

## Harnessing pharmacognosy to restore gut microbial harmony in women's health



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### Abstract

The human gut microbiome, often called an "invisible organ," is a crucial organ that brings about the balance of metabolic, immune, and neurobehavioral systems. The unraveling of microbial balance, a condition called dysbiosis, leads to a strong connection between these disruptions and numerous disorders, among which metabolic syndrome, autoimmune diseases, and neuropsychiatric dysfunctions are some of the most commonly known ones. In the case of women, the hormonal fluctuations during menarche, pregnancy, and menopause have a significant impact on the gut microflora, thereby determining the woman's vulnerability to disease. The gut-estrogen axis, particularly the estrobolome, is responsible for the modulation of systemic estrogen levels and is considered very important concerning reproductive and metabolic health. Pharmacognosy-based methods that involve the use of prebiotic plants, polyphenol-rich herbs, and fermented herbal compositions are among the outstanding therapies for achieving the microbial balance and increasing the gut's ability to resist diseases. These plant-based bioactive substances are capable of affecting the diversity of microbes, boosting the production of short-chain fatty acids and the strength of mucosal barriers.

**Keywords:** Gut microbiome, estrobolome, dysbiosis, pharmacognosy, hormonal regulation, women's health

### 1. Introduction

The human intestinal microbiota, that is, the collection of microorganisms that for a long time was considered a "silent organ," has proved to be a very lively and dynamic microbial ecosystem that plays an important role in host physiology with its strong influence on immune response, metabolism, and nutrition. A homeostatic and well-intact microbiota should be maintained because disruption of microbial equilibrium, or dysbiosis, has been associated with gastrointestinal disease, metabolic syndrome, autoimmune disease, and neurobehavioral disturbances (1). Healthy gut microbiota is most relevant in women because of the symbiotic

interaction between sex hormones and gut microbiota. Hormonal fluctuation throughout diverse life phases—menarche, pregnancy, and menopause—might potentially have a significant influence on the structure of microbiota and thereby on susceptibility to diseases such as polycystic ovary syndrome, gestational diabetes, postmenopausal osteoporosis, and affective disorders. Pharmacognosy is currently of topmost priority since medicinal plants and their ingredients, bioactive metabolites, polyphenols, saponins, and flavonoids, have the potential to modulate gut microbial community in a beneficial way (2). These plant constituents can serve as substrates of prebiotics, promote colonization of the beneficial microbes *Lactobacillus* and *Bifidobacterium*, and show anti-inflammatory and antioxidative activities that act synergistically to rebalance microorganisms. Therefore, the integration of pharmacognostic approaches to the extraction of plant bioactives provides an evidence-based, integrative paradigm for the augmentation of gut-associated health advantages in women, bridging ethnopharmacological heritage and modern biomedical science (3).

## **2. Gut Microbiota: Composition and Functions**

### **2.1. Organization of the Gut Microbiota**

Human gut microbiota is an extremely diverse microbial community, which is under the control of a few dominant phyla such as Firmicutes, Bacteroidetes, Actinobacteria, and Proteobacteria. *Lactobacillus*, *Bifidobacterium*, *Bacteroides*, *Clostridium*, and *Akkermansia* are some of the genera that create the ecological and functional diversity of the microbiome. The microbial community is influenced by various parameters such as mode of delivery, infant's feeding practices, diet, antibiotic exposure, and lifestyle, which result in a characteristic pattern of microbiota in each person (4).

### **2.2. Functions in Metabolism, Immunity, and Digestion**

Gut microbiota is the core to metabolize nutrients and hydrolyze complex carbohydrates and proteins to produce short-chain fatty acids (SCFAs) like acetate, propionate, and butyrate, which are absorbed by epithelial cells and control cellular and metabolic functions. Microbial enzymatic activity facilitates recovery of the nutrient and synthesis of compounds needed like vitamins and bile acids. Additionally, gut microbiota elicits immunity by preventing pathogen colonization, maintaining intestinal epithelial barrier integrity, and breaking down ingested nutrients in a synergistic manner of synthesizing bacteriocins and antimicrobial peptides. Commensal bacteria also regulate innate and adaptive immune cell differentiation and function, thus justifying their replaceable nature in immunomodulation (5).

