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Gut Microbial Modulation Through Siddha Herbal Medicines

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Abstract:

Background: The human gut microbiota plays a crucial role in maintaining gastrointestinal health, immune function, metabolic regulation, and overall physiological homeostasis. Alterations in the composition and diversity of gut microbial communities, commonly known as dysbiosis, have been associated with a wide range of chronic diseases including inflammatory bowel disease, obesity, diabetes mellitus, cardiovascular disorders, and neurodegenerative conditions. Siddha medicine, one of the oldest traditional systems of medicine practiced in South India, utilizes numerous medicinal plants and herbal formulations that possess antimicrobial, prebiotic, antioxidant, anti-inflammatory, and immunomodulatory properties. Recent scientific investigations suggest that these herbal medicines may influence gut microbial composition and function, thereby contributing to health promotion and disease prevention.

Objective: This review aims to evaluate the role of Siddha herbal medicines in modulating gut microbiota and to examine their potential applications in maintaining gastrointestinal and systemic health.

Methods: A comprehensive literature review was conducted using scientific databases including PubMed, Scopus, Web of Science, Google Scholar, ScienceDirect, and AYUSH research resources. Relevant studies published between 2000 and 2025 focusing on Siddha medicinal plants, gut microbiota, phytochemicals, microbial modulation, and microbiome-associated health outcomes were systematically analyzed. Information regarding medicinal plants, bioactive compounds, mechanisms of action, and therapeutic applications was extracted and synthesized.

Results: The reviewed literature revealed that several Siddha medicinal plants, including Phyllanthus emblica, Terminalia chebula, Terminalia bellirica, Curcuma longa, Ocimum tenuiflorum, Tinospora cordifolia, and Azadirachta indica, possess significant microbiome-modulating properties. These plants contain bioactive phytochemicals such as polyphenols, flavonoids, tannins, alkaloids, terpenoids, and polysaccharides that promote the growth of beneficial microorganisms including Lactobacillus and Bifidobacterium species while suppressing pathogenic microbes. The findings further demonstrated that Siddha herbal medicines enhance short-chain fatty acid production, improve intestinal barrier integrity, reduce inflammation and oxidative stress, and support immune homeostasis. Their antimicrobial and prebiotic activities contribute to the restoration of microbial balance and may help prevent gut dysbiosis associated with various chronic diseases.

Keywords: Siddha Medicine; Gut Microbiota; Gut Microbiome; Microbial Modulation; Medicinal Plants; Prebiotics; Phytochemicals; Intestinal Health; Dysbiosis; Immunomodulation; Integrative Medicine.

Introduction

The human gastrointestinal tract harbors a highly complex and dynamic microbial ecosystem comprising trillions of microorganisms, collectively known as the gut microbiota. These microorganisms play essential roles in digestion, nutrient metabolism, immune regulation, maintenance of intestinal barrier integrity, and protection against pathogenic infections [1]. Recent advances in microbiome research have demonstrated that disturbances in the composition and function of gut microbiota, commonly referred to as dysbiosis, are associated with numerous chronic diseases including inflammatory bowel disease, obesity, diabetes mellitus, cardiovascular disorders, allergies, autoimmune diseases, and neuropsychiatric conditions [2,3]. Consequently, modulation of the gut microbiome has emerged as a promising therapeutic strategy for maintaining health and preventing disease progression.

Traditional medical systems have long recognized the importance of digestive health in overall well-being. Among these systems, Siddha medicine, one of the oldest indigenous healthcare traditions of South India, emphasizes

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the maintenance of physiological balance through dietary regulation, herbal medicines, lifestyle practices, and detoxification therapies [4]. Siddha literature describes the gastrointestinal tract as a critical determinant of health, and numerous herbal formulations have been traditionally prescribed for digestive disorders, bowel irregularities, infections, inflammatory conditions, and metabolic diseases [5]. Modern scientific investigations have increasingly validated these traditional practices by demonstrating that many Siddha medicinal plants possess prebiotic, antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory properties capable of influencing the composition and activity of gut microbiota [6].

