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ROLE OF TRADITIONAL INDIAN MEDICINE AND INTERVENTIONS IN DYSBIOSIS MANAGEMENT AND PERSONALIZED GUT MICROBIOME INTERPLAY: A REVIEW

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ABSTRACT

The human gut microbiota, an intricate community of trillions of microorganisms, is essential to human health, influencing digestion, immunity, and neurochemistry. Dysbiosis, or imbalances within this ecosystem, has been linked to conditions such as obesity, diabetes, inflammatory diseases, and mental health disorders. Ayurveda medicine offers an array of therapies aimed at maintaining gut health through personalized dietary guidelines, herbal formulations, and detoxification techniques. This review evaluates the mechanisms by which specific Ayurvedic drugs and interventions particularly Triphala, Guduchi, Ashwagandha and Vaman (therapeutic emesis), Virechana (therapeutic purgation) and Basti karma (therapeutic enema) therapy modulate gut microbiota composition and functionality, potentially offering new therapeutic pathways for gut-related and metabolic disorders. The review synthesizes Ayurvedic principles with modern microbiome research, proposing that Ayurvedic practices could play a vital role in microbiome management. These practices collectively highlight Ayurveda's potential to address dysbiosis and its associated health conditions by targeting specific aspects of microbial diversity and functionality. By integrating ancient Ayurvedic wisdom with contemporary scientific findings, this review explores Ayurveda's contribution to personalized healthcare, emphasizing its potential to support metabolic, immune, and inflammatory health. This integrative approach offers a promising avenue for developing microbiome-targeted therapies that address preventive and therapeutic needs, aligning with the growing interest in personalized and holistic strategies.

Keywords: Ayurveda, Dysbiosis, Gut-microbiome, Triphala, Herbal, Guduchi, Turmeric

INTRODUCTION

The gut microbiota, a multifaceted and intricate community, is fundamental to maintaining human health influencing digestion, immunity, and overall physiology. Ayurvedic herbs, which are increasingly recognized for their therapeutic potential in gut health, may offer alternative or complementary therapies through their anti-inflammatory, antioxidant, and microbiota-modulating properties. This section provides a scientific overview of several prominent Ayurvedic herbs—*Triphala, Ashwagandha (Withania somnifera), Guduchi (Tinospora cordifolia), Neem (Azadirachta indica), Haridra* (*Curcuma longa*)*, Yashtimadhu* (*Glycyrrhiza glabra*)*,* and *Mishreya* (*Foeniculum vulgare*)—and their potential effects on gut microbiota.

The human gut microbiota a, consisting of trillions of microorganisms within a highly intricate ecosystem, is gaining recognition as a cornerstone of human physiology, with influences spanning digestion, immune response, and neurochemical pathways[1]. Dysbiosis, or disruption in microbial balance, has been associated with numerous health conditions, including metabolic syndrome, inflammatory bowel diseases, obesity, and mental health disorders[2]. Modern medicine has made strides in understanding how diet, pharmacology, and lifestyle can modulate gut microbiota, yet ancient Ayurvedic practices have long emphasized the gut's role in holistic health, viewing it as central to physical and mental well-being[3]. Ayurveda, a traditional Indian system of medicine, provides a framework for balancing "*Agni*" (digestive fire) and managing "*Ama*" (toxins) to maintain a harmonious gut environment. According to Ayurvedic principles, a weakened *Agni* contributes to *Ama* buildup, disrupting the gut and leading to disease[4]. Ayurvedic therapies, which include dietary regimens, herbal formulations, and detoxification practices, aim to restore balance among the *Doshas (Vata, Pitta,* and *Kapha*), thereby enhancing gut function and potentially improving microbial health[5]. This review synthesizes contemporary microbiome science with Ayurvedic insights, focusing on the impact of Ayurvedic drugs such as well as *Panchakarma* therapies, on gut microbiota modulation. Traditional Ayurvedic concepts such as "*Shashthi Pittadhara Kala*" (a physiological area associated with nutrient absorption and metabolism) are discussed in light of recent microbiome findings, supporting an integrative model that aligns with personalized healthcare approaches[6]. By bridging these perspectives, this review explores novel, evidence-based strategies for dysbiosis management and overall gut health enhancement through Ayurvedic practices. This integrative approach offers a promising avenue for developing microbiome-targeted therapies that combine the depth of traditional knowledge with scientific advancements, thereby potentially addressing a range of metabolic and inflammatory diseases in a personalized and holistic manner. This article follows a systematic review methodology, searching through databases such as PubMed, Scopus, and Google Scholar. Keywords used include "Ayurveda," "gut microbiota," "herbal medicine," "dietary interventions," and "probiotics in Ayurveda." Studies were selected based on their scientific rigor, relevance to Ayurvedic practices, and demonstrated impact on gut microbiota.

TRADITIONAL AYURVEDIC INTERVENTIONS AND THEIR MECHANISMS

Dietary Guidelines and Their Impact on Gut Health

Ayurveda, a traditional Indian system of medicine, has long recognized the central role of diet in maintaining overall health, particularly gut health. Its dietary guidelines are highly individualized, with recommendations tailored according to each person's *Dosha*—the unique combination of *Vata, Pitta*, and *Kapha* energies that defines a person's constitution, or *Prakriti*. According to Ayurvedic principles, foods have specific qualities that can either enhance or disrupt the balance of these *Doshas*, thus influencing gut function and health.