## **3. Gut Microbiota and Women's Health**

### **3.1. Hormone Interactions and Alterations in Gut Microbiota**

The sex hormones engage in a multilateral interaction with gut microbiota and affect women's health throughout the menstrual cycle, pregnancy, and menopause. Microbial modifications are triggered by fluctuations in estrogen and progesterone, with rising estrogen favoring diversity and a reduced risk of detrimental bacteria (e.g., *Lactobacillus* and *Bifidobacterium*) during the reproductive period. Reduction of estrogen in menopause is associated with reduced species richness, elevated *Enterobacter*, and metabolic and inflammatory disease. Endocrine alterations are the pathogenesis for disorders such as lipid metabolism disorder, central obesity, and immune and cognitive function alterations in women during menopause (6).

### **3.2. Gut–Estrogen Axis (Estrobolome) and Estrogen Regulation**

The gut–estrogen axis is governed by the *estrobolome*, a set of bacterial genes encoding  $\beta$ -glucuronidase and related enzymes that deconjugate estrogen metabolites. Conjugated

estrogens excreted in bile are hydrolyzed by these gut microbes (e.g., *Escherichia coli*, *Bacteroides*, *Clostridium*), allowing free estrogens to be reabsorbed into circulation through enterohepatic recycling. This microbial modulation directly affects systemic estrogen levels and receptor signaling. Dysbiosis lowers  $\beta$ -glucuronidase activity, reducing circulating estrogens and contributing to menopausal symptoms, metabolic disorders, and reproductive cancers, whereas excessive activity may promote estrogen-dominant conditions (7).

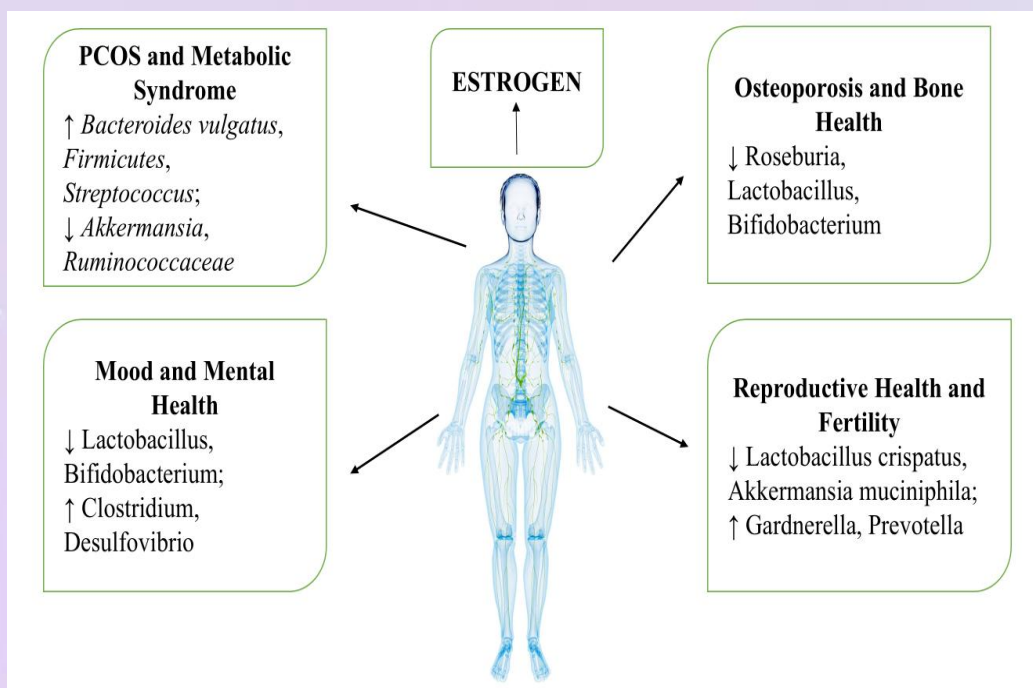
### 3.3. Health of Women Outcomes

PCOS and Metabolic Syndrome: An imbalance of microbes linked to PCOS is marked by the presence of *Bacteroides vulgatus*, Firmicutes, and *Streptococcus* as well as the absence of *Akkermansia* and Ruminococcaceae. The changed profile supports hyperandrogenism, insulin resistance, and obesity by meddling with bile acid signaling, low production of short-chain fatty acids, and disturbed glucose homeostasis.

