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Medicinal Plants as Modulators of Gut Microbiota

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ABSTRACT

The human gut microbiota is a complex and dynamic microbial ecosystem that plays a central role in health and disease. Dysbiosis, caused by factors such as diet, antibiotics, and stress, is associated with metabolic, inflammatory, immune, and neuropsychiatric disorders. Medicinal plants represent a promising strategy for modulating gut microbiota due to their diverse phytochemicals with antimicrobial, prebiotic, antioxidant, and immunomodulatory properties. Compounds such as polyphenols, flavonoids, terpenoids, alkaloids, and sulfur-containing molecules can selectively inhibit pathogens while stimulating the growth of beneficial bacteria and enhancing short-chain fatty acid and vitamin production. Well-studied plants, including garlic (Allium sativum), ginger (Zingiber officinale), turmeric (Curcuma longa), peppermint (Mentha piperita), and chamomile (Matricaria chamomilla), demonstrate the ability to reshape microbial communities, strengthen the gut barrier, reduce inflammation, and influence systemic functions, including immunity and mental health. Preclinical and clinical studies highlight both antimicrobial and prebiotic effects, though variability in plant composition, dosage, and host microbiota remains a challenge. Standardization, mechanistic studies, and integration with probiotics and prebiotics are necessary to advance the therapeutic potential of medicinal plants as microbiota modulators.

Keywords: Gut microbiota**,** Medicinal plants**,** Phytochemicals**,** Prebiotics, and Dysbiosis.

INTRODUCTION

The human gastrointestinal (GI) tract hosts a complex and dynamic microbial community, collectively known as the gut microbiota [1-5]. Six bacterial phyla dominate the community: Firmicutes, Proteobacteria, Bacteroidetes, Fusobacteria, Actinobacteria, and Verrucomicrobia. The large intestine typically harbours the highest density of bacteria, reaching concentrations of approximately 1011–1012 cells per g, and represents the widest and most complex ecosystem in the human body [6-9]. The human intestinal microbiota is modified by many intrinsic and extrinsic factors, including age, diet, stress, administration of antibiotics, and other drugs. Disruption of the natural microbial ecosystems during critical developmental periods can have physio-pathological consequences; for example, antibiotic overuse during early life is one of the environmental factors associated with the development of obesity [10-14]. Medicinal plants may play a pivotal role in restoring the balance of the gut microbiota and in preserving the transitions between different stages of physiological development. Different definitions of herbal medicine have been proposed [15-17]. The World Health Organization (WHO) defines herbal medicine as therapeutic substances obtained from plants, but also from minerals and animal parts; the term “phytomedicine” specifies those of exclusively vegetable origin; the term “botanical” is frequently used in the USA to indicate liquid, powder or encapsulated medicines that include one or more herbs or plant parts; when the active principle of a plant is extracted using an organic solvent and isolated, the term “phytopharmaceutical” is used [18-23]. Plant-based nutritional supplements supporting health and well-being are regulated in the USA under the category of “dietary supplements” and under the term “natural health product” in Canada. They are formulated to provide minerals, vitamins, fatty acids, or amino acids; plant extracts or biomolecules can be part of an encapsulated product, and medicine such as a polyphenol extract from green tea can be proposed under the formulation of a dietary supplement [24-26].

Overview of Medicinal Plants

Traditional or herbal medicines, based on the use of medicinal plants, have been used to treat human diseases for thousands of years [27-29]. The raw herbs are consumed in mixtures or infusions and contain complex chemical constituents with relatively low toxicity. Medicinal plants continue to provide humankind with important drugs and botanical products that constitute crucial raw materials for the pharmaceutical industry [30-32]. The use of medicinal plants as antimicrobials to prevent food spoilage and treat infectious diseases is almost as old as humanity [33-34]. The antimicrobial properties of medicinal plants are mainly associated with the production of secondary metabolites, including alkaloids, flavonoids, tannins, and phenolic compounds known to strongly influence microbial growth and viability 2. Additionally, the prebiotic potential of many medicinal plants to selectively modulate the gut microbiota composition and metabolic output is well described [35-38]. However, scientific assessments of the mechanisms by which medicinal plants modulate human gut microbial communities remain limited [39-42].

Mechanisms of Action of Medicinal Plants

Medicinal plants contain phytochemicals that enhance human health, including antimicrobial components. These agents modulate the gastrointestinal microbial system by stimulating the growth of beneficial organisms or by inhibiting pathogenic components via different mechanisms. Additionally, medicinal herbs are a rich source of substrates that are convertible to short-chain fatty acids (SCFAs) by gut microbiota [43-45]. The resulting metabolic transformation is likely key to mediating many health benefits associated with their consumption. These effects are mediated by dietary and host glycans that medicinal plants preferentially fuel for community-wide catabolism based on in vitro anaerobic cultivation studies, highlighting the broad stimulatory effects on glycan degradation, sugar fermentation, and SCFA production [46-49]. As a consequence, the herbal-modulated gut microbiota represents a rich source of vitamin producers, particularly B vitamins. Consequently, the vitamin biosynthesis capacity of medicinal plant-selected microbial communities was also interrogated by genome reconstruction, underscoring the potential physiological relevance of the modulation of microbial community structure by medicinal plants [50].

Phytochemical Composition

Medicinal plants are renowned for being full of bioactive chemicals, with their efficacy and bioactivities often depending on the kind of chemical constituents they contain. Terpenoids, flavonoids, alkaloids, and phenolic chemicals are among the phytochemicals in medicinal plants that have been demonstrated to have strong antimicrobial properties against a variety of bacteria [54-58]. Various medicinal plant parts, including the root, bark, leaf, and fruit, are employed to address various illnesses because they also contain antimicrobial qualities. A significant number of phytochemicals have been described, and the prebiotic effects of these chemicals have also been studied. Numerous studies have demonstrated that phytochemicals derived from medicinal plants, such as polyphenols, flavonoids, carotenoids, and saponins, can selectively suppress or promote gut microbiota growth [60]. For instance, garlic bulbs include the sulfur-containing allium flavour compounds alliin, allicin, and ajoene, which perform antibacterial, anti-inflammatory, anticancer, and antioxidant activities while also promoting the growth of Lactobacillus in the digestive system. Ginger, known for its distinctive flavour, also provides health advantages by lowering inflammatory markers, reducing blood sugar, reducing blood cholesterol, and promoting the development of Bifidobacterium spp. in the human microbiota [62-64]. Turmeric, a yellow-orange pigment that is frequently used as a spice in food, offers potential anticancer and anti-inflammatory properties as well as hypoglycemic qualities that have an impact on gut microbiota composition, especially by boosting the Bacteroidaceae family. Peppermint and chamomile plants serve as antiseptic and antispasmodic agents in addition to helping with digestive issues like indigestion and hypokinesia [5].