For instance, individuals with a predominance of *Vata Dosha*, which is associated with qualities like dryness and mobility, are encouraged to consume warming and grounding foods such as ginger (*Zingiber officinale*) and cumin (*Cuminum cyminum*). Ginger contains active compounds like gingerols, and cumin is rich in thymoquinone, both of which have demonstrated prebiotic properties in studies, supporting the growth of beneficial gut bacteria such as *Lactobacillus* and *Bifidobacterium* while suppressing pathogenic strains. This helps to maintain a balanced gut microbiota and reduces the risk of dysbiosis-related disorders, including irritable bowel syndrome and inflammatory conditions[7].

For *Pitta* individuals, who tend toward heat and acidity, cooling and anti-inflammatory foods are recommended, including fennel (*Foeniculum vulgare*) and aloe vera (*Aloe barbadensis*). Fennel, known for its soothing effect on the digestive tract, contains volatile oils that can alleviate gut inflammation, while aloe vera has demonstrated anti-inflammatory and antimicrobial effects, making it beneficial for gut health. These bioactive compounds may support a balanced gut environment by reducing inflammatory pathways and promoting beneficial bacterial growth[8].

Kapha individuals, associated with qualities of heaviness and stagnation, benefit from bitter and detoxifying foods, such as turmeric (*Curcuma longa*) and bitter gourd (*Momordica charantia*). Turmeric, rich in curcuminoids, is well-documented for its anti-inflammatory and antioxidant properties. These compounds help modulate the gut microbiota, stimulating the growth of beneficial bacteria while inhibiting harmful species. Additionally, bitter gourd has shown promise in modulating lipid metabolism and supporting microbiota composition, especially in cases of obesity and metabolic syndrome[9].

Ayurvedic dietary principles also emphasize the consumption of fresh, seasonal, and minimally processed foods. The approach advocates for mindful eating practices, including the consumption of warm, cooked foods rather than raw or processed options, and avoiding incompatible food combinations (e.g., fruit with dairy). Such practices, Ayurveda asserts, enhance digestive *Agni* (digestive fire), ensuring that food is effectively metabolized and absorbed without generating toxins (*Ama*). Emerging evidence supports this approach, as it aligns with modern understandings of digestion, which favours warm and cooked foods for optimal microbial diversity and functionality in the gut[10]. Probiotic-rich foods are also integral to Ayurvedic diets, particularly curd and buttermilk, which contain live beneficial bacteria that can help restore and maintain gut microbiota balance. Probiotics are increasingly recognized in modern microbiome science for their role in enhancing gut health, reducing inflammation, and preventing gastrointestinal disorders[11]. By recommending probiotic-rich foods, Ayurveda anticipates modern practices in microbiome science, which emphasizes the importance of beneficial microbes in maintaining gut integrity and supporting immune function. Ayurveda's dietary recommendations, which focus on balancing *Doshas*, support the maintenance of a healthy gut microbiota. The bioactive compounds in these foods work synergistically to promote beneficial microbial communities, reduce pathogenic strains, and protect against dysbiosis-related diseases. These insights provide a valuable, integrative framework for microbiome-centred nutrition and personalized health strategies.

Herbal Formulations and Microbiota Modulation

Ayurvedic herbal formulations have been recognized for their multifaceted therapeutic effects on human health, particularly in promoting digestive function and maintaining gut microbiota balance. Among these, *Triphala*[12] and *Ashwagandha (Withania somnifera*) stand out for their microbiota-modulating properties. Their bioactive compounds interact with the gut environment to foster beneficial bacterial growth, reduce inflammation, and strengthen the gut barrier, thus potentially aiding in the prevention and management of various metabolic and inflammatory conditions. The role of herbal formulations in promoting gut health is increasingly recognized, particularly through their prebiotic effects that support beneficial microbial populations. Among these, *Triphala* and *Guduchi* are two widely studied Ayurvedic herbal formulations, each showing promising potential in balancing gut microbiota composition and enhancing metabolic and immune functions.

Triphala is a polyherbal formulation composed of three fruits: *Emblica officinalis (Amla*), *Terminalia bellirica (Vibhitaki),* and *Terminalia chebula (Haritaki).* This blend is rich in polyphenols, such as tannins, flavonoids, and other antioxidant compounds, which play a crucial role in modulating gut microbiota. Studies have shown that the polyphenols in *Triphala* serve as substrates for gut microbiota, particularly for beneficial bacteria such as *Bifidobacterium* and *Lactobacillus species*[13]. These polyphenols undergo microbial fermentation, producing short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate. SCFAs are vital for colon health, as they nourish colonocytes, reduce inflammation, and help maintain gut barrier integrity[14]. The SCFAs generated from *Triphala's* fermentation has also been shown to exhibit systemic anti-inflammatory effects, potentially reducing the risk of gut-related inflammatory diseases and metabolic disorders[15]. In addition to its prebiotic effects, *Triphala* has demonstrated antimicrobial properties against certain pathogenic strains, which further supports a balanced gut environment. For example, studies suggest that *Triphala* reduces the relative abundance of harmful bacteria, including pathogenic Clostridium and *Escherichia coli*, which are often implicated in dysbiosis and gut inflammation[16]. By fostering beneficial microbes and suppressing pathogenic species, *Triphala* contributes to an overall healthier gut microbiome, which is essential for immune modulation and digestive health. Several studies have highlighted *Triphala's* ability to decrease the ratio of Firmicutes to Bacteroidetes, a microbial imbalance commonly linked with obesity and metabolic disorders[17]. This shift in microbial composition is significant, as a higher Firmicutes: Bacteroidetes ratio is often associated with increased energy harvest from the diet, leading to adiposity. By rebalancing this ratio, *Triphala* helps regulate metabolic pathways, which may contribute to weight management and reduce inflammatory markers associated with obesity. Furthermore, preliminary clinical trials have demonstrated that *Triphala* intake may lower body weight, fat mass, and inflammation, suggesting its therapeutic potential in addressing metabolic syndrome and other gut-related disorders[18]. The immunomodulatory effects of *Triphala* further enhance its prebiotic benefits, supporting both innate and adaptive immunity through the optimization of gut microbiota composition. In vitro studies with *Lactiplantibacillus plantarum*, *Lactobacillus fermentum*, and *Bifidobacteria infantis* have demonstrated that polyphenol-rich *Triphala* promotes beneficial bacteria in batch culture and simulated gut models[19], while hindering pathogens study examining *Triphala* combined with VSL#3, a medical probiotic, aims to assess changes in stool microbiome, inflammatory markers, and gastrointestinal symptoms after 8 weeks of supplementation[20]. The poly-compounds in *Triphala* support gut health by acting as substrates for beneficial microbes, thereby enhancing microbial diversity and promoting a stable microbial environment.