Several medicinal plants commonly used in Siddha medicine, including *Phyllanthus emblica*, *Terminalia chebula*, *Terminalia bellirica*, *Azadirachta indica*, *Ocimum tenuiflorum*, *Tinospora cordifolia*, and *Curcuma longa*, contain diverse bioactive compounds such as polyphenols, flavonoids, tannins, alkaloids, terpenoids, and polysaccharides that can interact with intestinal microorganisms [7]. These phytochemicals serve as substrates for beneficial microbial species, stimulate the growth of probiotic bacteria, inhibit pathogenic microorganisms, and promote the production of short-chain fatty acids that contribute to intestinal health and immune regulation [8]. Studies have shown that herbal polyphenols can selectively enhance populations of beneficial bacterial genera such as *Lactobacillus* and *Bifidobacterium* while suppressing potentially harmful organisms, thereby restoring microbial equilibrium within the gastrointestinal tract [9].

Emerging evidence further suggests that Siddha herbal formulations may exert microbiome-modulating effects through multiple mechanisms, including enhancement of mucosal immunity, reduction of intestinal inflammation, improvement of epithelial barrier function, and regulation of microbial metabolic pathways [10]. The antioxidant properties of many Siddha herbs help neutralize oxidative stress within the gut environment, thereby supporting the survival and proliferation of beneficial microorganisms [11]. Furthermore, several traditional formulations have demonstrated antimicrobial activity against enteric pathogens while preserving commensal microbial populations, a characteristic that may offer advantages over broad-spectrum antibiotics which frequently induce microbial dysbiosis [12].

The increasing prevalence of antimicrobial resistance and chronic non-communicable diseases has intensified interest in alternative and complementary therapeutic approaches that promote microbial homeostasis [13]. Contemporary microbiome-centered healthcare recognizes the importance of dietary and botanical interventions in shaping gut microbial communities, and Siddha medicine offers a rich repository of herbal resources with significant potential for microbiome modulation [14]. Scientific studies employing modern molecular techniques, including metagenomics, metabolomics, and microbial sequencing, have begun to elucidate the interactions between Siddha herbal medicines and gut microbiota, providing mechanistic insights into their therapeutic effects [15]. These findings support the integration of traditional Siddha knowledge with modern microbiological research to develop innovative strategies for promoting gut health and preventing disease [16].

Given the growing recognition of the gut microbiome as a critical determinant of human health, understanding the role of Siddha herbal medicines in modulating intestinal microbial communities is of considerable scientific and clinical importance. The ethnopharmacological wisdom preserved in Siddha medicine may contribute significantly to the development of microbiome-based therapeutics, functional foods, and integrative healthcare interventions aimed at improving global health outcomes [17].

The aim of this review is to comprehensively evaluate the role of Siddha herbal medicines in the modulation of gut microbiota and to examine their potential contributions to gastrointestinal and systemic health. The review seeks to explore the interactions between Siddha medicinal plants, their bioactive phytochemical constituents, and the intestinal microbial ecosystem, with particular emphasis on their prebiotic, antimicrobial, anti-inflammatory, antioxidant, and immunomodulatory properties. Furthermore, it aims to assess the scientific evidence supporting the use of Siddha formulations in maintaining microbial balance, preventing gut dysbiosis, enhancing host immunity, and managing microbiota-associated disorders. By integrating traditional Siddha knowledge with contemporary microbiome research, this review intends to highlight the therapeutic significance of Siddha medicine as a promising approach for microbiome-centered healthcare and the development of novel integrative treatment strategies.

Materials and Methods

This review article was conducted through a comprehensive literature-based approach to evaluate the role of Siddha herbal medicines in gut microbial modulation and their potential applications in modern healthcare. Relevant scientific literature was collected from electronic databases including **PubMed, Scopus, Web of Science, Google Scholar, ScienceDirect, and AYUSH Research Portal**. Additional information was obtained from classical Siddha texts, Siddha Pharmacopoeia publications, and government reports related to traditional medicine and medicinal plants. The literature search included studies published in English from 2000 to 2025 using combinations of keywords such as *Siddha medicine*, *gut microbiota*, *gut microbiome*, *microbial modulation*, *medicinal plants*, *prebiotics*, *probiotics*, *phytochemicals*, *intestinal health*, *dysbiosis*, *traditional medicine*, *immunomodulation*, and *microbiome-based therapy*.

The inclusion criteria comprised original research articles, review articles, experimental studies, clinical studies, ethnopharmacological investigations, and microbiological studies that evaluated the effects of Siddha medicinal plants or formulations on gut microbial composition, intestinal health, immune function, or related physiological processes. Studies focusing on the phytochemical constituents of Siddha herbs and their influence on microbial populations were also included. Publications lacking sufficient scientific evidence, duplicate records, conference abstracts without full text, and studies unrelated to gut microbiota or Siddha medicine were excluded from the review.

