Medicinal Plants as Functional Food Candidates

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Challenges and Opportunities

Edited by

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CHAPTER ONE

ROLE OF TRADITIONAL MEDICINAL PLANTS IN FUNCTIONAL FOOD DEVELOPMENT

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Abstract

Functional foods, a growing sector in the food industry, provide health benefits beyond basic nutrition through bioactive compounds like vitamins, minerals, antioxidants, and probiotics. These foods can improve health and reduce the risk of chronic diseases, driven by consumer awareness of diet-health links and a preference for natural, preventive healthcare solutions. Medicinal plants have been integral to traditional medicine for centuries, offering therapeutic compounds such as alkaloids, flavonoids, glycosides, and terpenoids including anti-inflammatory, antimicrobial, antioxidant, and anticancer properties. Medicinal plants, with herbal remedies from leaves, roots, bark, and flowers, are used to manage chronic diseases, boost the immune system, and enhance well-being. When integrated into functional foods, medicinal plants like turmeric, garlic, ginger, and aloe vera enhance dietary value and promote health by reducing chronic disease risks, improving mental health, and boosting overall well-being. The continued research, sustainable practices, and integration of medicinal plants with modern medicine highlight their potential in global healthcare. Continued study, sustainable practices, and integration with modern medical approaches are essential to harness the full benefits of medicinal plants, highlighting their potential application in global healthcare systems.

Keywords: medicinal plants; functional foods; nutrition; chronic diseases; immune booster.

Introduction

The affirmative rise of functional foods has created a dazzling new paradigm in the world of nutrition, reshaping our understanding of human health. At the heart of this shift lies an intriguing paradox: while modern life pulls us away from natural bounty, the essence of optimal health may be found in foods that return us to that lost nutritional paradise. These foods are more than merely sustenance, they are essential components of a lifestyle conducive to wellness, offering benefits that extend beyond basic nutrition. The gravity of their impact on health is immense, creating a buoyant sense of hope in the fight against chronic diseases. In an ambiance of scientific discovery and growing deference to ancient wisdom, the integrity of functional foods stands strong. They embody a harmonious balance between tradition and innovation, offering solutions grounded in nature while supported by cutting-edge research. This chapter explores the vibrant role of functional foods, their undeniable importance, and how they illuminate a path toward a healthier future.

According to FSSAI, "functional foods" refer to foods that offer benefits beyond basic nutrition and can help lower the risk of specific diseases and health issues. These functional foods increase general well-being and promote overall health. They generally target in a physiological way along with specific health issues. Products with omega-3 added, foods high in antioxidants, probiotics (active bacteria for gut health), prebiotics (fiber for probiotic growth), and fortified foods (such as juice enriched with calcium). These days, consumers prefer to eat more functional meals to improve their health. These foods guarantee preventative healthcare and a comprehensive approach to wellness. Functional foods are a wide range of products that offer specific health benefits over simple nourishment. Functional foods can be naturally occurring or enhanced with plant bioactive compounds that promote health. Bioactive substances, particularly phenolics, are abundant in plants (Obayomi et al. 2024).

Plant phenolics are considered as an important and sustainable agent with promising antibiofilm and antifungal properties. Apart from these benefits, it is also highlighted that the frequent presence of phenolic and flavonoid compounds is crucial, as they are closely correlated with the best anti-inflammatory and antioxidant activities in medicinal plants, complementing their therapeutic potential (Ahlawat et al. 2024).

Classification of Medicinal Plant-Based Functional Foods

Medicinal plants have long been used in traditional medicine as sustainable sources of therapeutic remedies, offering a wealth of bioactive compounds with pharmacological properties. Despite advances in conventional therapies, interest in herbal medicine is growing due to concerns over the toxicities of standard treatments. Free radicals play a key role in many diseases, including cancer, Alzheimer's, and cardiovascular disease, and antioxidants from medicinal plants can help mitigate their effects. These antioxidants, influenced by factors like plant origin and environment, possess anti-inflammatory and anti-cancer properties (Shoker, Al-Shammery, and Al-Aidy 2023).

In modern times, A diverse range of plant-material-based pharmaceutical products, including extracts, oleoresins, essential oils, tinctures, decoctions and infusions are eligible for therapeutic use. Apart from their conventional applications, medicinal plants hold the imperative potential for contributing to the synthesis and development of novel drugs. The classification of medicinal plant-based functional foods can be approached from various perspectives depending on their properties, uses, and active components. Here's a breakdown of how medicinal plant-based functional foods are typically classified by:

1. Functional Benefits.

Immunomodulatory foods derived from medicinal plants contain compounds that help regulate the immune system, enhancing its response or bringing it into balance to combat infections, diseases, or reduce inflammation. Echinacea, for example, is often used to boost immune function, especially during colds and flu, as it promotes white blood cell production, essential for fighting infections. **Antioxidant**-rich foods like green tea, berries, and turmeric help mitigate oxidative stress. Matcha tea, a traditional Japanese tea, contains approximately ten times more bioactive compounds and polyphenols than typical green teas. As a powdered form of green tea leaves, it is dissolved directly in hot water and consumed unfiltered, making it one of the most potent natural antioxidant sources available (Sivanesan et al. 2021). **Anti-inflammatory** plants, such as ginger, turmeric, and garlic, also support immune health. Ginger, for instance, offers anti-inflammatory, antioxidant, anti-cancer, and neuroprotective benefits; fresh ginger roots are high in gingerols, while dried ginger contains abundant shogaols (Pázmándi, Szöllősi, and Fekete 2024).

Natural products also offer cardioprotective effects through their anti-oxidative, anti-hypercholesterolemic, anti-ischemic, and platelet aggregation-inhibiting properties. Certain medicinal plants, including garlic (*Allium sativum* L.), ginkgo biloba, quinine (Cinchona ledgeriana), curry leaf (*Murraya koenigii*), fenugreek, and sweet pepper (*Capsicum annuum*), show potential in managing cardiovascular health (Singhai, Rathee, Jain, and Patil 2024). Additionally, plants like fennel, peppermint, and aloe vera aid digestion, while carom seeds (*Trachyspermum ammi*) and fennel seeds (*Foeniculum vulgare*) provide anti-diabetic, antioxidant, and antibacterial benefits (Karamat et al. 2024).

2. Phytochemical Content

Plant-derived natural antioxidants primarily consist of polyphenols—such as stilbenes, anthocyanins, flavonoids, lignans, and phenolic acids—as well as carotenoids (including carotenes and xanthophylls) and vitamins C and E. These antioxidants, especially carotenoids and polyphenols, are known for their wide range of biological effects, including anti-aging, anti-inflammatory, antiviral, antimicrobial, and anti-cancer properties (Xu et al. 2017). *Moringa concanensis* leaves are noted for their antioxidant and antibacterial capabilities (Ayyanar et al. 2024). **Polyphenols**, found in foods like green tea, berries, and olive oil, are recognized for their antioxidant effects.

Alkaloids, nitrogenous compounds of plant origin, play roles in various biological processes across plants, animals, and microorganisms at cellular levels and are studied for their stimulant or sedative properties in plants like ginseng and certain herbal teas (Laghezza et al. 2021). **Terpenoids**, found in spices such as ginger and turmeric, also possess anti-inflammatory effects. For instance, terpenoids in *Chrysanthemum indicum*, such as Chrysanthemulide A, have shown potential anti-inflammatory activity by inhibiting the LPS-induced NF-κB pathway and reducing MAPK activation.

Flavonoids, present in fruits, vegetables, and teas, provide cardiovascular benefits and have anti-cancer properties. These, along with other phenolic components, are widely regarded for their antioxidant, anticancer, antibacterial, and cardioprotective effects, as well as their roles in anti-inflammation, immune support, skin UV protection, and potential pharmaceutical applications (Andreu et al. 2018). Flavonoid content was found in Whole plant of *Aerva lanata* (L.) Juss. Ex Schult., *Jasminum grandiforum* Linn., *Justicia adhatoda* L. and in the bark of *Cassia fistula* L., *Ficus racemosa* L. They contribute to the nutritional value providing health-beneficial effects (Sulaiman and Balachandran, 2012).

3. Plant Part Used

Functional foods can be categorized based on the specific part of the plant utilized. Plants such as ginseng, ginger, and turmeric are valued primarily for their **root**-derived active compounds. Ashwagandha roots are used to address a wide range of health issues, including insomnia, arthritis, constipation, stress, gastrointestinal and skin conditions, nerve breakdown, diabetes, fever, snake bites, memory loss, and reducing the risk of cancers in the lungs, kidneys, breasts, and prostate (Shantabi and Jagetia 2015). Ashoka bark is applied in gynecology, especially for menstrual irregularities and excessive bleeding (Petri and Ashok 2012), and for conditions like arrhythmia and cardiac weakness (Pillai et al., 2012). Gambhari roots are used to treat abdominal tumors, hallucinations, hemorrhoids, and urinary infections (Mishra and Padhy 2013). Medicinal plants like green tea, basil, and moringa rely on their **leaves** for functional benefits. Gambhari (*Gmelina arborea*) leaves, for instance, are used in epilepsy management (Mishra and Padhy 2013).