Ashwagandha (*Withania somnifera*), another extensively studied Ayurvedic herb, has shown promising effects in modulating the gut microbiota and promoting gut barrier function. Known primarily for its adaptogenic and immunomodulatory properties[21], *Ashwagandha* contains bioactive compounds such as withanolides, which have anti-inflammatory and antioxidative effects[22]. Recent research in animal models indicates that *Ashwagandha* exhibits prebiotic-like effects by enhancing the growth of beneficial gut bacteria. This herb has been observed to increase microbial diversity, particularly fostering bacteria associated with improved gut health, such as *Akkermansia muciniphila*, which plays a key role in maintaining gut mucosal integrity and reducing inflammation[23]. Furthermore, *Ashwagandha's* impact on gut-barrier integrity is noteworthy. It has been shown to strengthen the gut barrier by promoting the expression of tight junction proteins, which help to prevent the translocation of endotoxins and other harmful substances from the gut lumen into systemic circulation. This barrier-protective effect is essential in mitigating the "leaky gut" phenomenon, which is often linked to chronic inflammation and various metabolic diseases[24]. Inflammatory and metabolic benefits associated with *Ashwagandha's* gut-modulating effects suggest its potential as an adjunct treatment for conditions such as irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD), as well as for general immune health[25]. Their ability to promote beneficial bacteria, inhibit harmful species, and support gut integrity provides a compelling basis for further clinical research. Integrating these herbal formulations into modern therapeutic strategies for managing gut health and systemic inflammatory conditions may hold considerable promise in the field of personalized and integrative medicine. Known for its adaptogenic effects, *Ashwagandha* supports gut-brain axis modulation by mitigating stress-related dysbiosis[26]. Chronic stress, linked to cortisol elevation, is associated with microbial imbalance and reduced gut microbial diversity. *Ashwagandha's* bioactive compounds, particularly withanolides, have anti-inflammatory properties that promote a balanced gut microbiota by reducing cortisol levels and enhancing the stability of beneficial bacterial populations. Studies suggest that *Ashwagandha* supplementation in stressed individuals improves microbial diversity and increases beneficial bacteria typically depleted under stress[27].

Guduchi (*Tinospora cordifolia): Guduchi* or *Giloy*, is celebrated in Ayurvedic medicine for its wide-ranging therapeutic properties, including anti-inflammatory, antioxidant, and immunomodulatory effects[28]. *Guduchi* contains a variety of bioactive compounds, such as alkaloids, glycosides, and diterpenoid lactones, which contribute to its medicinal properties[29]. Recent research on *Guduchi* underscores its role in supporting gut health by enhancing microbial diversity, specifically by promoting beneficial bacterial strains and inhibiting pathogenic microbes. *Guduchi's* impact on gut health is further evident in its immune-supporting functions. Studies in both animal and human models have shown that *Guduchi* can enhance immune responses by stimulating both humoral and cell-mediated immunity[30]. This immunomodulatory action is attributed to its ability to modulate gut microbiota composition, which in turn, plays a crucial role in immune regulation. *Guduchi* has been associated with reductions in liver enzyme levels and decreased plasma uric acid, suggesting its role in mitigating gut inflammation and supporting liver health[31]. Furthermore, *Guduchi's* antimicrobial properties help reduce gut pathogens, thereby addressing dysbiosis-related conditions such as infections and chronic inflammation, which can disrupt gut health and compromise immunity. The prebiotic and antimicrobial characteristics of *Guduchi* make it a valuable adjunct in managing gut-related infections and chronic inflammatory diseases[32]. By modulating the gut microbiome to enhance beneficial bacteria and suppress pathogenic strains, *Guduchi* provides a dual approach to maintaining gut and systemic health. Additionally, its role in promoting immune resilience suggests potential applications in the prevention and management of immune-related gastrointestinal disorders[33]. Animal studies indicate that *Guduchi* supplementation can decrease gastrointestinal inflammation, promoting an improved microbial profile that supports immune function[34].