Antimicrobial Properties

Medicinal plants encompass plant material and derived products utilized to prevent or treat ailments through non-pharmaceutical means. Historical evidence from Egyptians, Assyrians, Babylonians, Greeks, Romans, Indians, and Chinese documents the longstanding use of therapeutic plants globally. From traditional systems such as Ayurveda and Traditional Chinese Medicine to contemporary practices, medicinal plants have significantly influenced human health and continue as vital therapeutic agents [6]. Phytochemicals, including alkaloids, flavonoids, phytoestrogens, phenols, polyphenols, terpenoids, terpenes, glucosinolates, saponins, tannins, and unsaturated fatty acids, constitute the active compounds in medicinal plants, conferring broad-spectrum antimicrobial properties against bacteria, fungi, viruses, and protozoa [6]. The global rise in drug-resistant pathogens necessitates novel antimicrobial agents. While synthetic antimicrobials dominate medical practice, many originate from natural sources [6]. Medicinal plants serve as reservoirs of bioactive compounds that may function as antimicrobial agents or as chemosensitizers, enhancing antibiotic efficacy. The antimicrobial activity depends on the interaction between phytochemicals and microbial constituents, such as proteins, enzymes, and various phylogenetic cell structures. Plant extracts may disrupt vital microbial processes by permeabilizing cell membranes or inhibiting replication, transcription, and translation. Notably, the efficacy varies with the nature of the extract, extraction solvent, and extraction temperature [6]. The ability to target resistant strains and disrupt biofilms underscores the microbiota-modulating potential of medicinal plants [6].

Prebiotic Effects

Medicinal plants may promote gut microbial balance by a prebiotic mechanism, leading to the stimulation or inhibition of microbial growth [6]. Prebiotics are substances that serve as an energy source for the bacteria. Phytochemicals in medicinal plants, particularly polyphenols, can act as prebiotics for bacteria not normally enriched by dietary fiber and other prebiotics [2, 6]. Herb-supplemented cultures of the Human gut microbiota exhibited substantial and diverse shifts in taxonomic composition. Several taxa reported to have beneficial effects on human health, such as Ruminococcus, Oscillospira, and Faecalibacterium, all exhibited increased relative abundance in herb+culture [5]. Medicinal herbs generally induced proliferation of commensal bacteria at the expense of pathogens [2].

Role of Gut Microbiota in Human Health

The gut microbiota is a highly dynamic and diverse microbial community performing many operations that affect health and disease risk. It includes bacteria, archaea, fungi, viruses, and other eukaryotic microbes colonizing the gastrointestinal (GI) tract. Their collective metabolic activities are extensive, involving the production of short-chain fatty acids, vitamins, amino acids, and other nutrients. Resident microbes also impact drug metabolism and play an important role in educating the immune system [7]. Due to their many activities, the gut microbiota is now considered an endocrine organ in its own right. The human GI tract is central to health and host-microbe co-evolution [7, 3]. The gut acts as a selective barrier, allowing absorption while limiting potentially harmful substances, and establishing gradients important for proper tissue organization. The intestinal immune system is the largest in the body and mediates the dynamic interaction between the host and the gut microbiota. The metabolic capacity of the combined 105–10^7 microorganisms per anaerobic gram of the intestinal contents far exceeds that of human metabolism, continuously releasing bioactive compounds whose bioavailability is controlled by epithelial and immune factors [3]. Numerous immunity-regulated conditions are associated with altered host–microbiota interaction, involving chronic inflammation and increased risk for many metabolic, inflammatory, and autoimmune diseases.

Digestive Health

Phytotherapeutic drugs offer an attractive alternative to conventional treatments due to their natural origin and minimal side effects 8. Digestive disorders, including inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), gastro-oesophageal reflux disease (GERD), peptic ulcer disorder (PUD), and colorectal cancer (CRC), pose significant health challenges. The Mediterranean diet, rich in plant-based foods and phytochemicals, exerts protective effects on the cardiovascular and cerebrovascular systems by reducing chronic inflammation and regulating inflammatory biomarkers. Consequently, this diet may represent an effective means of stabilizing or reducing gastrointestinal lesions and inflammation. Herbal medicines represent a readily available therapeutic resource; although research into their interactions with gut microbiota remains in its early stages, preliminary findings are promising [5]. Analyses of over 70 medicinal herbs frequently used in the USA and China confirm that many exert prebiotic effects. In vitro assessments of 40 different herbal supplements for digestive health reveal that numerous herbs promote the growth of beneficial gut bacteria, including Bifidobacterium and Lactobacillus species [5]. Herb-induced increases in short-chain fatty acids, particularly butyrate and propionate, enhance anti-inflammatory responses, fortify the gut barrier, and reduce circulating endotoxins. Although some Bacteroides species can modulate immune functions by influencing regulatory T-cell populations, the clinical implications of these changes require further investigation [5].

Immune Function

Modulation of the human gut microbiota by medicinal plants may present unique opportunities to influence immune function. A well-balanced gut microbiota plays a significant role in maintaining human health, which is characterized by the predominance of strictly anaerobic bacteria that favor saccharolytic metabolism [3, 7]. The intestinal microbiota is highly diverse and contributes a greater gene pool than the host genome, impacting the host's physiology by facilitating the uptake, development, proliferation, and functioning of the immune system. Changes in microbial communities disturb the immune system and promote gastrointestinal tract disorders and bacteria translocation [3, 7]. Medicinal plants have demonstrated stimulatory effects on the immune system in humans. As a multifarious ecological system in the human gut, a balanced microbial community is therefore essential to maintaining the optimal physiological function of the human immune system. Medicinal plants such as

Ganoderma lucidum, Rhodiola rosea, and Grifola frondosa have been reported to contain natural products that regulate the gut microbial community, which indicates the therapeutic development of immune disorders [3]. The role of the gut microbiota in homeostasis of the immune system has been established through various sterile mouse models. Immunomodulatory pathways can be induced at the mucosal level by microbes and interaction with dietary factors and compounds from the host, which are yet to be fully understood [7].