Lemon **fruit** juice is recognized for its immune-boosting and weight-loss properties (Boukhatem et al. 2014). Cassia fistula fruits are used to treat skin conditions, abdominal pain, rheumatism, leprosy, and burning sensations. **Seeds** like flaxseeds, chia, and fenugreek are valued for their nutrient density and medicinal properties, while black pepper enhances digestive health (Sidhu et al. 2007). Chamomile and hibiscus are commonly used for their health benefits derived from their **flowers**. Neem flowers are employed in treating bile disorders and infertility (Garg, Talwar, and Upadhyay 1998).

4. Form of Consumption

Medicinal plants are consumed in various forms to optimize their therapeutic benefits and suit individual needs. **Capsules** and tablets are commonly used for standardized dosing, offering consistent amounts of active compounds like curcumin from turmeric or allicin from garlic. **Teas and infusions** are also popular, especially for plants like chamomile or peppermint; steeping these in hot water effectively extracts their beneficial compounds with minimal processing. Beverages, such as kombucha, turmeric lattes, and aloe vera juice, are frequently consumed to address common flu symptoms and support general health and fitness. **Powders** made from dried herbs, such as ashwagandha or ginger, are versatile and can easily be added to smoothies or meals. Dried Licorice is used in pharmaceuticals and herbal medicine industry. (Mohammadi and Saghaian 2022)

For localized relief, topical applications such as ointments, creams, and essential oils are used for plants like aloe vera and lavender, which are beneficial for treating skin issues or muscle pain. Fresh or dried whole herbs are also sometimes consumed **directly**; for example, fresh mint leaves can be chewed for digestive support, and garlic cloves are often incorporated into meals to boost immune health. Each consumption method offers specific advantages, with choices often depending on desired outcomes, convenience, and the plant's potency. Additionally, functional foods, like granola bars, are increasingly enriched with medicinal plant extracts, such as ginseng or turmeric, to enhance their health benefits.

5. Legal and Market Classification

Regulatory bodies categorize functional foods according to their ingredients and the health claims they make. **Nutraceuticals**, for instance, are foods enriched with medicinal plants designed to deliver specific health benefits, while dietary supplements provide concentrated doses of these plants in forms like pills, capsules, or powders. **Herbal medicines** focus on using medicinal plants for therapeutic purposes and are often classified under natural or alternative medicine categories. For example, turmeric (*Curcuma longa*) contains curcumin, a compound with known anti-inflammatory and antioxidant properties that aids in managing inflammation and boosting immune health. Ginger (*Zingiber officinale*), with its active compound gingerol, supports digestion and alleviates nausea. Ginseng (*Panax ginseng*), recognized as a traditional adaptogen, is valued for enhancing energy, mental clarity, and stress resilience. Similarly, garlic (*Allium sativum*), high in allicin, is studied for its cardiovascular benefits, such as lowering blood pressure and cholesterol levels. These examples illustrate how nutraceuticals can leverage natural compounds in medicinal plants to target specific health benefits.

Nutraceuticals are particularly valuable for their therapeutic properties, as they contain bioactive compounds like polyphenols, terpenoids, tannins, alkaloids, and flavonoids, which may help manage serious diseases such as diabetes, atherosclerosis, cancer, neurodegenerative, and blood disorders (Espinosa-Paredes 2021). Baicalin, a flavonoid derived from the dried root of *Scutellaria baicalensis*, is used to address central nervous system (CNS) disorders, liver diseases, and inflammatory issues. Another example, kaempferol—a flavonol from *Moringa oleifera* (the miracle tree)—is known to inhibit CDK1, arresting the cell cycle in the G2/M phase (Akram, Iqbal, Daniyal, and Khan 2017). Researchers have identified kaempferol as a potent Nrf2 inducer, which may regulate Nrf2 and its enzyme NAD(P)H: quinone oxidoreductase 1 (NQO1) in MCF-7 cells, potentially preventing

oncogene transformation. Additionally, polyphenol-rich foods like pomegranates, strawberries, walnuts, and muscadine grapes are known to suppress cancer cell growth and promote apoptosis. These medicinal plants are also available as dietary supplements in concentrated doses, including pills, capsules, and powders.

The Table format for the classification of medicinal plant-based functional foods is given below:

Table 1. Classification of Medicinal Plant-Based Functional Foods

classification	Description	Example of plants	Primary compounds	Health benefits
nutraceuticals	Foods enriched with medicinal plant compounds to deliver specific health benefits and therapeutic effects, often for managing serious health conditions.	Turmeric (*Curcuma longa*), Garlic (*Allium sativum*), Pomegranate (*Punica granatum*), Green tea (*Camellia sinensis*), Moringa (*Moringa oleifera*)	Curcumin, Allicin, Polyphenols, Catechins	Anti-inflammatory, antioxidant, heart health, immune support, cancer prevention
Dietary Supplements	Concentrated plant extracts provided in capsule, pill, or powder form for ease of consumption and controlled dosing.	Flaxseed (*Linum usitatissimum*), Ginseng (*Panax ginseng*), Ashwagandha (*Withania somnifera*), Bilberry (*Vaccinium myrtillus*), Fenugreek (*Trigonella foenum-graecum*)	Omega-3 fatty acids, Ginsenosides, Withanolides, Anthocyanins	Supports heart health, cognitive function, energy boost, blood sugar regulation, digestive health
Herbal Medicines	Medicinal plants used in natural or alternative medicine for their therapeutic	Ginger (*Zingiber officinale*), Neem (*Azadirachta indica*), Holy Basil (*Ocimum*	Gingerols, Azadirachtin, Eugenol, Cichoric acid, Glycyrrhizin	Anti-inflammatory, immune support, stress relief, antiviral,