***Haridra*/Turmeric** (*Curcuma longa*)- Curcumin, the active compound in turmeric, is well-documented for its anti-inflammatory and antioxidant properties, beneficial for modulating gut microbiota[35]. Curcumin supplementation has been shown to selectively promote beneficial bacteria like Lactobacillus and Bifidobacterium, while inhibiting pathogenic species [36]. This selective antimicrobial action, combined with anti-inflammatory effects, makes turmeric potentially effective in managing inflammatory bowel disease (IBD) and other inflammation-driven gut disorders[37].

Neem *(Azadirachta indica)- Neem's* antimicrobial properties are particularly effective against pathogenic gut bacteria, such as *Escherichia coli*, while sparing beneficial microbes[38]. Animal studies demonstrate *Neem's* selective action in suppressing harmful bacteria, helping to balance the microbiota in cases of dysbiosis. Its anti-inflammatory properties further aid in maintaining a favourable gut environment, reducing inflammation and enhancing conditions for beneficial microbial growth[39].

***Madhuiyasthi*/Liquorice** (*Glycyrrhiza glabra*)- Liquorice root is known for its soothing and mucosal protective effects, which benefit gut health by reducing inflammation and supporting microbial balance[40]. The active compounds in liquorice promote the growth of beneficial bacteria and protect the gut lining, creating a favourable environment for healthy microbial colonization. Studies indicate that liquorice extract supplementation may alleviate gut inflammation, aiding in conditions like ulcers and IBD[41].

***Shatpuspa*/Fennel** (*Foeniculum vulgare*)- Traditionally used for its digestive benefits, Fennel positively influences gut microbiota by reducing bloating, gas, and other dysbiosis-related symptoms. Fennel contains compounds that serve as prebiotics, promoting the growth of beneficial bacteria[42]. Research indicates that fennel supplementation can enhance microbial diversity and support a healthy balance of gut flora, making it beneficial in managing symptoms of digestive discomfort and dysbiosis.[43] It also protect gastric damage[44] and possesses anti-colitic property[45].

***Shigru (Moringa oleifera*)** -It shows promise in modulating gut microbiota, with particular potential in addressing anaemia due to its high nutritional content, including iron and other micronutrients[46]. Studies have shown that *Moringa oleifera* leaves contain bioactive compounds, including polysaccharides and flavonoids, which foster beneficial gut bacteria such as

Bifidobacteria and Lactobacillus[47]. These bacteria play a critical role in maintaining a balanced gut microbiome and supporting nutrient absorption, including essential minerals like iron.[48] Additionally, *Moringa's* polysaccharides have been found to improve the gut microbiota composition in obese models by increasing beneficial bacteria and reducing inflammation-associated species, suggesting their prebiotic effects. *Moringa* has been directly linked to haematological improvements in various models. In animal studies, *Moringa* oleifera leaf extracts administered to rats induced significant increases in red blood cell count, haemoglobin levels, and overall blood iron content, supporting its potential as an anti-anaemia nutraceutical. *Moringa's* synergy with probiotics enhances its therapeutic impact on anaemia. When combined with *Enterococcus durans* in animal studies, *Moringa* leaf extract improved haemoglobin levels significantly more than either alone, suggesting a compounded benefit to gut health and iron absorption through probiotic interaction[49]. *Moringa oleifera* impacts gut microbiota positively by enhancing beneficial bacterial growth, which can support improved nutrient absorption, particularly iron. Its high iron content and potential to work synergistically with probiotics make it a valuable candidate for anaemia management[50].

DETOXIFICATION (*PANCHAKARMA*) AND ITS ROLE IN MICROBIAL BALANCE

Detoxification is a core element of Ayurvedic medicine, focusing on the elimination of accumulated toxins, or "*Ama*," which are believed to impair the body's physiological functions and disrupt the balance of *Doshas (Vata, Pitta*, and *Kapha*)[51]. *Panchakarma*, the Ayurvedic system of detoxification, involves five major therapeutic procedures: *Vamana* (therapeutic emesis*), Virechana* (purgation therapy*), Basti* (medicated enema*), Nasya* (nasal administration of herbal oils*),* and *Raktamokshana* (bloodletting*)*[52]. These procedures are intended to purify the body by directly removing toxins from key systems, thereby restoring homeostasis and enhancing the efficacy of therapeutic interventions. One of the critical objectives of *Panchakarma* is to re-establish a balanced microbial environment in the gut, which is increasingly recognized as essential for both metabolic and immune health. *Panchakarma*, particularly therapies like *Virechana* and *Basti*, has been associated with significant modulations of gut microbiota composition, enhancing microbial diversity and reducing pathogenic species[53]. *Virechana*, a purgative therapy, is hypothesized to alter gut microbial balance by physically clearing the intestines of harmful bacteria, thereby facilitating the growth of beneficial bacteria such as Lactobacillus and Bifidobacterium[54]. This therapy is carried out in carefully sequenced stages—*Poorva Karma* (preparatory phase), *Pradhana Karma* (main procedure), and *Paschat Karma* (post-procedure phase)—which together optimize its detoxifying effects. In the preparatory phase (*Poorva Karma*), digestive aids (*Deepana Pachana*) are administered to improve digestion, followed by internal oleation (*Snehapana*) and external oleation (*Bahya Snehan*) combined with sudation therapy (*Swedana*), both aimed at loosening toxins for easier elimination. The main procedure (*Pradhan Karma*) involves administering herbal purgatives to expel toxins effectively. The post-procedure phase (*Paschat Karma*), involves a dietary regimen (*Samsarjana Krama*) tailored to reintroduce foods gradually and maintain digestive equilibrium, supporting the replenishment of beneficial gut flora[55].