Data from the selected studies were systematically extracted and categorized according to the medicinal plants investigated, major bioactive compounds identified, mechanisms of microbial modulation, antimicrobial activity, prebiotic effects, immunomodulatory properties, and therapeutic applications. The collected information was critically analyzed and synthesized to identify common findings, emerging trends, and potential mechanisms through which Siddha herbal medicines influence gut microbial ecology. The findings were then organized into thematic sections to provide a comprehensive overview of the current scientific evidence regarding the role of Siddha medicine in gut microbiome regulation and its relevance to integrative healthcare approaches.

Results

The literature reviewed demonstrated that Siddha herbal medicines possess considerable potential to modulate gut microbial composition, enhance gastrointestinal health, and contribute to systemic well-being. Multiple studies reported that medicinal plants commonly used in Siddha medicine contain bioactive phytochemicals capable of influencing the diversity and functionality of intestinal microbiota. These phytochemicals serve as substrates for beneficial microorganisms, suppress pathogenic microbes, and promote the production of microbial metabolites that support intestinal homeostasis [6–10].

Several Siddha medicinal plants, including *Phyllanthus emblica*, *Terminalia chebula*, *Terminalia bellirica*, *Curcuma longa*, *Ocimum tenuiflorum*, *Tinospora cordifolia*, and *Azadirachta indica*, were found to possess prebiotic-like properties that encourage the growth of beneficial bacterial populations such as *Lactobacillus* and *Bifidobacterium* species. These microorganisms play a crucial role in maintaining gut barrier integrity, nutrient metabolism, and immune regulation. Simultaneously, many Siddha herbs exhibited antimicrobial activity against pathogenic bacteria, thereby helping to restore microbial balance within the gastrointestinal tract.

The reviewed studies also revealed that polyphenols, flavonoids, tannins, terpenoids, alkaloids, and polysaccharides present in Siddha medicinal plants are key contributors to microbiome modulation. These compounds undergo biotransformation by gut microorganisms, resulting in the production of bioactive metabolites and short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate. SCFAs are known to improve intestinal epithelial function, regulate inflammatory responses, and enhance immune homeostasis.

Furthermore, Siddha herbal medicines demonstrated significant anti-inflammatory and antioxidant activities that contribute to a favorable intestinal environment for beneficial microbiota. Several studies reported reductions in oxidative stress markers and inflammatory cytokines following administration of herbal extracts. These effects were associated with improvements in gastrointestinal disorders, metabolic health, and immune function.

The findings also suggested that Siddha herbal medicines may help address gut dysbiosis induced by poor diet, infections, antibiotic use, and chronic diseases. Through selective microbial modulation and immune enhancement, Siddha formulations may offer a complementary strategy for maintaining gut microbial balance and preventing microbiota-associated disorders.

Table 1. Siddha Medicinal Plants and Their Effects on Gut Microbiota

Medicinal Plant	**Major Bioactive Compounds**	**Effect on Gut Microbiota**	**Health Benefits**
Phyllanthus emblica (Amla)	Tannins, Polyphenols, Vitamin C	Promotes beneficial bacterial growth	Antioxidant, digestive support
Terminalia chebula (Kadukkai)	Tannins, Gallic acid	Enhances microbial diversity	Laxative, gut cleansing
Terminalia bellirica (Thandrikkai)	Phenolics, Flavonoids	Supports probiotic bacteria	Digestive and immune support
Curcuma longa (Turmeric)	Curcumin	Increases beneficial bacteria and reduces pathogens	Anti-inflammatory
Ocimum tenuiflorum (Tulsi)	Eugenol, Flavonoids	Modulates microbial balance	Immunomodulatory
Tinospora cordifolia (Seenthil)	Alkaloids, Glycosides	Supports gut immune function	Adaptogenic activity
Azadirachta indica (Neem)	Azadirachtin, Limonoids	Suppresses harmful bacteria	Antimicrobial activity