Mental Health

Gut microbiota, one of the largest reservoirs of microorganisms in the human body, plays an essential role in health and homeostasis. The microbiota's pivotal processes include immune function, inflammatory response, nutrient processing, and biosynthesis [9]. Of particular interest are recent clinical and preclinical studies that suggest a role for medicinal plants in the modulation of gut microbiota. Medicinal plants are defined as herbs, herbal materials, herbal preparations, and finished herbal products with therapeutic or other human health benefits. The phytochemical composition of these plants may include one or more of the following: secondary metabolites (such as flavonoids and tannins), antimicrobial compounds, or prebiotic compounds. Through these chemicals, medicinal plants may have a modulatory effect on the microbiota, enhancing the growth of beneficial bacteria at the expense of opportunistic and potentially pathogenic bacteria. Specific examples of different classes of medicinal plants with a demonstrated ability to modulate the gut microbiota and exert beneficial effects on mental health are reported below [10]. Growing evidence has demonstrated that imbalances in gut microbiota composition, termed dysbiosis, can result in increased gastrointestinal permeability, heightened intestinal inflammation, and enhanced vulnerabilities to incident depression and anxiety. Mounting data suggest gut microbiota can influence a broad range of mental health-related outcomes, including mood and emotional regulation, cognition, and ultimately behavior [11]. Dysregulation of the blood–brain barrier (BBB) has also frequently been implicated as a causative contributor to the development of neurological disorders [10, 11].

Medicinal Plants and Gut Microbiota Interaction

Medicinal plants are renowned reservoirs of bioactive chemicals and exert direct antimicrobial activities [2]. Additionally, many herbs and spices exhibit prebiotic-like properties, which justify the profound modulatory effects attributed to them. The modulation of the gut microbiota by medicinal plants has attracted worldwide interest, as evidenced by the increasing number of in vitro and in vivo studies, including clinical examinations that confirm this ability. From antiquity, plants and natural compounds have played a fundamental role in the cure of diseases. Recently, research interest has been placed in the preclinical and clinical evaluation of medicinal plants as modulators of the gut microbiota [2].

In Vitro Studies

Medicinal plants used in traditional medicine have been shown to modulate the composition and function of intestinal microbiota by providing undegraded substrate for microbial fermentation or through antimicrobial activity [6]. The molecular mechanisms by which medicinal herbs impact the growth of individual microbes and whole microbial communities are still poorly understood, but emerging research offers new insights into this process. For example, sixteen selected medicinal plant species commonly used for dietary supplements and herbal formulations effectively promoted the growth of probiotic Lactobacillus, Bifidobacterium, and Bacillus species. The stimulatory capacity displayed by the herbs, in increasing bacterial growth, ranged from a 6- to more than 200-fold increase in three bacterial species, Lactobacillus acidophilus, Bifidobacterium animalis, and Bacillus subtilis [5]. A wide range of medicinal plants that are rich in polyphenols stimulate the growth of probiotic microbes while suppressing the growth of pathogens [6]. The capacity of twelve commonly used medicinal herbs to modulate erythrocytic glutathione transferase activity, a biomarker for oxidative stress, has recently been demonstrated [3]. In vitro fecal anaerobic cultivation and 16S rRNA gene sequencing revealed that complex changes in microbial community composition are driven by mucilage and pectin degradative activity in ginger. Culture-independent analyses of the community metabolic potential suggest that sugar fermentation may drive these shifts in community composition and their resulting potency. The magnitude of changes observed in vitro may, however, be significantly dampened in vivo owing to the inherent resilience of gut microbiota.

In Vivo Studies

Several studies have investigated the modulatory effects of medicinal plants on gut microbial communities using in vitro culturing systems. Cultivation of fecal-derived microbial communities in anaerobic chemically defined media containing individual medicinal plants at 1% (w/v) induced marked alterations to community composition. Each tested herb uniquely modulated gut microbiota structure, altering the growth dynamics of diverse taxa [3]. A total of 125 distinct bacterial species exhibited growth modulation, reflecting either activation or inhibition. Whole-genome metabolic reconstructions of herb-selected communities predicted shifts in community metabolism, particularly in sugar utilization, pentose phosphate pathways, and amino acid metabolism. Sugar degradation preferences attributed to specific phytochemical determinants suggest that the bioactive constituents of the herbs shape the metabolic environment driving observed microbial alterations [5]. Anaerobic fecal cultivation in complex media supplemented with medicinal herbs, followed by 16S rRNA sequencing, provided a framework for interpreting in vivo studies. Polyphenols impact microbial growth and alter communities through various mechanisms such as oxidative stress modulation, release of auxiliary substrates, and metabolic by-product consumption [2]. The compositional diversity of herbs warrants individual assessment, as different species known to alleviate distinct clinical conditions yield unique microbial signatures encoding divergent community metabolic functions. Genome reconstruction of 11,438 gut bacterial genomes encoded across 588 taxa predicted the community-wide capacity for short-chain fatty acid (SCFA) production, glycosyl hydrolase representation, and B-vitamin biosynthesis. Analysis of medicinal herb-selected communities implicated an elevation in the production of acetate, propionate, and butyrate and indicated that glycan harvest from medicinal herbs underpins community modulation. Inferred Vitamin B_1, B_2, B_6, and B_9 biosynthetic capacities were enriched in herb-selected communities [2, 5].

Common Medicinal Plants and Their Effects

Garlic is a promising antimicrobial agent, of which the phenols eugenol, carvacrol, and thymol possess greater antibacterial potency [2]. These compounds altered the gut microbiota. Allicin, one of the main ingredients in garlic, showed an inhibitory effect on Bacillus subtilis. Different concentrations of garlic extracts have been reported to exert an inhibitory effect against almost all pathogens. Thus, garlic also interacts with the intestinal microbiota. However, garlic possesses prebiotic potential and can increase the abundance of Lactobacillus and Bifidobacterium, though it inhibits a broad range of microorganisms. At low concentrations and in short-term interaction with the gut environment, allicin cannot inhibit the growth of certain bacteria. The capacity to both inhibit and modulate gut microbiota is a peculiar feature of such a molecule [2]. Ginger (Zingiber officinale) extracts against numerous bacteria, resulting in various effects. The secondary metabolites and volatile compounds present in ginger inhibit the respiration of the cell by the loss of ions such as K+ and phosphate and leading to the transformation of the membrane potential and pH of cells and cell death. Turmeric alters the microbial composition in the gut and increases the concentration of beneficial SCFAs that stimulate the production of the anti-inflammatory cytokine IL-22 in the colon. Turmeric also possesses both antimicrobial and anti-inflammatory activity [2]. Peppermint (Mentha piperita) exerts phytochemical properties that make it suitable for digestive complaints, and it has anti-inflammatory, antimicrobial, and antioxidant features. A study showed the beneficial properties of peppermint on the modulation of intestinal microflora since the measured increase in Bifidobacterium makes this plant suitable for the prevention and treatment of dysbiosis. Chamomile (Matricaria chamomilla) contains volatile oils with anti-inflammatory and pain-relieving properties [2]. The plant's antioxidant activities are mainly ascribed to the presence of terpenoids and flavonoids that are effective against several maladies. The main molecules responsible for its antimicrobial and anti-inflammatory effects are apigenin, quercetin, luteolin, and patuletin. Chamomile preparations have anti-inflammatory and antispasmodic properties attributable to the stimulation of biosynthesis and secretion of prostaglandins [2].