Vaman Karma: *Vaman Karma* has gained scientific interest for its potential to influence the gut microbiota, the complex ecosystem of trillions of microorganisms crucial to immune function, digestion, and overall health. The process of *Vaman Karma* involves the oral intake of emetic substances, often herbal formulations, which stimulate gastric contractions and vomiting[56]. By inducing the expulsion of stomach contents, *Vaman Karma* may help reduce the load of pathogenic or opportunistic microbes, particularly those that proliferate in dysbiosis conditions. This clearance could prevent bacterial overgrowth and, by extension, reduce toxins and inflammatory mediators produced by pathogenic bacteria. Through the detoxification action of *Vaman Karma*, there may be an indirect effect on microbial homeostasis by creating a cleaner, less congested digestive environment. This could enable beneficial bacteria to thrive without competition from overgrown pathogenic species. *Vaman Karma*'s preparatory phase involves consuming fat-based substances, such as ghee, to lubricate and stimulate the digestive tract. These substances may support a beneficial microbiota by stimulating bile production and digestive enzymes, which aid in creating an environment less conducive to pathogenic growth and more supportive of beneficial bacteria, such as *Lactobacillus* and *Bifidobacterium*[57]. Ayurvedic literature suggests *Vaman Karma* is beneficial for managing *Kapha*-related disorders such as chronic indigestion, nausea, and respiratory conditions. These conditions often correlate with microbial imbalances that lead to inflammation. The gut-cleansing effects of *Vaman Karma* could reduce gut inflammation and restore microbial balance, benefiting GI tract health. Dysbiosis has been linked to metabolic diseases like obesity and type 2 diabetes. Through detoxification, *Vaman Karma* may help manage obesity by reducing endotoxins that influence insulin resistance and inflammation[58]. Although direct studies on *Vaman Karma's* effects on microbiota in metabolic health are limited, related *Panchakarma* practices show promise for gut microbiota modulation in metabolic conditions.

Virechana Karma, an ayurvedic therapeutic purgation, has demonstrated potential in modulating gut microbiota, particularly in addressing dysbiosis-related conditions. *Virechana* is one of the five main detoxification methods in *Panchakarma*, traditionally aimed at eliminating toxins (*Ama*) and balancing the "*Pitta*" *Dosha* in the gastrointestinal tract. Emerging research has explored the biological impact of *Virechana* on gut flora, suggesting its relevance for modern health concerns, including obesity and metabolic disorders[59]. In a recent clinical study, *Virechana* therapy was applied to individuals with obesity, examining changes in the gut microbiota. Results indicated a significant reduction in the population of *Escherichia coli*, a facultative anaerobic bacterium often associated with dysbiosis in obese individuals[60]. The purgative nature of *Virechana* appears to reduce colonization by aerobic bacteria, fostering an environment more supportive of beneficial anaerobes that can enhance metabolic health. The microbiota shifts following-*Virechana* may also impact short-chain fatty acid (SCFA) production. SCFAs like butyrate and acetate, produced by beneficial gut bacteria, are known to support intestinal integrity and reduce inflammation. *Virechana* could indirectly support SCFA-producing bacteria by reducing competing pathogenic bacteria, thereby improving gut health and metabolic function[61]. While these findings are promising, rigorous and large-scale studies are needed to further validate *Virechana's* role in gut microbiome modulation and its potential applications in treating gut-related diseases and metabolic disorders. Standardized protocols and consistent measures of gut microbiota before and after Virechana would enhance the credibility of these effects within integrative healthcare settings. Modern studies validate the therapeutic effects of *Virechana*, indicating that it induces beneficial shifts in gut microbiota. Research suggests that *Virechana* may reduce the abundance of pathogenic bacteria such as *Escherichia coli*, which is often elevated in dysbiosis states like obesity. A clinical study on patients with moderate digestive sensitivity (*Madhyama Koshtha*), involving stool analyses before and after *Virechana*, found reductions in *E. coli* colonization, highlighting *Virechana's* potential in managing obesity-related dysbiosis[60]. Another clinical trial investigating Ayurvedic interventions for irritable bowel syndrome (IBS) showed that *Virechana*, combined with *Avipattikar Churna*, significantly modulated gut microbiota composition, resulting in symptom reduction and improved quality of life, as measured by IBS-specific scoring scales This study reported statistically significant improvements ($p < 0.05$) in patient-reported outcomes, affirming *Virechana's* effectiveness in modulating the gut microbiome[62]