- **Osteoporosis and Bone Health:** The microbial diversity loss after menopause has a negative impact on the absorption of calcium and bone metabolism, resulting in higher rates of osteoporosis. The absence of estrogen not only diminishes the prevalence of bacteria (like *Roseburia*) that have anti-osteoporotic properties but also limits the production of beneficial SCFA as a consequence.
- **Mood and Mental Health:** The gut microbiota-brain axis is a major determinant of emotional health; low estrogen increases the risk of altered microbial signaling, thus resulting in an increased prevalence of anxiety, depression, and cognitive decline in postmenopausal women. Probiotics and dietary interventions targeting gut microbes have been reported to produce a favorable impact on one's mood and stress response.
- **Reproductive Health and Fertility:** There is a link between microbial diversity and the regulation of estrogen and androgen, which in turn affects ovulatory cycles, fertility, and pregnancy outcomes. Dysbiosis creates an unfavorable hormonal environment for ovulation, implantation, and embryo development.
- **Male vs. Female Microbiome Differences:** Women in their premenopausal stage of life have more diverse gut microbiomes than men and postmenopausal women because of higher populations of *Alistipes*, *Bifidobacterium*, and *Ruminococcus*, and fewer *Bacteroides*. At menopause the female microbiota becomes more similar to that of males due to hormonal as well as metabolic changes (3, 8). In Figure 1, there is a pictorial representation of the role and mechanism of gut microbes in women's health.

### 4. Dysbiosis and Disease Linkages

Dysbiosis is the alteration of gut microbiota's composition and function, which usually results from a combination of the factors stated above: antibiotic use, unhealthy eating habits, and chronic stress. All of these reduce microbial diversity and disrupt the beneficial populations. Antibiotics are a must when it comes to controlling infections; however, they also have the downside of killing good gut bacteria along with the bad ones. This could result in harmful bacteria taking over and the gut losing its balance. Similarly, a low-fiber and mainly processed food diet makes it difficult for the gut microbes to break fiber down and eventually produce short-chain fatty acids (SCFAs). The absence of gut metabolism and immune modulation functions follows thereafter. Psychological stress also influences the gut environment changes through neuroendocrine mechanisms, thus affecting the intestinal flora's composition and the level of inflammation (9).



**Figure 1:** Pictorial Representation of Gut Microbes with Women's Health

Dysbiosis is a condition that occurs upon the alteration of the microbiome composition, wherein the pathogens mainly take over the body. In this particular instance, the role of dysbiotic states in women-related diseases becomes highly significant. The classic instance of a disorder that has been greatly affected by dysbiosis is polycystic ovary syndrome (PCOS), where the condition is exacerbated by systemic inflammation, insulin resistance, and hyperandrogenism. Besides, the imbalance in gut bacteria leads to a situation of "leaky gut," which in turn causes an increase in the absorption of lipopolysaccharides (LPS) and some other microbial products into the bloodstream, leading to the development of low-grade chronic inflammation that has been associated with autoimmune diseases such as rheumatoid arthritis and systemic lupus erythematosus, which are more prevalent in women. This inflammatory state also predisposes one to metabolic syndrome and heart diseases. Thus, the role of a healthy gut microbiome is crucial in halting the inflammatory process and immune system dysregulation that primarily affects women; this is why it is even more critical to have microbiota-targeted therapeutic strategies that facilitate the treatment of dysbiosis-associated diseases (10).

## 5. Pharmacognosy-Based Approaches to Gut Health

### 5.1. Prebiotic Phytoconstituents

Prebiotic efficacy in gut health is primarily attributed to non-digestible phytoconstituents such as **inulin**, **galactooligosaccharides**, and **saponins**, which selectively stimulate beneficial microbes (*Bifidobacterium*, *Lactobacillus*). Inulin, derived from chicory and Jerusalem artichoke, enhances the production of short-chain fatty acids (SCFAs) like acetate and butyrate that strengthen the intestinal barrier and modulate immune responses. Saponins from fenugreek and glycosides from flaxseed improve lipid metabolism and glucose tolerance while supporting microbial balance (11).

### 5.2. Polyphenols and Related Bioactives

Polyphenolic compounds such as **curcumin**, **catechins**, **resveratrol**, and **quercetin** are key mediators of host–microbe interaction. These compounds undergo microbial transformation in

the colon to yield bioactive metabolites that influence oxidative stress, inflammation, and microbial diversity. Curcumin enhances epithelial tight junctions and suppresses pro-inflammatory cytokines, whereas green tea catechins and grape-derived resveratrol promote *Akkermansia* and *Bifidobacterium* growth while inhibiting pathogenic *Clostridium* species (12).