Garlic (Allium sativum)

Garlic (Allium sativum) is widely recognized for its therapeutic properties. The bulbs, leaves, cloves, and flowers are used in traditional treatments as well as food additives. In India, garlic is applied for fever, coughs, scabies, hair graying, eczema, and inflammation [12, 13]. Pakistani practices use it against stomach ailments, respiratory problems, and fever. In Nepal, the Middle East, and East Asia, it addresses fevers, rheumatism, liver disorders, diabetes, colic, intestinal worms, dysentery, flatulence, tuberculosis, high blood pressure, facial paralysis, and bronchitis. African applications target antibiotic, antiviral, hypolipidemic, hypoglycemic, and antithrombotic effects. Phytochemical studies identify sulfur-containing compounds as key contributors to these beneficial effects. Allicin represents a primary bioactive molecule; other relevant sulfur compounds include diallyl disulphide, diallyl trisulfide, and S-allyl cysteine. Garlic influences metabolic, cardiovascular, autoimmune, and antimicrobial responses, supporting its notable role in traditional medicine [12]. The phytotherapeutic properties are studied in tandem with ethnobotanical usage, exposure to medicinal products, and cellular and molecular mechanisms of action. Each constituent imparts chemopreventive functions and antimicrobial activities, including the inhibition of quorum-sensing genes that regulate bacteria–host interactions. Biological effects associated with pathological conditions are analyzed through molecular oncology and immunomodulation, pointing to directions for future laboratory and preclinical studies on the curative potential of A. sativum [13].

Ginger (Zingiber officinale)

Ginger (Zingiber officinale) belongs to the Zingiberaceae family and is cultivated in tropical and subtropical regions. The major bioactive compounds of ginger are gingerols and shogaols, which are responsible for its pungent taste and are credited with digestive and antiemetic properties [12]. Ginger is used to treat a variety of gastrointestinal disorders affecting the stomach and small intestines, as well as infections, constipation, diarrhea, and nausea [12]. Ginger exhibits antimicrobial activity against several strains of bacteria and fungi. In vitro studies have shown that ginger extracts can modulate the human gut microbiota composition; aqueous ginger extracts have been found to increase the abundance of Bacteroidetes, Firmicutes, and Proteobacteria while decreasing Firmicutes. Given its high polyphenol content, ginger acts as a prebiotic, promoting the growth of beneficial bacteria such as Lactobacillus and Bifidobacterium and increasing short-chain fatty acid production. Animal studies confirm these effects, demonstrating antibacterial activity [13]. Furthermore, ginger supplementation has been shown to protect against ethanol-induced fatty liver disease by enhancing intestinal barrier function and modulating gut microbiota populations.

Turmeric (Curcuma longa)

Turmeric (Curcuma longa) is a flowering plant in the ginger family, indigenous to tropical Southeast Asia and cultivated extensively in India. The rhizomes are dried or boiled, then dried, producing a deep orange-yellow powder central to cooking and medicinal practices in the Indian subcontinent [14]. Curcumin, the main curcuminoid derived from turmeric, is extensively researched for its physiological and pharmacological activities. In ovariectomized female rats, curcumin increased gut microfloral diversity and altered the abundance of specific species relative to controls. Turmeric intake modified microbial composition and function, slowed gastrointestinal transit via changes in bile acid metabolism, and influenced intestinal motility [14]. Dietary supplementation with turmeric or curcumin caused significant, individualized shifts in gut microbiota, suggesting that curcumin fosters the growth and survival of beneficial microbes. Mechanisms include microbial utilization of polyphenols and enhanced carbohydrate fermentation. A rise in certain lactobacilli strains stimulated by turmeric can inhibit gastrointestinal pathogens through lactic acid production. The gut microbiota also critically contributes to curcumin metabolism and the formation of its conjugates and reduced forms [14].

Peppermint (Mentha piperita)

Mentha piperita is an aromatic perennial herb characterized by underground rhizomes and erect, square, branched stems. Peppermint leaves, both fresh and dried, along with essential oil, are widely used in pharmaceuticals, foods, and cosmetics, primarily for their antioxidant properties [15]. The essential oil's antimicrobial activities are attributed mainly to volatile bioactives such as oxygenated monoterpenoids, monoterpene hydrocarbons, and sesquiterpenes. Essential oils from Mentha species exhibit antibacterial activity against a range of Gram-negative and Gram-positive bacteria, including Pseudomonas aureus, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Serratia marcescens, and Streptococcus aureus [15]. Specifically, M. piperita demonstrates broad-spectrum antibacterial activity toward strains such as E. coli, Salmonella typhus, B. subtilis, S. aureus, P. aeruginosa, S. epidermidis, and K. pneumonia. The essential oil shows notable efficacy against Gram-negative bacteria, including P. aeruginosa, E. coli, and S. enterica. In contrast, methanol extracts of peppermint are only weakly active against Helicobacter pylori strains. The antibacterial effectiveness of peppermint oil varies with plant variety, bacterial strain, and testing conditions [15].

Chamomile (Matricaria chamomilla)

Chamomile (Matricaria chamomilla), a member of the Asteraceae family, is an extensively studied medicinal herb primarily indigenous to Europe and Asia [16]. It is commonly consumed as tea, tonic, or in traditional medicinal preparations. The herb is generally regarded as safe and is predominantly used to address gastrointestinal disturbances, mild skin irritation, inflammation, spasm, flatulence, colic, anxiety, fever, depression, ulcers, and wounds [17]. The essential oil derived from chamomile comprises more than 120 constituents, with terpenoids – including bisabolol, chamazulene, and β-farnesene, forming the major components. The concentration and abundance of these oil constituents are influenced by several parameters, such as geographical origin, farming method, environmental conditions, harvest stage, plant part used, post-harvest drying and storage, and extraction technique. Chamomile extracts contain significant quantities of phenolic compounds, including phenolic acids, flavonoids, and coumarins [17]. Pharmacological investigations of chamomile demonstrate a broad spectrum of activities: antioxidant, antibacterial, antifungal, anti-inflammatory, antiparasitic, insecticidal, anti-diabetic, and anticancer effects. The herb exhibits therapeutic potential in the management of disorders affecting the nervous, reproductive, metabolic, cardiovascular, gastrointestinal, skin, eye, and oral systems. Additionally, chamomile serves as an analgesic, wound-healing promoter, and a protective agent for the liver, kidney, gastrointestinal system, skin, eye, and oral cavity [17]. Beyond its medicinal applications, chamomile finds utility in aquaculture, animal nutrition, food industries, agriculture, chemical processing, and anti-corrosion strategies. Encapsulation of chamomile constituents into nanoparticles has been shown to amplify their therapeutic benefits and supports potential development as a functional food additive [17].