Basti another vital component of *Panchakarma*, involves the administration of medicated oils and decoctions directly into the colon, where they exert local effects on the gut lining and microbial milieu. *Basti* is considered especially effective in balancing *Vata Dosha* and has been observed to reduce inflammation and support beneficial microbial populations, potentially enhancing gut health and immune function[63]. The introduction of herbal compounds in *Basti* therapy may act as prebiotics, nourishing beneficial bacteria and helping to re-establish microbial equilibrium. These preparations often contain ingredients with bioactive compounds that exhibit antimicrobial, anti-inflammatory, and antioxidant properties[64]. The introduction of herbal oils and decoctions in *Basti Karma* potentially enhances the production of short-chain fatty acids (SCFAs), including butyrate, propionate, and acetate, due to the fermentation of bioactive compounds by gut bacteria. SCFAs play a key role in maintaining gut health, as they provide energy for colonic cells, reduce inflammation, and support gut barrier integrity[65]. *Basti Karma* may help reduce dysbiosis, or the imbalance of gut microbiota linked to various diseases such as inflammatory bowel disease (IBD) and irritable bowel syndrome (IBS). Many *Basti* formulations are rich in polyphenols and flavonoids, known for their anti-inflammatory properties, which can lower gut inflammation markers and support the growth of beneficial bacteria while decreasing harmful species that thrive in inflammatory environments[66]. This reduction in dysbiosis may also contribute to improved gut barrier function, thereby preventing pathogenic bacteria from translocating through the gut lining and triggering immune responses. *Basti Karma's* modulation of gut microbiota can enhance overall digestive health. By promoting beneficial bacteria, it may improve nutrient absorption, regulate bowel movements, and relieve symptoms associated with digestive disorders, such as constipation and bloating. Since a significant portion of the body's immune cells reside in the gut, *Basti Karma's* influence on microbiota composition may positively affect immune responses. By enhancing the growth of immune-supporting bacterial strains[67], *Basti Karma* may bolster the body's resistance to infections and autoimmune conditions. Emerging evidence suggests a bidirectional link between gut microbiota and metabolic or neurological health (gut-brain axis)[68]. By rebalancing gut microbiota, *Basti Karma* may play a role in managing conditions like metabolic syndrome and certain mental health disorders, such as anxiety or depression, although more specific research is needed to validate these effects.

Nasya Karma involves the administration of herbal extracts or oils through the nasal passages, aiming to clear sinus blockages and improve respiratory function. Ayurveda suggests that *Nasya* (medication through nasal route) not only clears the nasal passages but also supports mental clarity and impacts the body's overall *Dosha* balance, particularly affecting *Kapha Dosha*, which is believed to regulate aspects of fluid and mucous in the body[69]. This aligns with concepts in modern neuro-gastroenterology, where nasal pathways are thought to affect the central nervous system, which in turn can modulate gut health via the gut-brain axis. In recent years, research has highlighted that gut-brain axis interactions—mediated by microbial metabolites such as short-chain fatty acids and neurotransmitter-like molecules—play a significant role in gastrointestinal function, immune response, and mood regulation[70]. *Nasya* may influence the microbiota indirectly by affecting the vagal tone, which is crucial for maintaining gut motility and integrity of the intestinal mucosa. Studies on the gut-brain connection support the idea that mental and emotional well-being, which *Nasya* aims to enhance, can influence gut health through the release of hormones and neurotransmitters, which are crucial in modulating gut microbiota balance.[71] While direct evidence on *Nasya's* impact on the gut microbiota is still emerging, Ayurvedic texts and modern studies on nasal therapies suggest that practices impacting the nervous system, particularly those influencing stress and mental balance, could benefit the microbiome indirectly.

Raktamokshana, a bloodletting therapy in Ayurvedic medicine, is traditionally used to detoxify the body and balance the *Doshas*, particularly addressing disorders related to *Pitta* and *Rakta* (blood)[72]. Though historically understood within a humoral and energetic framework, emerging insights into the gut microbiome have begun to provide a possible scientific basis for the observed benefits of *Raktamokshana* (bloodletting) on systemic health, particularly through its indirect effects on gut microbiota. *Raktamokshana* is hypothesized to reduce inflammatory markers in the blood by removing excess *Pitta* and *Rakta*, which Ayurveda correlates with blood toxicity and inflammation. Chronic inflammation is known to disrupt gut microbiota composition, promoting dysbiosis by increasing pathogenic bacteria and reducing beneficial microbial diversity[73]. By lowering systemic inflammation, *Raktamokshana* may create a more favourable environment for the gut microbiome, indirectly supporting microbial diversity and stability. Inflammation reduction in the systemic environment has been shown to allow beneficial gut bacteria like Lactobacillus and Bifidobacterium to thrive, while discouraging pathogenic species[74]. Ayurveda views certain toxins or *Ama* in the bloodstream as disruptive to health. Modern science correlates high toxin levels in blood with increased intestinal permeability or "leaky gut," which can lead to bacterial translocation and dysbiosis. By detoxifying the blood, *Raktamokshana* may help maintain gut barrier integrity, which is essential for controlling the interaction between gut microbes and the immune system. A well-maintained gut barrier has been associated with healthier microbial composition and a reduced likelihood of inflammatory diseases[75]. Bloodletting in *Raktamokshana* is also thought to recalibrate the immune system. Ayurveda suggests that *Raktamokshana* releases "excess" humoral factors, thus restoring immune balance. This aligns with modern immunology, which notes that controlled blood removal can modulate immune responses, potentially impacting gut immune interactions. Gut microbiota is known to shape and interact with the immune system, influencing both local and systemic immunity. Therefore, immune modulation from *Raktamokshana* could indirectly foster a more balanced gut microbial environment. Emerging studies suggest that therapies like bloodletting could play a role in managing disorders associated with both gut dysbiosis and systemic inflammation, such as inflammatory bowel disease (IBD), metabolic syndrome, and autoimmune conditions[76]. By reducing bloodborne inflammation and potentially restoring immune balance, *Raktamokshana* may be particularly effective for gut disorders that have an inflammatory component[77].