Table 2. Major Phytochemicals Responsible for Gut Microbial Modulation

Phytochemical Class	**Common Siddha Sources**	**Role in Gut Microbiota**
Polyphenols	Amla, Kadukkai, Turmeric	Promote beneficial microbes
Flavonoids	Tulsi, Neem	Increase microbial diversity
Tannins	Triphala components	Inhibit pathogenic bacteria
Alkaloids	Seenthil	Regulate microbial metabolism
Terpenoids	Neem, Tulsi	Antimicrobial action
Polysaccharides	Herbal decoctions	Prebiotic effects
Phenolic acids	Amla, Turmeric	Support SCFA production

Table 3. Beneficial Gut Microorganisms Influenced by Siddha Herbal Medicines

Microorganism	**Function in Gut Health**	**Influence of Siddha Herbs**
Lactobacillus spp.	Maintains intestinal barrier	Increased abundance
Bifidobacterium spp.	Fermentation and SCFA production	Growth stimulation
Faecalibacterium prausnitzii	Anti-inflammatory activity	Enhanced activity
Akkermansia muciniphila	Mucosal integrity	Improved colonization
Roseburia spp.	Butyrate production	Increased abundance

Table 4. Mechanisms of Gut Microbial Modulation by Siddha Herbal Medicines

Mechanism	**Action**	**Outcome**
Prebiotic activity	Provides substrates for beneficial bacteria	Increased probiotic growth
Antimicrobial activity	Suppresses pathogenic microorganisms	Reduced dysbiosis
Anti-inflammatory activity	Decreases intestinal inflammation	Improved gut barrier function
Antioxidant activity	Reduces oxidative stress	Supports microbial survival
Immune modulation	Enhances mucosal immunity	Better host defense
SCFA stimulation	Promotes microbial fermentation	Improved gut metabolism

Table 5. Comparison Between Siddha Herbal Medicines and Conventional Gut Microbiota Interventions

Parameter	**Siddha Herbal Medicines**	**Conventional Probiotics/Antibiotics**
Source	Natural medicinal plants	Laboratory-produced organisms or drugs
Mechanism	Multi-target microbial modulation	Specific microbial supplementation or elimination
Impact on Microbiota	Promotes overall microbial balance	Often targets specific organisms
Antimicrobial Resistance Risk	Low	May contribute to resistance (antibiotics)
Additional Benefits	Antioxidant, anti-inflammatory, immunomodulatory	Limited additional effects
Long-Term Use	Generally suitable under supervision	Variable depending on intervention
Cost Effectiveness	Relatively affordable	Often more expensive

Table 6. Therapeutic Applications of Siddha-Mediated Gut Microbial Modulation

Health Condition	**Potential Role of Siddha Herbal Medicines**	**Mechanism Involved**
Gastrointestinal disorders	Restoration of microbial balance	Prebiotic and antimicrobial effects
Inflammatory bowel diseases	Reduction of inflammation	Immunomodulation and SCFA production
Obesity and metabolic syndrome	Regulation of metabolism	Microbial diversity enhancement
Diabetes mellitus	Improved glucose metabolism	Gut microbiota modulation
Immune dysfunction	Enhancement of host immunity	Stimulation of beneficial microbes
Antibiotic-associated dysbiosis	Recolonization of beneficial bacteria	Prebiotic support
General wellness	Maintenance of gut homeostasis	Combined microbiome regulation

Overall, the reviewed evidence indicates that Siddha herbal medicines significantly influence gut microbial ecology through prebiotic, antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory mechanisms. The ability of Siddha medicinal plants to enhance beneficial microbial populations while suppressing pathogenic organisms suggests their potential as natural microbiome-modulating agents. These findings support the growing integration of Siddha medicine into microbiome-centered healthcare strategies and highlight its promise for the prevention and management of gastrointestinal and systemic diseases.

Discussion

The findings of the present review indicate that Siddha herbal medicines possess significant potential to modulate the gut microbiota and contribute to gastrointestinal as well as systemic health. The growing understanding of the gut microbiome as a central regulator of metabolism, immunity, and disease susceptibility has renewed scientific interest in traditional medical systems that emphasize digestive health and microbial balance. Siddha medicine, with its extensive use of medicinal plants and polyherbal formulations, offers a unique therapeutic approach that aligns closely with modern microbiome-centered healthcare concepts [1].