Clinical Applications of Medicinal Plants

A proper understanding of factors influencing the gut microbiota requires consideration of interventions permitting the microbiota to re-establish a healthy state. Probiotics are living microorganisms with proposed benefits that range from maintenance of microbial homeostasis to prevention of critical illness, acquired diarrhea 2. Probiotic supplements have expands the repertoire of gut microflora and exert modulatory actions on the host such as decreased inflammation and increased immunity. Probiotics may also contribute to the maintenance and restoration of the intestinal microbiota [17]. The continuous ingestion of pro-biotics furnishes a means of maintaining and modulating the composition of the intestinal community. Prebiotics are selectively fermented ingredients that promote specific changes in the composition and activity of the gastrointestinal microbiota, which confer benefits upon the host's well-being and health. They make an excellent base for phytochemicals with antimicrobial properties 3. Herbal medicine is a pillar of complementary and/or alternative medicines that uses plants or plant extracts to treat or prevent disease. Indonesia's bio-cultural diversity supports an immense range of traditional herbal medicine (Jamu) formulations [17]. In isolation, the efficacy of phytochemical constituents has been examined, but the interplay of medicinal plants and gut microbiota has not been extensively studied, even though numerous medicinal plants are associated with the promotion of healthy immune-compromised, metabolic, neurodegenerative, and cardiovascular health conditions, all influenced by gut microbiota [17]. The Ayurvedic medical system focuses on the maintenance and promotion of healthy gastrointestinal function and microbiota by prescribing medicinal herbs, dietary, and lifestyle medicine. To gain insight into the interaction between medicinal herbs commonly used in Ayurveda and the function and composition of gut microbiota, 21 plant- and fungal-derived medicinal herbs used in 63 Ayurveda formulations are analyzed. Modulatory effects on gut microbiota can be accurately recapitulated when medicinal herbs are solely the carbon sources, indicating that altered ecological performance arises from the ability of microbes to metabolize the herbs [17]. Gut microbiota reshaping is evident when each medicinal herb is examined in the presence of existing fecalderived communities, mimicking more closely in vivo conditioning of microbiota. The unique taxa induced by each medicinal herb and their correlation with the predicted sugar utilization and amino acid auxotrophy profiles are employed to deconvolute community-wide patterns of substrate utilization associated with their structural diversity. Microbe-sensitive interactions that define community assemblage are also revealed [17].

Probiotics and Prebiotics

Probiotic and prebiotic agents maintain the physiological functions of gut microbiota, the complex microbial ecosystem residing in the lumen of the colon [6]. Probiotics contain live beneficial microbes at a concentration of at least 106 CFU per mg, which, when administered in adequate amounts, help improve intestinal microbial balance by promoting colonization of health-promoting microbiota and suppressing pathogens [3]. Prebiotics are non-digestible compounds that elicit a health benefit through modulation of the microbiota, representing the substrate source for growth of beneficial microorganisms [3]. Several medicinal plant formulations, approved foods, and dietary supplement–herbal combinations have been shown to enhance the activity of probiotic microbes, prevent inflammatory gut disorders, and dampen colonization of diarrheal pathogens.

Herbal Formulations

Alternative medicine based on plants has been the most ancient approach to health maintenance and prevention of disease throughout the history of humankind. Herbal medicines possess many active phytochemical components with medicinal properties vital for human health. Several formulations based on natural medicinal products derived from herbs have been demonstrated to possess anti-cancer, anti-inflammatory, antioxidant, anti-bacterial, anti-viral, anti-aging, and anti-diabetic properties [5, 1]. The gastrointestinal tract is colonized by trillions of living microorganisms dominated by Firmicutes and Bacteroidetes, the gut microbiota, with a strong impact on health and disease status. The gut microbiota provides effective protection against pathogens, stimulates differentiation of the intestinal epithelium, reinforces the development of the immune system, and controls brain function and behaviour. This may be considered as an unbiased bioassay of the host-microbe interaction, which displays global effects on host fitness and represents a valid tool to reconstruct evolutionary trajectories of the animal-microbe interactions [5]. Many herbal formulations, such as probiotics, prebiotics, and synbiotics, play an important role in the modulation of gut microbiota and provide protection from distinct stressors [5, 1].

Challenges in Research and Development

The exploration of using medicinal plants to modulate the gut microbiota has led to several challenges in research and development. Beyond difficulties in establishing precise clinical research standards, the inherent ecological complexity of the gut poses obstacles to producing standardized medicines that deliver consistent, potent therapeutic effects [2]. Highly variable influences on the gut flora across different individuals and health conditions require personalized profiling before prescribing herbal medicines. Numerous medicinal plants have demonstrated the ability to influence gut microbial communities in vitro and in vivo, yet only a few have been adopted in effective commercial formulations despite extensive integration with probiotics and prebiotics. Ongoing investigations seek clinically practical medicinal plants with established efficacy and clear mechanisms of action, but overcoming current barriers remains essential [2]. Pharmaceutical innovation must therefore enhance the quality and performance of gut modulators by reducing heterogeneity inherent in natural products through thorough compound characterization and advanced chemometric analysis to increase concentration and efficiency. Although medicinal plants offer synergistic benefits compared to synthetic drugs, the pharmaceutical industry is still developing suitable analytical techniques to fully characterize mixtures of compounds from plant extracts and interactions among multiple pure compounds [2].

Standardization of Herbal Products

The herbal preparations deriving from botanicals encompass a broad category that comprises crude or processed materials taken from plant parts such as leaves, stems, flowers, and roots, as well as exudates (frankincense and myrrh) [3]. Different collections and processing methods generate a wide range of products with distinct characteristics, such as powders, granules, liquids, and glycerides, which might originate from the same plant and show quite heterogeneous chemical compositions [5]. Given these multiple sources of variation, ensuring standardization among herbal products represents a significant issue requiring thorough consideration. Indeed, the reproducibility of therapeutic effects that are fully reflected in the quality control of a final medicinal plant-enabled product is influenced by numerous influencing factors, spanning from the proper identification of a botanical source to geographical origin, cultivation methods, environmental patterns, harvesting seasons and procedures, and preparation technology [3, 5]. These constitute critical parameters conditioning the yield, type, and concentration of phytochemicals in the raw material, and hence the efficacy of a preparation undergoing clinical use, specifically concerning the modulation of gut microbiota.