MECHANISMS OF AYURVEDIC DRUGS ON GUT MICROBIOTA

The specific mechanisms by which Ayurvedic drugs modulate the gut microbiota are under ongoing investigation. Current evidence suggests that these traditional herbal formulations exert their effects through multiple pathways, supporting gut health by fostering a balanced microbiota. Here, we explore the primary mechanisms proposed for these effects, each contributing uniquely to the microbiome's equilibrium and overall host health.

Prebiotic Effects- Certain Ayurvedic herbs, such as *Triphala*, have demonstrated prebiotic effects due to their high levels of dietary fibres, polyphenols, and bioactive compounds. These compounds provide essential nutrients for beneficial bacteria, particularly Bifidobacterium and Lactobacillus species, enhancing their growth and activity. Polyphenols within *Triphala* undergo microbial fermentation in the colon, producing short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate, which support gut barrier function, reduce inflammation, and contribute to metabolic health. This prebiotic function of Ayurvedic herbs aligns with modern understandings of diet-gut microbiome interactions, emphasizing the role of non-digestible fibres in sustaining beneficial microbes and their metabolites, which are vital for gut integrity and systemic health[78].

Antimicrobial Properties- Several Ayurvedic herbs exhibit selective antimicrobial properties, which inhibit pathogenic bacteria while sparing beneficial microbes. Herbs like *Neem* (*Azadirachta indica*), *Triphala*, contain bioactive compounds that exhibit bactericidal effects against harmful species such as *Escherichia coli* and *Salmonella* spp. These selective actions help in sustaining microbial diversity and maintaining a balanced gut microbiota, crucial for preventing dysbiosis-related diseases such as inflammatory bowel disease and infections[79]. These antimicrobial properties not only contribute to the preservation of microbial balance but also align with the growing interest in natural antimicrobials as alternatives to conventional antibiotics.

Anti-inflammatory Actions- Ayurvedic herbs like turmeric (*Curcuma longa*) and *Guduchi* (*Tinospora cordifolia*) are known for their potent anti-inflammatory properties, which support gut health by modulating inflammatory pathways. Curcuminoids in turmeric, for instance, inhibit pro-inflammatory cytokines (e.g., TNF-α, IL-1β) and NF-κB signalling, reducing inflammation in the gut and fostering an environment conducive to beneficial bacterial growth[80]. *Guduchi*, with its anti-inflammatory phytochemicals, further reduces inflammation, supporting a stable gut ecosystem that minimizes pathogen overgrowth and dysbiosis. These anti-inflammatory actions underscore Ayurveda's emphasis on reducing chronic inflammation, a factor implicated in many modern diseases linked to gut health.[81]

Modulation of the Gut-Brain Axis- Ayurvedic adaptogenic herbs, such as *Ashwagandha* (*Withania somnifera*), play a significant role in modulating the gut-brain axis, a two-way communication network linking the central nervous system with the gut, plays a critical role. Through the regulation of cortisol levels and the stress response, *Ashwagandha* mitigates the effects of stress-induced dysbiosis, supporting a balanced microbiome[82]. This adaptogenic action not only helps in preserving beneficial bacteria but also highlights the holistic nature of Ayurveda, which recognizes the interplay between mental and physical health in disease. This regulation of the gut-brain axis by Ayurvedic herbs underscores a unique mechanism where stress reduction supports microbial diversity and function, highlighting Ayurveda's comprehensive approach to health[83].

IMPLICATIONS FOR MODERN HEALTH

Ayurvedic therapies, rooted in principles of individualized care, present a compelling model for personalized medicine by aligning treatment strategies with a person's unique *Dosha* (bodily constitution) and specific health conditions. In the context of rising gut-related disorders and microbial imbalances (dysbiosis), integrating Ayurvedic practices with contemporary medical approaches may provide synergistic benefits. Below, we outline key areas where Ayurvedic therapies show potential contributions to managing modern health issues:

Prevention and Management of Metabolic Disorders - Metabolic disorders, such as obesity, type 2 diabetes, and metabolic syndrome, have been closely linked to gut dysbiosis, characterized by a harmful imbalance in gut microbial composition. Ayurvedic interventions, particularly dietary adjustments and herbal formulations, offer a pathway to manage these disorders by fostering a healthy gut microbiota balance. For instance, herbs like *Triphala*, a polyherbal blend traditionally used to support digestion, have shown promise in improving glucose and lipid metabolism, potentially by modulating gut microbial populations. Studies indicate that *Triphala* enhances the proliferation of beneficial bacteria like Bifidobacterium and Lactobacillus while reducing pathogenic bacteria, thereby potentially improving insulin sensitivity and supporting weight management. Regular integration of such herbs could serve as an adjunct to modern treatments for metabolic disorders, supporting a holistic and sustainable approach to metabolic health.

Immune System Modulation - The gut microbiota is deeply intertwined with immune system regulation, playing a crucial role in the development and function of immune responses. Ayurvedic therapies, particularly those involving polyphenol-rich herbs, may offer immunomodulatory effects by enhancing beneficial microbial populations and reinforcing gut barrier integrity. Herbs like *Turmeric* (*Curcuma longa*) and *Guduchi* (*Tinospora cordifolia*) are particularly notable for their anti-inflammatory and antimicrobial properties, which may support immune resilience and reduce inflammation. These herbs have demonstrated potential in alleviating symptoms associated with inflammatory bowel diseases (IBD), such as ulcerative colitis and Crohn's disease. For instance, curcumin in turmeric has been observed to modulate immune pathways and reduce pro-inflammatory cytokines, thus fostering a gut environment conducive to health. Through modulation of the gut microbiota, Ayurvedic herbs can provide additional support in managing chronic inflammation and immune-related conditions.