	effects, often consumed as teas, tinctures, or extracts.	*sanctum*), Echinacea (*Echinacea purpurea*), Licorice root (*Glycyrrhiza glabra*)		digestive and liver support
Functional Foods	Everyday foods fortified with medicinal plant extracts to provide additional health benefits, often incorporated in diets as snacks or meal supplements.	Baicalin (from *Scutellaria baicalensis*), Ginseng (*Panax ginseng*), Goji berry (*Lycium barbarum*), Elderberry (*Sambucus nigra*), Reishi mushroom (*Ganoderma lucidum*)	Baicalin, Ginsenosides, Polysaccharides, Anthocyanins	Supports mental clarity, immune health, anti-inflammatory, liver support, respiratory health
Infusions & Teas	Plant-based teas or infusions that release bioactive compounds when steeped, providing wellness benefits in a natural form.	Chamomile (*Matricaria chamomilla*), Peppermint (*Mentha piperita*), Hibiscus (*Hibiscus sabdariffa*), Dandelion root (*Taraxacum officinale*), Lemon balm (*Melissa officinalis*)	Apigenin, Menthol, Anthocyanins, Inulin, Rosmarinic acid	Relaxation, digestive health, antioxidant, liver health, stress reduction
Topical Applications	Medicinal plants used in creams, ointments, and oils for targeted, localized relief, often for skin conditions, inflammation, or muscle pain.	Aloe vera (*Aloe barbadensis*), Lavender (*Lavandula angustifolia*), Tea tree (*Melaleuca alternifolia*), Calendula (*Calendula officinalis*), Arnica (*Arnica montana*)	Aloin, Linalool, Terpinen-4-ol, Flavonoids, Sesquiterpene lactones	Skin health, wound healing, anti-inflammatory, antimicrobial, pain relief

Whole Herbs & Fresh Forms	Fresh or dried herbs consumed directly or in cooking to add natural health benefits in daily diets.	Garlic, Mint (*Mentha* spp.), Basil (*Ocimum basilicum*), Cilantro (*Coriandrum sativum*), Rosemary (*Rosmarinus officinalis*)	Allicin, Menthol, Eugenol, Coriandrol, Carnosic acid	Immune support, digestive relief, anti-inflammatory, detoxification, cognitive support

Medicinal plants and chronic diseases

The development of functional foods using medicinal plants has gained significant attention. Recent studies suggest that integrating bioactive components from medicinal plants into diets can improve outcomes for various chronic conditions, including cancer, cardiovascular diseases, hyperuricemia, and neurodegenerative disorders like Alzheimer's and Parkinson's disease. Plant-based compounds like polyphenols, flavonoids, and terpenoids offer antioxidant, anti-inflammatory, and neuroprotective benefits. These bioactive ingredients, found in traditional medicinal plants such as tulsi, neem, and ashwagandha, are increasingly incorporated into functional foods aimed at enhancing health and preventing disease progression. This approach leverages the natural therapeutic potential of plants, making them a valuable tool in modern healthcare and nutrition.

1. Diabetes mellitus (DM)

Diabetes mellitus (DM) represents the genesis of metabolic abnormalities characterized by insane levels of glucose due to disruptions in insulin production or naive insulin resistance, sometimes both (Sivakumar et al. 2023). DM is classified into three apart types (Faselis et al. 2020). Type 1 diabetes, an autoimmune disorder, arises from the destruction of insulin-producing cells in the pancreas, leading to minimal or no insulin production. —a condition where daily insulin intake is unacceptable to neglect for survival. This form primarily affects children and young adults and develops with shocking ease. Type 2 diabetes, accounting for over 90% of adult cases, occurs when the pancreas produces sufficient insulin, but the body fails to use it effectively, reflecting insulin resistance. Despite adequate insulin, its utilization becomes a major development issue. Gestational diabetes mellitus (GDM), a disorder commonly arising during second or third trimester of pregnancy, occurs due to hormonal changes or insulin deficiency. While buoyant during pregnancy, this form is one of the

most frequent and innovative metabolic challenges faced during that time (Adler et al., 2021). Some of the indigenous medicinal plants used in the management of dibetes are *Moringa oleifera, Aloe babadensis* miller, *Azadiracta indica, Trigonella Foenum-graecum, Opuntia ficus-indica, Cassia occidentalis, Urtica dioica L.* etc (Frimpong et al. 2024). *Cassia angustifolia* is known to be chosen as an anti-diabetic medicinal plant because its phytochemicals can bind to alpha amylase for anti-diabetic prophylaxis (Devaraji, Sivaraman, and Prabhu 2024).