### 5.3. Functional Role of Major Phytoconstituent Classes

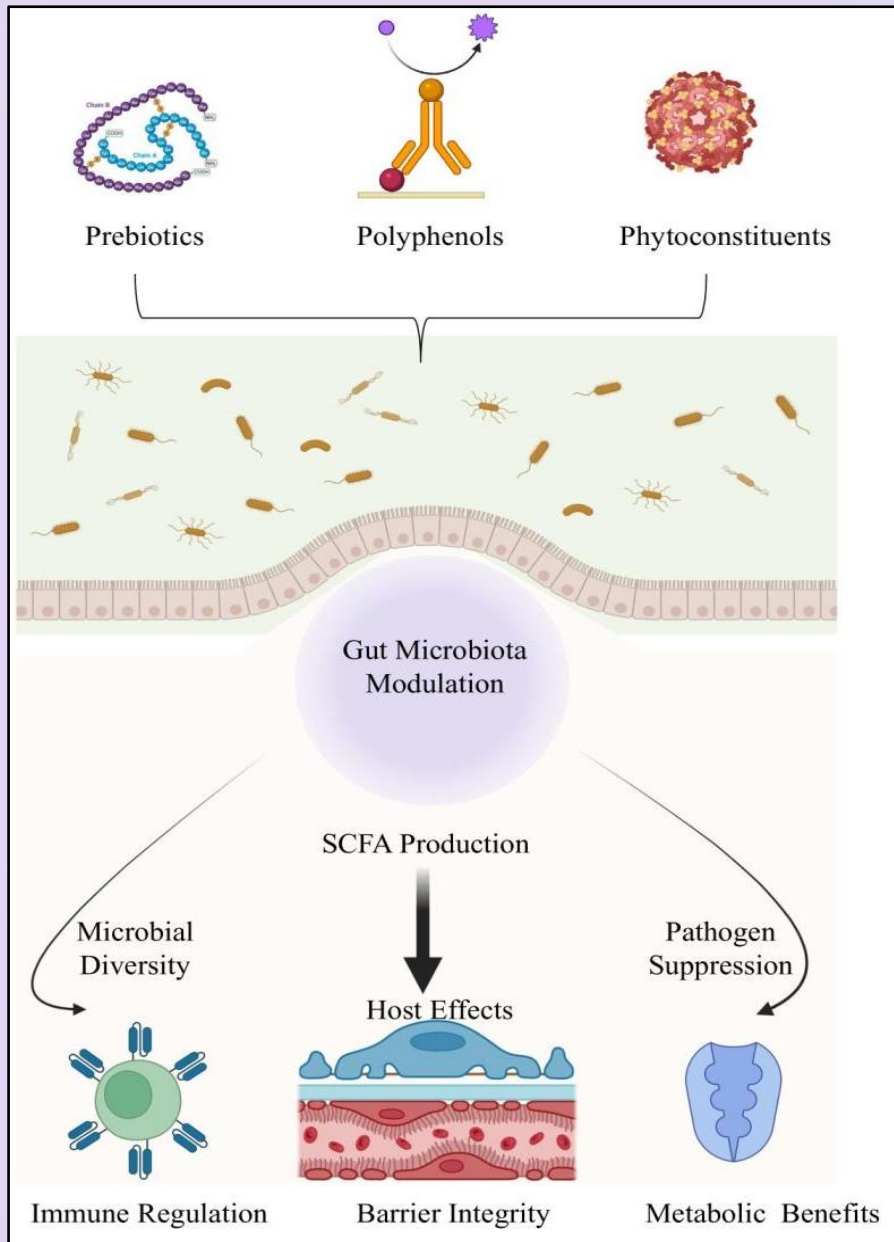
Phytochemical classes such as **alkaloids**, **flavonoids**, **terpenoids**, and **phenolic acids** exert distinct effects on gut microbiota by modulating microbial metabolism, enzymatic activity, and quorum sensing. Flavonoids stimulate beneficial bacterial colonization and SCFA synthesis; terpenes exhibit antimicrobial and antioxidant actions that preserve mucosal homeostasis; and alkaloids like berberine regulate microbial gene expression linked to glucose metabolism and lipid regulation (13). Collectively, these bioactives act as microbiota modulators, restoring gut–host symbiosis.

### 5.4. Fermented Herbal Preparations in Ayurveda

Fermented herbal foods and medicinal preparations integral to Ayurveda and folk medicine, including fermented rice products (idly, dosa), buttermilk (takra), and herbal Asavas and Arishtas, provide probiotic microbes and fermentative metabolites that enhance microbial diversity and digestive "agni" (digestive fire). These preparations improve nutrient bioavailability and gut immune function (14). *Table 1* shows examples of pharmacognostic agents for gut health. Conceptual *figure 2* shows prebiotics, polyphenols, and phytoconstituents modulating gut microbial diversity, SCFA production, immune regulation, and barrier integrity.