Mental Health and the Gut-Brain Axis- Ayurveda has historically emphasized the connection between digestive health and mental well-being, a concept that aligns with modern scientific understanding of the gut-brain axis. This bi-directional communication system links gut microbiota to neurological function, impacting mood, cognition, and overall mental health. Ayurvedic herbs like *Brahmi* (*Bacopa monnieri*) and *Shankhapushpi* (*Convolvulus pluricaulis*) have been traditionally used to support cognitive function and emotional balance. Emerging research suggests these herbs may influence mental health by modulating gut microbiota composition, with potential benefits for anxiety, depression, and cognitive performance. Furthermore, adaptogenic herbs like *Ashwagandha* (*Withania somnifera*) offer unique advantages by reducing stress-induced dysbiosis and supporting gut barrier health, thereby potentially benefiting mental health through a stabilized gut environment. This alignment between Ayurveda's holistic perspective and the gut-brain axis provides a promising avenue for integrated approaches to mental health care.

CHALLENGES AND FUTURE DIRECTIONS IN INTEGRATING AYURVEDIC THERAPIES WITH MICROBIOME SCIENCE

The potential of Ayurvedic therapies to modulate the gut microbiome offers a promising pathway for novel interventions in metabolic, immune, and digestive health. However, there are significant challenges to translating these traditional practices into microbiome science, particularly for integration with modern medical frameworks. Addressing these challenges will require standardized methodologies, rigorous clinical research, and an interdisciplinary approach to bridge traditional Ayurvedic knowledge with contemporary microbiome science.

Standardization and Quality Control- One of the foremost challenges in studying Ayurvedic interventions is the lack of standardization across formulations. Ayurvedic preparations often vary widely in composition due to differences in plant source, extraction method, and regional variations in traditional practices[84]. Such variability makes it difficult to achieve consistent, reproducible outcomes across scientific studies. To establish reliable data on efficacy and safety, there is a pressing need to develop standardized protocols for the preparation and administration of Ayurvedic drugs. This standardization should encompass detailed documentation of plant sources, bioactive compounds, and precise dosages to ensure quality and reproducibility in research and clinical applications.

Need for Large-Scale Clinical Trials- While preclinical studies and small-scale clinical research suggest positive effects of Ayurvedic therapies on gut microbiota, large-scale, randomized controlled trials (RCTs) are essential to validate these findings in human populations. Most of the current evidence is derived from animal studies or small human trials that may not account for inter-individual differences or placebo effects. Robust RCTs will provide a more comprehensive understanding of the efficacy, safety, and potential side effects of these therapies in diverse populations. Furthermore, such trials should be designed to investigate specific mechanisms by which Ayurvedic formulations, such as *Triphala* and *Guduchi*, influence gut microbiota composition and function, providing insights into their therapeutic potential for conditions such as metabolic syndrome, inflammatory bowel disease, and obesity[85].

Interdisciplinary Integration with Modern Medicine - The integration of Ayurveda and microbiome science with modern medical practice requires a cross-disciplinary approach involving collaboration between Ayurvedic practitioners, microbiologists, pharmacologists, and clinicians. Developing integrative treatment protocols that combine the benefits of traditional Ayurvedic practices with evidence-based modern medicine will enhance patient outcomes, particularly for conditions influenced by gut microbiota, such as irritable bowel syndrome and autoimmune disorders. This collaborative approach will also require training and education programs to equip healthcare providers with the knowledge needed to understand and apply integrative therapies. Additionally, regulatory frameworks will be necessary to ensure that Ayurvedic interventions are safely and effectively incorporated into modern treatment paradigms, with appropriate oversight and patient monitoring.

Mechanistic Studies: Investigating the molecular pathways by which specific Ayurvedic herbs and formulations affect gut microbiota can lead to more targeted therapeutic applications. Advanced technologies, such as metagenomics and metabolomics, could facilitate deeper insights into herb-microbiome interactions and their systemic effects.

Personalized Approaches: Given Ayurveda's emphasis on individualized treatment (*Prakriti*), future research should explore personalized interventions based on an individual's microbiome profile. This approach may enhance therapeutic efficacy and align with the growing trend toward precision medicine.

Collaborative Research Networks: Establishing international collaborations and research networks can accelerate the validation and global acceptance of Ayurvedic therapies, fostering a greater understanding of their potential contributions to microbiome-related health outcomes.

CONCLUSION

The exploration of Ayurvedic interventions in the management of gut dysbiosis highlights their significant potential as integrative therapeutic strategies. This manuscript synthesizes traditional Ayurvedic knowledge with modern microbiome science, showcasing the ability of interventions such as *Triphala*, *Guduchi*, *Ashwagandha*, and *Panchakarma* therapies to modulate gut microbiota composition, promote microbial diversity, and restore gut health. These practices, grounded in holistic principles, provide not only targeted approaches to metabolic and inflammatory disorders but also open avenues for personalized and preventive healthcare. By leveraging Ayurvedic formulations' bioactive compounds and aligning them with contemporary research, this study underscores the relevance of integrative medicine in addressing the growing prevalence of gut-related health issues. Future research focusing on standardized protocols, mechanistic insights, and interdisciplinary integration will be pivotal in bridging traditional Ayurvedic practices with modern therapeutic paradigms, ultimately enhancing their applicability in personalized medicine.

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