Data analysis revealed that certain medicinal plants, including *Allium sativum* (garlic), *Cinnamomum verum* (cinnamon), *Trigonella foenum-graecum* (fenugreek), *Silybum marianum* (milk thistle), *Citrullus colocynthis* (bitter apple), *Abelmoschus esculentus* (okra), *Eryngium*, *Coriandrum sativum* (coriander), and *Zingiber officinale* (ginger), are frequently utilized in managing diabetes. These plants help lower blood sugar levels through their active medicinal compounds and natural antioxidants. Although they generally have fewer side effects, the treatment duration tends to be longer (Gholamine et al. 2024)

2. Cancer

Cancer is a major public health concern that places a significant burden on healthcare systems worldwide. In particular, the rising incidence of cancer is putting immense strain on medical infrastructure, treatment resources, and healthcare providers. However, a study conducted by the World Health Organization (WHO) indicates that the prevalence of cancer in India is notably lower compared to Western countries such as the United States. One of the key factors attributed to this difference is the traditional Indian diet, which intricately weaves together religious and cultural practices with secular health principles. This diet, deeply rooted in ancient wisdom, emphasizes the use of natural, plant-based ingredients that may offer protective health benefits.

For centuries, herbs and spices have been an indispensable part of the traditional Indian diet. The ancient system of medicine known as Ayurveda, which has been practiced for thousands of years in India, includes over 700 plant-based remedies aimed at promoting overall health and preventing illness. Many of these remedies have been scientifically explored for their potential anti-cancer properties. Herbs such as safed musli (*Chlorophytum borivilianum*), harshringar (*Nyctanthes arbor-tristis*) (Parekh, Smita, and Soni 2020), *neem* (*Azadirachta indica*) (Moga et al. 2018), and tulsi (*Ocimum sanctum*) are a few of the botanicals that researchers have studied for their cancer-preventive qualities. Numerous studies have shown that these herbs possess a range of bioactive compounds with antioxidant, anti-

inflammatory, and immune-promoting properties, which may help inhibit the growth of cancer cells or prevent their formation in the first place.

3. Cardiovascular diseases (CVDs)

Cardiovascular diseases (CVDs) are a prime cause of death in developed countries and are estimated to increase financial health expenditures. World Health Organization (WHO) study states that by 2030, CVDs will lead to 23.3 million deaths around the world. Smoking, diabetes, obesity and hypertension are pioneer causes of CVDs. Epidemiologists have reported that plant-based diet is healthy against the risk of CVDs. Foods derived from plants, particularly fruits and vegetables, include a variety of bioactive substances called phytochemicals that can help with health problems. Likewise, research has shown that eating fruits and vegetables can lower the risk of developing chronic illnesses. According to Dar et al. (2023), bioactive substances such phenolic acid, flavonoids, glucosinolates, and terpenoids have great biological uses against inflammation and a variety of other disorders.

4. Hyperuricemia

Hyperuricemia is well-known metabolic disease resulting from overproduction or obstructed excretion of uric acid (UA) in body. Lack of purine metabolism, renal insufficiency or hereditary factors are prime factors for hyperuricemia. Patients suffering from prolonged hyperuricemia find themselves with the case deposition of monosodium urate crystals (MSU) on smaller body joints leading to the condition known as gout, which with further complications could convert to arthritis (Sun et al. 2022).

Two types of medications are used to treat hyperuricemia: uricosurics, which stimulate the excretion of UA, such as probenecid and benzbromarone, and xanthine oxidase inhibitors (XOI), which include allopurinol, febuxostat, and others. Despite being anti-hyperuricemic medications, many medications may have adverse effects. According to epidemiologic findings, hyperuricemia can be managed with a nutritious diet and way of life. Animals, plants, and microbes all contain bioactive substances, which have demonstrated encouraging promise in treating hyperuricemia. They are extensively employed in the development of functional foods and nutraceuticals for the prevention of anti-oxidant, anti-inflammatory, and anti-cancer effects. In mice with potassium oxonate (PO)-induced hyperuricemia, the treatment of allopurinol (2.5 mg/kg) and highly acylated anthocyanins from purple sweet potatoes (25 mg/kg) dramatically decreased kidney damage and inflammatory cell infiltration. A

decrease in blood malondialdehyde content, serum total superoxide dismutase activity, and the production of inflammatory cytokine proteins may be the cause of this impact (Jiang et al. 2020).