## 6. Gut Microbiota and Herbal Metabolites

The metabolism of gut microbiota and herbal metabolites is two-way, interactive, and metabolic and an essential factor in the pharmacological action of herbal medicine. Intestinal microbiota metabolize sophisticated plant compounds like polyphenols, alkaloids, and flavonoids to minimize bioactive metabolites having higher pharmacological action and bioavailability. For instance, curcumin, a polyphenol present in turmeric, is not significantly absorbed in its natural form but gets conjugated by gut microbiota to produce more anti-inflammatory and antioxidant activity-containing metabolites, enhancing the health effect of curcumin. Correspondingly, berberine, a compound alkaloid, regulates gut microbiota by selectively activating SCFA-producing bacteria like *Blautia* and *Allobaculum* that are associated with elevated metabolic response with anti-obesogenic activity. Conversely, plant phytochemicals modulate the structure and function of the gut microbiota through the stimulation of beneficial microbes and inhibition of pathogens, thus restoring microbial abundance (21). Soy isoflavones and other legume isoflavones are biotransformed by microbes into equol and other estrogenically active metabolites that influence host hormone balance. Neem limonoids have been reported to exhibit antimicrobial activity with the potential to cause microbial balance and reducing gut inflammation. The interaction between the substances coming from plants and the gut bacteria not only plays a part in the suitable usage of herbal medicine but also indirectly through the proper functioning of the gut bacteria. Therefore, it is imperative to unscramble these rather complex relationships to bring out the full power of herbs in treating gut issues and other diseases (22).



**Figure 2:** Interaction of Pharmacognostic Agents with Gut Microbiota

**Table 1:** Examples of Pharmacognostic Agents for Gut Health

Botanical Source	Key Bioactives	Mechanism of Action	Health Effects	References
Inulin (chicory)	Non-digestible fiber	Stimulates <i>Bifidobacterium</i> , SCFA production	Improved gut barrier, immunity	(15)
Fenugreek seed	Soluble fiber, saponins	Prebiotic effects, modulates glucose metabolism	Insulin sensitivity, microbiota balance	(16)
Turmeric	Curcumin (polyphenol)	Anti-inflammatory, enhances barrier function	Reduces gut inflammation	(17)

Green tea	Catechins (polyphenol)	Antimicrobial, promotes probiotic growth	Modulates dysbiosis	(18)
Triphala (amla, haritaki, bibhitaki)	Polyphenols, tannins	Mild laxative, prebiotic activity	Bowel regularity, microbial diversity	(19)
Neem	Flavonoids, terpenes	Antimicrobial, antioxidant	Gut microbial balance	(20)

## 7. Future Perspective

The determination of the women's personalized gut microbiota dynamics through the integrative approach of metagenomics, metabolomics, and AI-based microbiome profiling should be the primary goal of future studies. The gender-specific microbial biomarkers will provide the necessary precision therapies for disorders such as PCOS, osteoporosis, and mood swings. The collaboration of pharmacognostic practices and contemporary microbiome research will enable the development of next-gen phytotherapeutics that will have the dual action of being prebiotics and probiotics. In addition, the knowledge of the co-metabolism between herbs and gut flora will lead to the higher absorption and potency of the medicine (5, 19).

## 8. Conclusion

One could say that the gut microbiota have already dictated and are still dictating the considerable changes and exchanges in the body physiology of women. The extremely delicate interplay between estrogen, progesterone, and gut microbes determines not only microbial composition but also metabolic and immune homeostasis. Among the most beneficial species, *Lactobacillus*, *Bifidobacterium*, *Akkermansia muciniphila*, *Faecalibacterium prausnitzii*, and *Roseburia* are known to maintain mucosal integrity, regulate estrogen metabolism, and produce short-chain fatty acids essential for hormonal and metabolic balance. Conversely, a rise in *Bacteroides* and *Clostridium* species is often linked with dysbiosis, inflammation, and endocrine disturbances. Such imbalance, if left uncorrected, contributes to women-specific disorders like PCOS, osteoporosis, and mood fluctuations, highlighting the need for a balanced microbial ecosystem. Pharmacognostic agents derived from medicinal plants may serve as pivotal modulators of this gut flora through their prebiotic, antioxidant, and anti-inflammatory activities. Polyphenol-rich phytoconstituents, dietary fibers, and fermented herbal preparations promote the growth of probiotic microbes and strengthen the intestinal barrier. The realization of the co-action of these herbal metabolites with key gut microbes opens new possibilities in optimizing natural remedies. Thus, the fusion of traditional pharmacognostic wisdom with modern microbiome science has paved the way for sustainable strategies in women's health, targeting gut harmony, hormonal regulation, and chronic disease prevention.

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