Regulatory Issues

The marketing of plant protection products and other pesticide products is regulated in different ways around the world, with important implications for exporters that must be able to supply the products within each receiving country's legal and administrative framework. In China, the regulatory framework includes the Pesticide Administration Regulation of the People's Republic of China, Implementing Regulations of the Pesticide Administration Regulations, and other regulations and policy documents [3]. For plant protection products containing biopesticide active substances of microbial, botanical, or animal origin, and substances or micro-organisms controlling harmful organisms through chemical or biological means, registration procedures are laid out by the Ministry of Agriculture and Rural Affairs [5]. Such registration requires documentation on product efficacy, safety to humans and the environment, product specifications, and standard operating procedures for production and product analysis. In the United States, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) governs the registration of biopesticides. This legislation requires producers to submit details on product chemistry, acute and chronic toxicity, effects on nontarget species and the environment, and efficacy. Registration and sale of biopesticides is considered a faster and cheaper process than for synthetic chemical pesticides, thus supporting rapid development of products designed to combat resistant pest populations [3, 5].

Future Directions in Research

Modern definitions assume that gut microbiota includes both the microbial strains and their genes. The dependence of gut microbiota function on the diversity and the number of genes present in these microorganisms explains the comprehensive roles of gut microbiota in health and disease [7]. The colonic microbiota maintains healthy enteric function, participates in the metabolism of nutrients, safeguards normal development of the immune system, and prevents colonization by opportunistic pathogens [5]. The colonic microflora also exerts toxic and genotoxic effects via the production of free radicals and reactive oxygen species and the alteration of gene expression. Despite extensive research, it is a challenge to identify beneficial, opportunistic, and probiotic bacteria as well as key genes that confer these qualities [5, 7].

Personalized Medicine

The longitudinal nature of the human adult gut microbiota, alongside its receptivity to dietary and environmental stimulus and the complexity of host–microbe interactions linked to health and disease states, represents a dual challenge and opportunity for personalized medicine based upon phytochemical intervention [5]. With the gut microbiome having emerged as a key modifier of a wide variety of diseases, individually tailored therapeutics hold considerable promise for the development of next-generation, more efficacious formulations [3]. The future of medicine will likely require full integration of community profiling, established or predictive metabolic status, and host genetics to enable an accurate, tailor-made assignment of the most beneficial herbal formulation. Given the variables involved, the resulting formulation will inevitably be distinct from one patient to the next and potentially dynamic in nature for an individual over time [5, 3].

Microbiome Profiling

Understanding the complex community of microorganisms that inhabit our bodies provides vital information about the functioning of the whole system. The human topographic gut is a highly diversified environment that contains potentially the largest and most diverse population of microbes in the human body. Molecular, genomic, and metagenomic techniques have established considerable progress in the profiling of the human microbiome and its association with health and disease [4]. The results indicate that an unbalanced composition of the human microbiome is a fundamental component associated with well-known and emergent human medical conditions, such as diabetes, cardiovascular disease, and allergy. Therefore, the study of the human body as a host comprising several ecosystems has emerged as a central paradigm for the coming era of genomic medicine. Medicinal plants have been used throughout history due to their healing properties in various human diseases. These plants can alter the metabolism of the gut microorganisms, which ultimately influences the composition of the microbial community and affects human health [4].

CONCLUSION

Medicinal plants exert significant effects on the gut microbiota, offering antimicrobial, prebiotic, and immunomodulatory benefits that may help prevent or manage a wide range of disorders. Phytochemicals such as polyphenols, flavonoids, alkaloids, and terpenoids selectively enhance beneficial bacteria, suppress pathogens, and promote the production of metabolites such as short-chain fatty acids and vitamins. Evidence from garlic, ginger, turmeric, peppermint, and chamomile underscores their therapeutic promise in supporting digestive, immune, metabolic, and even mental health. However, challenges remain in translating preclinical and in vitro findings into consistent clinical applications, largely due to variability in plant composition, host microbiota diversity, and the lack of standardized preparations. Future progress will depend on rigorous clinical trials, improved formulation technologies, and integration with probiotics and dietary strategies. By bridging traditional knowledge with modern research, medicinal plants can be developed into effective microbiota-targeted interventions to improve global health.

REFERENCES

1. Lyu M, Wang YF, Fan GW, Wang XY, Xu SY, Zhu Y. Balancing herbal medicine and functional food for prevention and treatment of cardiometabolic diseases through modulating gut microbiota. Frontiers in microbiology. 2017 Nov 8;8:2146.
2. Spisni E, Turroni S, Alvisi P, Spigarelli R, Azzinnari D, Ayala D, Imbesi V, Valerii MC. Nutraceuticals in the modulation of the intestinal microbiota: Current status and future directions. Frontiers in Pharmacology. 2022 Mar 18;13:841782.
3. Peterson CT, Iablokov SN, Uchitel S, Chopra D, Perez-Santiago J, Rodionov DA, Peterson SN. Community metabolic interactions, vitamin production, and prebiotic potential of medicinal herbs used for immunomodulation. Frontiers in genetics. 2021 Feb 3;12:584197.
4. Köberl M, Schmidt R, Ramadan EM, Bauer R, Berg G. The microbiome of medicinal plants: diversity and importance for plant growth, quality and health. Frontiers in microbiology. 2013 Dec 20;4:400.
5. Peterson CT, Sharma V, Uchitel S, Denniston K, Chopra D, Mills PJ, Peterson SN. Prebiotic potential of herbal medicines used in digestive health and disease. The Journal of Alternative and Complementary Medicine. 2018 Jul 1;24(7):656-65.
6. Milutinović M, Dimitrijević-Branković S, Rajilić-Stojanović M. Plant extracts rich in polyphenols as potent modulators in the growth of probiotic and pathogenic intestinal microorganisms. Frontiers in Nutrition. 2021 Jul 30;8:688843.
7. Mukherjee S, Joardar N, Sengupta S, Babu SP. Gut microbes as future therapeutics in treating inflammatory and infectious diseases: lessons from recent findings. The Journal of Nutritional Biochemistry. 2018 Nov 1;61:111-28.
8. Kmail A. Mitigating digestive disorders: Action mechanisms of Mediterranean herbal active compounds. Open Life Sciences. 2024 Apr 18;19(1):20220857.
9. Góralczyk-Bińkowska A, Szmajda-Krygier D, Kozłowska E. The microbiota–gut–brain axis in psychiatric disorders. International journal of molecular sciences. 2022 Sep 24;23(19):11245.
10. Ganci M, Suleyman E, Butt H, Ball M. The role of the brain–gut–microbiota axis in psychology: The importance of considering gut microbiota in the development, perpetuation, and treatment of psychological disorders. Brain and behavior. 2019 Nov;9(11):e01408.
11. Del Toro-Barbosa M, Hurtado-Romero A, Garcia-Amezquita LE, García-Cayuela T. Psychobiotics: mechanisms of action, evaluation methods and effectiveness in applications with food products. Nutrients. 2020 Dec 19;12(12):3896.