5. Alzheimer's disease (AD)

Alzheimer's disease (AD) is a well-known neurological condition that significantly impairs memory and changes how people think. It is the fifth most deadly disease in the world and causes the majority of dementia cases. as a neurodegenerative disease (NDD) that frequently impairs memory, thinking, and eventually the capacity for everyday motor tasks. The illness is more prevalent in those over 65, although it can also strike younger people. The main risk factor for AD is getting older. According to research, 32% of patients 85 years of age or older, 17% of patients 75-84 years of age, and 3% of patients 65-74 years of age had Alzheimer's disease dementia. Research has shown that the bioactive components of plants can help people with AD by lowering their symptoms. Foods high in antioxidants from plants have a variety of pharmacological benefits because they reduce oxidative stress in the brain. Flavonoids such flavones, isoflavones, flavanones, and chalcones, as well as alkaloids like glantamine, huperzines, berberine, and aporphine, have demonstrated encouraging results in lessening the effects of AD in people. Nature contains large quantities of these alkaloids and flavonoids. As a result, it could be readily utilized by patients as a component of virgin or supplemental foods (Islam et al. 2022).

6. Parkinson's Disease (PD)

Parkinson's Disease (PD) ranks as second most absolute chronic neurodegenerative disorder, followed by Alzheimer's Disease (AD), and is predominantly observed in the aging population. The intense progression of PD is defined by synucleinopathy, where neurons in specific brain regions are subjected to immense damage, thereby generating motor symptoms such as muscle stiffness, tremors, and postural instability. Synucleinopathies are a group of disorders marked by the prion-like propagation through neuronal pathways and the abnormal buildup of α-synuclein in glial or neuronal cells. Despite this, comprehending the root causes of Parkinson's disease remains difficult, as the factors triggering its onset are not yet completely understood (Kumari et al. 2023). Phytochemicals derived from medicinal plants, such as polyphenols, terpenes, and alkaloids, exhibit significant potential as therapeutic agents for Parkinson's Disease (PD). Medicinal plants such as *Ocimum sanctum* (tulsi), *Tinospora cordifolia* (giloy), and *Withania somnifera* (ashwagandha) are rich sources of these bioactive compounds,

offering a readily available reservoir of neuroprotective substances that may help mitigate the progression of PD and its associated neurodegenerative effects.

Characterization of Bioactive Compounds Present in Medicinal Plants

Enzymes, active protein molecules, are essential for life, mediating critical biochemical processes like metabolism, cellular signaling, cell cycle regulation, and development. Dysfunction in these processes often leads to disease, typically due to abnormal enzyme activity or overexpression. Enzyme inhibitors, which can be either irreversible or reversible, reduce enzyme function by forming enzyme-inhibitor complexes. Many therapeutic and nutritious plants contain enzyme-inhibiting compounds, offering promising applications in nutrition and medicine. Key enzymes targeted by these inhibitors include cholinesterase, urease, xanthine oxidase, angiotensin I-converting enzyme, α-amylase, α-glucosidase, lipoxygenase, and tyrosinase, all associated with conditions such as hypertension, diabetes, skin disorders, inflammation, neurodegenerative diseases, and *Helicobacter pylori* infections (Adler et al. 2021). Given their role in modulating enzyme activity, these inhibitors present potential in health treatments, though careful application is necessary to avoid adverse interactions.

Medicinal plants are vital sources of phytochemicals, which are bioactive compounds crucial for the development of natural and synthetic medicines, cosmetics, and dietary supplements (Li et al. 2020). These compounds also offer nutritional benefits and play key roles as insect attractants, growth hormones, and in influencing sensory properties (Han et al. 2020). Despite their abundance of bioactive compounds, medicinal plants remain underexplored (Nastić et al. 2018). Characterizing these compounds is essential to better understand their properties. The initial stages of utilizing plant bioactive compounds include extraction, pharmacological screening, isolation, and characterization, followed by toxicological and clinical assessments. Figure 1 summarizes the general methods used in extracting, isolating, and characterizing bioactive compounds from plant extracts.

The extraction process is the first critical step in quantifying, identifying, and utilizing these compounds (Tušek et al. 2018). Most extraction methods depend on solvents and often involve heat or mixing. The techniques vary depending on the plant material and the desired substances. The standard procedure includes pre-washing, drying or freeze-drying the plant material, grinding it to ensure uniformity, and enhancing extraction kinetics by

increasing the surface contact with the solvent. The choice of solvent system is influenced by the nature of the bioactive compound. Polar solvents like methanol, ethanol, or ethyl acetate are commonly used to extract hydrophilic compounds, while dichloromethane or a dichloromethane-methanol mix is used for lipophilic compounds. In some cases, hexane extraction removes chlorophyll (Cosa et al. 2006).

