pH, and the use of a microbial inoculum (often derived from human fecal samples). Through these controlled settings, researchers can observe how gut microbes metabolize food, how microbial populations grow, and what metabolic products are formed (Oliver et al., 2021) (Rodriguez et al., 2024).

In practice, the model works by introducing a dietary substrate—commonly different types of fiber—into the system and monitoring microbial activity over time. The microbes ferment these fibers, producing important metabolites such as short-chain fatty acids (SCFAs), which play key roles in maintaining gut health, supporting the intestinal barrier, and regulating immune function. This process closely reflects what happens in the large intestine, where undigested fibers are broken down by gut bacteria (Vinelli et al., 2022).

What makes this model especially valuable is its potential application in personalized nutrition. Every individual has a unique gut microbiome, shaped by genetics, diet, lifestyle, environment, and health status. As a result, the way each person responds to the same type of fiber can vary significantly. Some individuals may produce higher levels of beneficial metabolites like butyrate, while others may experience different microbial shifts or lower fermentation efficiency (Rodriguez et al., 2024).

Using the in vitro fermentation model, scientists can test how an individual's gut microbiota responds to various types of fiber before recommending a diet. For example, by analyzing a person's microbial composition and simulating fermentation in the lab, it becomes possible to identify which fibers are most beneficial for that individual. This allows for the development of customized dietary plans that optimize gut health, improve digestion, and support overall well-being (Thomson et al., 2021) (Isenring et al., 2023).

This approach highlights a key principle: every body is different. There is no single “ideal” diet that works for everyone because each person’s gut microbiome functions uniquely. Some individuals may benefit more from certain fibers, while others may require different dietary adjustments to achieve balance. Therefore, personalized nutrition based on microbiome analysis represents a shift from a one-size-fits-all diet to a more precise, individualized approach.

In this way, the in vitro gut fermentation model serves as a bridge between scientific research and real-world dietary planning. It helps translate microbiome behavior into actionable insights, enabling healthcare professionals and researchers to design personalized, fiber-rich diets that are tailored to an individual’s unique biological needs—ultimately promoting better digestion, reduced disease risk, and improved long-term health (Isenring et al., 2023)

Conclusion

This paper highlights the intricate evolutionary relationship between dietary diversity and the structural, functional, and microbial adaptations of the human gastrointestinal system. Throughout human history, a fiber-rich and varied diet played a central role in shaping a resilient gut ecosystem, characterized by high microbial diversity, efficient digestion, and stable immune regulation. In contrast, the modern shift toward low-residue, fiber-deficient dietary patterns represents a significant departure from this evolutionary framework, leading to notable alterations in gut function and microbiome composition (Vadatchkoria & Narayan, 2025).

The reduction in dietary fiber has been shown to disrupt microbial balance, impair gut motility, weaken the intestinal barrier, and contribute to a range of gastrointestinal and systemic disorders. These changes underscore how deeply interconnected diet, microbiota, and host physiology are, and how deviations from ancestral dietary patterns can have far-reaching health consequences. From common conditions such as constipation and hemorrhoids to more complex disorders like diverticulosis, inflammatory bowel disease, and metabolic syndromes, the impact of dietary regression is evident across multiple levels of human health (Desai et al., 2016).

Importantly, this study emphasizes the critical role of dietary fiber as a foundational component in maintaining gut health and microbial diversity. Fiber not only supports the structural integrity of the gastrointestinal system but also sustains the metabolic and immunological functions of the gut microbiome. The comparison between ancestral and modern diets further reinforces the necessity of adopting balanced, fiber-rich dietary practices to preserve gut ecosystem stability and overall health (Fu et al., 2022).

In conclusion, understanding the evolutionary context of human nutrition provides valuable insight into the importance of maintaining dietary diversity. Promoting fiber-rich, minimally processed foods is essential not only for optimal digestion but also for supporting the complex and adaptive ecosystem within the human gut, ultimately safeguarding long-term health and preventing disease (Carmody et al., 2021).

Recommendations

This article is recommended for the teachers of Medical Basic Sciences, Biologist, Nutritionists, Physicians and for the students of Medical and Biological specialties, as well as for a wide range of readers in related fields.

Scientific Ethics Declaration

* This article was presented as a poster presentation at the International Conference on Medical, Health and Life Sciences (www.icmehels.net) held in Batumi/Georgia on July 09-12, 2026.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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