12. Tudu CK, Dutta T, Ghorai M, Biswas P, Samanta D, Oleksak P, Jha NK, Kumar M, Radha, Proćków J, Pérez de la Lastra JM. Traditional uses, phytochemistry, pharmacology and toxicology of garlic (Allium sativum), a storehouse of diverse phytochemicals: A review of research from the last decade focusing on health and nutritional implications. Frontiers in Nutrition. 2022 Oct 28;9:949554.
13. Chen K, Nakasone Y, Xie K, Sakao K, Hou DX. Modulation of allicin-free garlic on gut microbiome. Molecules. 2020 Feb 5;25(3):682.
14. Zam W. Gut microbiota as a prospective therapeutic target for curcumin: A review of mutual influence. Journal of nutrition and metabolism. 2018;2018(1):1367984.
15. Tafrihi M, Imran M, Tufail T, Gondal TA, Caruso G, Sharma S, Sharma R, Atanassova M, Atanassov L, Valere Tsouh Fokou P, Pezzani R. The wonderful activities of the genus Mentha: Not only antioxidant properties. Molecules. 2021 Feb 20;26(4):1118.
16. Sah A, Naseef PP, Kuruniyan MS, Jain GK, Zakir F, Aggarwal G. A comprehensive study of therapeutic applications of chamomile. Pharmaceuticals. 2022 Oct 19;15(10):1284.
17. El Mihyaoui A, Esteves da Silva JC, Charfi S, Candela Castillo ME, Lamarti A, Arnao MB. Chamomile (Matricaria chamomilla L.): a review of ethnomedicinal use, phytochemistry and pharmacological uses. Life. 2022 Mar 25;12(4):479.
18. Alum EU, Ugwu OPC, Obeagu EI, et al. Nutritional care in diabetes mellitus: A comprehensive guide. Int J Innov Appl Res. 2023;11(12):16-25.
19. Obeagu EI, Ahmed YA, Obeagu GU, Bunu UO, Ugwu OPC, Alum EU. Biomarkers of breast cancer: Overview. Int J Curr Res Biol Med. 2023;1:8-16.
20. Uti DE, Alum EU, Atangwho IJ, Ugwu OPC, et al. Lipid-based nano-carriers for the delivery of anti-obesity natural compounds: Advances in targeted delivery and precision therapeutics. J Nanobiotechnol. 2025;23:336.
21. Ugwu CN, Ugwu OPC, Alum EU, Eze VHU, Basajja M, Ugwu JN, Ogenyi FC, et al. Medical preparedness for bioterrorism and chemical warfare: A public health integration review. Medicine. 2025;104(18):e42289.
22. Obeagu EI, Scott GY, Amekpor F, Ugwu OPC, Alum EU. COVID-19 infection and diabetes: A current issue. Int J Innov Appl Res. 2023;11(1):25-30.
23. Offor CE, Ugwu OPC, Alum EU. Anti-diabetic effect of ethanol leaf extract of *Allium sativum* on albino rats. Int J Pharm Med Sci. 2014;4(1):1-3.
24. Asogwa FC, Okechukwu PCU, Esther UA, Chinedu OE, Nzubechukwu E. Hygienic and sanitary assessment of street food vendors in selected towns of Enugu North District, Nigeria. Am-Eurasian J Sci Res. 2015;10(1):22-26.
25. Alum EU, Uti DE, Agah VM, Orji OU, Nkeiru N, et al. Physico-chemical and bacteriological analysis of water used for drinking and domestic purposes in Amaozara Ozizza, Afikpo North, Nigeria. Niger J Biochem Mol Biol. 2023;38(1):1-8.
26. Ugwu OPC, Alum EU, Okon MB, Obeagu EI. Mechanisms of microbiota modulation: Implications for health, disease, and therapeutic interventions. Medicine. 2024;103(19):e38088.
27. Ezekwe CI, Uzomba CR, Ugwu OPC. Effect of methanol extract of *Talinum triangulare* on hematology and liver parameters in rats. Glob J Biotechnol Biochem. 2013;8(2):51-60.
28. Alum EU, Inya JE, Ugwu OPC, Obeagu EI, Aloke C, Aja PM, Okpata MG, et al. Ethanolic leaf extract of *Datura stramonium* attenuates methotrexate-induced biochemical alterations in Wistar rats. RPS Pharmacol Rep. 2023;2(1):1-6.
29. Ugwu OPC, Erisa K, Inyangat R, Obeagu EI, et al. Indigenous medicinal plants for managing diabetes in Uganda: Ethnobotanical and pharmacotherapeutic insights. INOSR Exp Sci. 2023;12(2):214-224.
30. Alum EU, Aja W, Ugwu OPC. Vitamin composition of ethanol leaf and seed extracts of *Datura stramonium*. Avicenna J Med Biochem. 2023;11(1):92-97.
31. Ezenwaji CO, Alum EU, Ugwu OPC. Digital health in pandemic preparedness and response: Securing global health? Glob Health Action. 2024;17(1):2419694.
32. Adonu CC, Ugwu OP, Bawa A, Ossai EC, Nwaka AC. Intrinsic blood coagulation studies in patients with diabetes and hypertension. Int J Pharm Med Bio Sci. 2013;2(2):36-45.
33. Offor CE, Ugwu PC, Okechukwu PM, Igwenyi IO. Proximate and phytochemical analyses of *Terminalia catappa* leaves. Eur J Appl Sci. 2015;7(1):9-11.
34. Enechi YS, Ugwu OC, Ugwu KK, Ugwu OPC, Omeh N. Evaluation of antinutrient levels of *Ceiba pentandra* leaves. IJRRPAS. 2013;3(3):394-400.