Traditional extraction methods, such as Soxhlet extraction, maceration, and hydrodistillation, are widely used to obtain plant bioactive compounds. Soxhlet extraction is commonly applied for valuable bioactive compounds from natural sources, while maceration has been a cost-effective method for home-prepared tonics and essential oils. Hydrodistillation, which involves no organic solvents, is a traditional technique for extracting essential oils and bioactive compounds. It can be performed before dehydrating plant material and includes three types: water distillation, water and steam distillation, and direct steam distillation (Brusotti et al. 2014; Kamil Hussain, Saquib, and Faheem 2019).

Modern extraction methods, including solid-phase micro-extraction, supercritical-fluid extraction, pressurized-liquid extraction, microwave-assisted extraction, solid-phase extraction, and surfactant-mediated techniques, provide benefits such as minimizing solvent use, avoiding sample degradation, and removing the necessity for extra clean-up before chromatographic analysis. These techniques enhance extraction efficiency, selectivity, and kinetics, and are preferred for their potential to be automated (Huie 2002).

Biological assays are used to evaluate a substance's biological activity, such as its potency, efficacy, and toxicity, by testing its effects on living organisms or biological systems. In-vitro assays are laboratory tests using cell cultures or isolated enzymes to measure a substance's impact on biological processes like cell growth and enzyme activity. In-vivo assays involve whole-animal testing to determine therapeutic efficacy, toxicity, and pharmacokinetics. Clinical trials are large-scale studies in humans that evaluate a drug's safety and effectiveness across different patient groups, identifying potential side effects.

The identification and characterization of plant extracts are complex because of the multiple bioactive compounds with different polarities. Various separation techniques like thin-layer chromatography (TLC), column chromatography, flash chromatography, Sephadex chromatography, and high-performance liquid chromatography (HPLC) are used to isolate and identify these compounds. Once isolated, pure compounds undergo structural and biological activity analysis. Non-chromatographic techniques like immunoassays with monoclonal antibodies, phytochemical screening,

and Fourier-transform infrared spectroscopy (FTIR) are also useful in identifying bioactive compounds.

The ultrasound-assisted extraction method is frequently applied to obtain valuable molecules. For instance, extracts from *Sambucus nigra* flowers and *Aspalathus linearis* leaves is found to be rich in polyphenols with strong antioxidant properties, making them promising bioactive substance sources. However, more in-vivo studies are needed to fully understand their mechanisms of action (Gadjalova and Mihaylova 2019). FTIR allows for quick and direct quantification of various phenolic acids in plant extracts through PLS-ATR-FTIR analysis, enabling the identification of common plant compounds by comparing their spectra to a reference library (Sasidharan et al. 2011). Studies have also assessed the total phenolic content in plants like *Thymus vulgaris*, *Origanum vulgare*, *Salvia Rosmarinus*, *Cinnamomum cassia*, and *Syzygium aromaticum* (Bensemmane et al. 2020).

Medicinal Plant-Based Functional foods

1. Herbal tea

Herbal teas are crafted from various plant parts, including leaves, flowers, seeds, fruits, roots, and rhizomes, often enhanced with Chinese herbs for added flavor (Li et al. 2019a; Zhao et al. 2013). Tea has a long and esteemed history, having been enjoyed in China for thousands of years, with herbal (non-camellia) teas dating back to the Tang Dynasty. Herbal teas offer a diverse and gratifying selection, crafted from a wide range of natural ingredients, particularly herbs, that provide key health benefits. Research shows that certain herbal infusions, such as those made from cinnamon bark, mulberry leaves, and blackberry fruits, can significantly inhibit glucose release from complex carbohydrates, helping to reduce postprandial hyperglycemia. These teas could serve as a preventive measure for type II diabetes by modulating glycemic responses and supporting glucose metabolism. Commonly used plants for herbal teas include *Chrysanthemum morifolium* (Hao et al. 2022), *Ilex asprella* (Feng et al. 2022), *Prunella vulgaris*, and *Morus alba*, which are valued for their properties in detoxification, cooling, and addressing urinary tract issues.

Most herbal teas are non-fermented and follow the standard green tea production process, which includes picking, withering, blanching, rolling, and drying. A particularly mature example is the use of tender buds from *Castanopsis lamontii*, dried to create a tea in southwest China that refreshes breath and prevents oral inflammation. Fermented teas, though less

common, also rise to prominence in the herbal tea world, produced in a same way the only difference is including fermentation before drying. Rooibos, a popular herbal tea with immense potential, is produced from *Aspalathus linearis*, indigenous to South Africa, highlighting the sustainable and diverse nature of herbal tea across cultures (Liu et al. 2023).