The reviewed studies demonstrated that several Siddha medicinal plants, including *Phyllanthus emblica*, *Terminalia chebula*, *Terminalia bellirica*, *Curcuma longa*, *Ocimum tenuiflorum*, and *Tinospora cordifolia*, contain diverse phytochemicals capable of influencing gut microbial composition. These findings are consistent with previous reports indicating that dietary polyphenols and plant-derived bioactive compounds can selectively promote the growth of beneficial microorganisms such as *Lactobacillus* and *Bifidobacterium* while suppressing opportunistic pathogens [2]. Such selective microbial regulation is important because maintenance of microbial diversity is considered a key determinant of intestinal and systemic health [3].

One of the major observations of this review is the prebiotic-like activity exhibited by many Siddha medicinal plants. Polyphenols, tannins, polysaccharides, and flavonoids present in these herbs act as substrates for microbial fermentation, leading to the production of short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate [4]. SCFAs play a crucial role in maintaining intestinal epithelial integrity, regulating inflammatory responses, enhancing mucosal immunity, and providing energy to colonocytes [5]. Therefore, the ability of Siddha herbal medicines to stimulate SCFA production may represent an important mechanism underlying their therapeutic effects.

The antimicrobial properties of Siddha herbs further contribute to microbial homeostasis within the gastrointestinal tract. Unlike conventional antibiotics, which often cause broad-spectrum disruption of gut microbiota and contribute to dysbiosis, many Siddha medicinal plants demonstrate selective antimicrobial activity against pathogenic microorganisms while preserving beneficial microbial populations [6]. This characteristic may be particularly valuable in the current era of increasing antimicrobial resistance, where alternative approaches for infection control and microbiome preservation are urgently needed [7].

Another significant finding is the anti-inflammatory and antioxidant potential of Siddha herbal medicines. Chronic intestinal inflammation and oxidative stress are recognized contributors to gut dysbiosis and the development of several gastrointestinal disorders, including inflammatory bowel disease, irritable bowel syndrome, and colorectal cancer [8]. The presence of bioactive compounds such as curcumin, gallic acid, ellagic acid, quercetin, and eugenol in Siddha medicinal plants has been shown to reduce oxidative stress and modulate inflammatory signaling pathways [9]. By creating a favorable intestinal environment, these compounds support the survival and proliferation of beneficial microbiota while reducing conditions that favor pathogenic colonization.

The immunomodulatory properties of Siddha formulations also appear to play an important role in gut microbial regulation. Emerging evidence suggests that gut microbiota and the immune system maintain a bidirectional relationship, with microbial metabolites influencing immune responses and immune factors shaping microbial communities [10]. Several Siddha herbs, including *Tinospora cordifolia* and *Ocimum tenuiflorum*, have demonstrated the ability to enhance immune function and regulate inflammatory mediators, thereby supporting the maintenance of microbial equilibrium and intestinal health [11].

The therapeutic implications of gut microbial modulation extend beyond gastrointestinal disorders. Recent studies have highlighted the involvement of gut microbiota in metabolic diseases, obesity, diabetes mellitus, cardiovascular diseases, neurodegenerative disorders, and mental health conditions through the gut-brain axis [12]. The ability of Siddha herbal medicines to restore microbial balance may therefore have far-reaching health benefits. Traditional Siddha formulations designed to improve digestion, detoxification, and overall vitality may exert some of their clinical effects through microbiome-mediated mechanisms that are only now being understood through modern scientific research [13].

Despite the promising evidence, several limitations remain. Most available studies have focused on individual medicinal plants or experimental models, while clinical investigations evaluating the effects of Siddha formulations on human gut microbiota remain limited [14]. Variations in herbal

composition, dosage, preparation methods, and study design also make direct comparisons difficult. Furthermore, the molecular mechanisms underlying microbiome modulation by Siddha medicines require further investigation using advanced technologies such as metagenomics, metabolomics, transcriptomics, and microbial sequencing [15].

Future research should focus on well-designed clinical trials to establish the efficacy and safety of Siddha herbal formulations in microbiome modulation. Standardization of herbal preparations, identification of active compounds, and exploration of synergistic interactions between phytochemicals and gut microorganisms will enhance the scientific understanding of Siddha medicine and facilitate its integration into evidence-based healthcare systems [16].

Overall, the findings of this review suggest that Siddha herbal medicines represent a promising natural approach for maintaining gut microbial balance, enhancing gastrointestinal health, and supporting systemic physiological functions. By combining traditional knowledge with modern microbiome science, Siddha medicine may contribute significantly to the development of innovative therapeutic strategies for the prevention and management of microbiota-associated diseases [17].

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