35. Alum EU, Uti DE, Ugwu OPC, Alum BN, Edeh FO, Ainebyoona C. Microbiota in cancer development and treatment. Discov Oncol. 2025;16(1):646.
36. Asogwa FC, Okoye COB, Ugwu OPC, Edwin N, Alum EU, Egwu CO. Phytochemistry and antimicrobial assay of *Jatropha curcas* extracts. Eur J Appl Sci. 2015;7(1):12-16.
37. Enechi OC, Oluka HI, Ugwu PCO. Acute toxicity and ameliorative properties of *Alstonia boonei* leaf extract on diabetic rats. Afr J Biotechnol. 2014;13(5).
38. Alum EU, Obeagu EI, Ugwu OPC. Enhancing water, sanitation, and hygiene for diarrhoea control and SDGs: A review. Medicine. 2024;103(38):e39578.
39. Odo CE, Nwodo OFC, Joshua PE, Ugwu OPC, Okonkwo CC. Anti-diarrhoeal effect of chloroform–methanol extract of *Persea americana* seeds in rats. J Pharm Res. 2013;6(3):331-335.
40. Ugwu OPC, Obeagu EI, Alum EU, Michael M, et al. Effect of ethanol leaf extract of *Chromolaena odorata* on hepatic markers in diabetic rats. IAA J Appl Sci. 2023;9(1):46-56.
41. Ibiam UA, Alum EU, Orji OU, Aja PM, Nwamaka EN, Ugwu OPC, et al. Anti-inflammatory effects of *Buchholzia coriacea* leaf extract in arthritic rats. Indo Am J Pharm Sci. 2018;5(7):6341-6357.
42. Obeagu EI, Obeagu GU, Odo EO, Alum EU. Nutritional approaches for enhancing immune competence in HIV-positive individuals. IDOSR J Appl Sci. 2024;9(1):40-50.
43. Obeagu EI, Alum EU, Ugwu OPC. Hepcidin: Gatekeeper of iron in malaria resistance. Newport Int J Res Med Sci. 2023;4(2):1-8.
44. Nyamboga TO, Ugwu OPC, Ugwu JN, et al. Biotechnological innovations in soil health management: a systematic review of integrating microbiome engineering, bioinformatics, and sustainable practices. Cogent Food Agric. 2025;11(1):2519811.
45. Madu ANB, Alum EU, Aloh HE, Ugwu OPC, Obeagu EI, Uti DE, Egba SI, Ukaidi CUA. The price of progress: Assessing the financial costs of HIV/AIDS management in East Africa. Medicine. 2025;104(18):e42300.
46. Alum EU, Ugwu OPC. Beyond pregnancy: Understanding long-term implications of gestational diabetes mellitus. INOSR Sci Res. 2024;11(1):63-71.
47. Ugwu OPC, Alum EU, Okon MB, Aja PM, Obeagu EI, Onyeneke EC. Anti-nutritional and GC-MS analysis of ethanol root extract and fractions of *Sphenocentrum jollyanum*. RPS Pharmacol Pharm Rep. 2023;2(2):rqad007.
48. Eze VHU, Eze CE, Mbabazi A, Ugwu CN, Ugwu PO, Ogenyi CF, Ugwu JN, et al. Qualities and characteristics of a good scientific research writing: Step-by-step approaches. IAA J Appl Sci. 2023;9(2):71-76.
49. Igwenyi IO, Nchi PO, Okechukwu UPC, Igwenyi IP, Obasi DC, Edwin N. Nutritional potential of *Azadirachta indica* seeds. Indo Am J Pharm Sci. 2017;4(2):477-482.
50. Enechi OC, Oluka IH, Ugwu OPC, Omeh YS. Effect of ethanol leaf extract of *Alstonia boonei* on lipid profile of alloxan-induced diabetic rats. Afr J Biotechnol. 2013;24.
51. Ugwu OPC. Anti-malaria effect of ethanol extract of *Moringa oleifera* leaves on malaria-induced mice. University of Nigeria Nsukka; 2011:39.
52. Alum EU, Ugwu OPC, Obeagu EI. Nutritional interventions for cervical cancer patients: Beyond conventional therapies. J Cancer Res Cell Ther. 2024;8(1):1-6.
53. Obeagu EI, Obeagu GU. Advancements in immune augmentation strategies for HIV patients. IAA J Biol Sci. 2024;11(1):1-11.
54. Okechukwu PU, Nzubechukwu E, Ogbanshi ME, Ezeani N, Nworie MO. Effect of ethanol leaf extract of *Jatropha curcas* on chloroform-induced hepatotoxicity in albino rats. Glob J Biotech Biochem. 2015;10:11-15.
55. Ilozue NM, Ikezu UP, Okechukwu PCU. Antimicrobial and phytochemical screening of *Persea americana* seed extracts. IOSR J Pharm Biol Sci. 2014;9(2):23-25.
56. Onyeze R, Udeh SM, Akachi B, Ugwu OP. Isolation and characterization of fungi associated with spoilage of corn (*Zea mays*). Int J Pharm Med Biol Sci. 2013;2(3):86-91.
57. Obeagu EI, Alum EU, Ugwu OPC. Hepcidin: The gatekeeper of iron in malaria resistance. Newport Int J Res Med Sci. 2023;4:1-8.
58. Obeagu EI, Alum EU, Obeagu GU, Ugwu OPC. Prostate cancer: Review on risk factors. Eurasian Exp J Public Health. 2023;4(1):4-7.

59. Offor CE, Okaka ANC, Ogbugo SO, Egwu CO, Okechukwu PC. Effects of ethanol leaf extract of *Pterocarpus santalinoides* on haemoglobin, packed cell volume and platelets. IOSR J Nurs Health Sci. 2015;4:108-112, 93.
60. Offor C, Aja PC, Ugwu O, Agbafor KN. Effects of ethanol leaf extract of *Gmelina arborea* on serum proteins in albino rats. Glob J Environ Res. 2015;9(1):1-4.
61. Alum EU, Uti DE, Obeagu EI, Ugwu OPC, Alum BN. Cancer's psychosocial aspects: Impact on patient outcomes. Elite J Med. 2024;2(6):32-42.
62. Alum EU, Ugwu OPC, Egba SI, Uti DE, Alum BN. Climate variability and malaria transmission: Unravelling the complex relationship. INOSR Sci Res. 2024;11(2):16-22.
63. Alum EU, Obeagu EI, Ugwu OPC, Egba SI, EjimUti DE, Ukaidi CUA, et al. Confronting dual challenges: Substance abuse and HIV/AIDS. Elite J HIV. 2024;2(5):1-8.
64. Isaac Edyedu PMA, Ugwu OPC, Ugwu CN, Alum EU, et al. The role of pharmacological interventions in managing urological complications during pregnancy and childbirth: A review. Medicine. 2025;104(7):e41381.

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