2. Plant based fermented foods

The growing popularity of fermented plant-based foods is fueled by their appeal to various consumer groups, such as vegetarians, vegans, and individuals with dietary restrictions like lactose intolerance. These products are appreciated for their nutritional benefits, especially their positive impact on gut health, and resonate with ethical and environmental principles, making them a favorite among health-conscious consumers. Additionally, cultural traditions and preferences contribute to the sustained demand for these products, appealing to those with gluten sensitivities and people looking to reduce their environmental footprint.

As such, fermented plant-based foods have garnered widespread interest across different demographic groups, emphasizing their broad-based appeal. Fermented plant extracts (FPEs), especially those originating from Japan, are significant in this category, offering rich sources of nutrients like antioxidants, vitamins, and probiotics. Research highlights their potential health benefits, including cardioprotective, antifungal, and lipid-lowering effects. Fermented foods derived from plants have been researched for their medicinal benefits. Traditional Manipuri medicinal plants, including *Andrographis paniculata*, *Ocimum sanctum*, and *Centella asiatica*, have demonstrated potential for treating ailments such as cancer, diabetes, and neurological disorders (Ayajuddin et al. 2016). These findings have encouraged industrial interest in developing plant-derived fermented beverages, with a focus on extending shelf life and stabilizing formulations. The fermentation process itself, involving microbial interactions, has long been used to preserve food and enhance its nutritional value. The growing market for probiotic products, particularly soy or cereal-based options, is fueled by dairy allergies, gluten or lactose intolerance, and lifestyle choices like veganism (Khayatan et al. 2024).

3. Plant based Functional yogurt

Plain yogurts offer several health benefits, such as boosting antioxidant activity, improving the absorption of vitamins and minerals, and enhancing the immune system. However, due to the lack of certain nutrients like phenolics, flavonoids, and iron, plain yogurt has limited antidiabetic,

antiobesity, and antimicrobial effects. To overcome these limitations, enriching yogurt with natural functional ingredients can significantly improve its biological activities. These natural ingredients introduce bioactive compounds that, when combined with yogurt's matrix, help stabilize phenolic compounds like catechin and kaempferol, enhancing their bioavailability and increasing their effectiveness.

Research indicates that fortifying yogurt with medicinal plants such as thyme (*Origanum onites*), rosemary (*Rosmarinus officinalis*), basil (*Ocimum basilicum*), and mint (*Mentha piperita*) enhances its antimicrobial properties and supports probiotic activity over a 30-day storage period. These fortified yogurts showed strong effects against pathogens, including *Bacillus cereus*, *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans* (Bayram, Kinik, and Büyükkileci 2024). Another study found that adding extracts from *Codonopsis pilosula*, *Illicium verum*, *Lycium barbarum*, and *Psidium guajava* contributed antioxidant and anti-diabetic properties, positioning the yogurt as a beneficial functional food (Shori and Baba 2023). Moreover, the fermentation process in yogurt can produce amino acids and peptides with antioxidant properties, and lactic acid bacteria can convert compounds like procyanidins into more bioactive forms. By adding functional ingredients rich in antioxidants—such as polysaccharides, phenolics, and flavonoids—the antioxidant activity of yogurt is greatly enhanced. This combination not only improves yogurt's overall health benefits but also amplifies its capacity to support better metabolic and immune functions (Rashwan, Osman and Chen 2023).

Conclusion

The exploration of medicinal plants as key components of functional foods highlights a blend of tradition and modern innovation. In an era marked by chronic diseases and lifestyle challenges, these plants offer a wealth of bioactive compounds that enhance health. They provide essential nutrients and possess therapeutic properties, including antioxidant and anti-inflammatory benefits. The rise of functional foods reflects a shift toward holistic health, where dietary choices are informed by a deeper understanding of food's impact on our well-being. Incorporating medicinal plants into our diets represents a proactive approach to addressing diseases like diabetes, cancer, and cardiovascular issues, underscoring their importance in contemporary nutrition. Nonetheless, additional research is required to thoroughly comprehend the mechanisms of action of these compounds and to guarantee the quality and effectiveness of medicinal plant-based functional foods. As consumer awareness of health and

wellness grows, the demand for functional food products is expected to increase, making medicinal plants a valuable resource for innovative and beneficial food commodities.

Future Perspectives

The field of medicinal plants and functional foods is filled with exciting developments. Research indicates that studying medicinal plants and how different bioactive compounds work together could lead to better dietary strategies for managing chronic diseases. New technologies for extracting and analyzing these compounds will enhance our understanding of their health benefits. Future applications might include creating new functional foods prepared to meet specific health needs and responding to consumer demand for natural products. Collaboration among nutritionists, botanists, and food scientists can maximize the potential of these plants. As interest in sustainability grows, it's important to focus on ethically sourcing and conserving medicinal plants. Regulatory frameworks will also need to adapt to support innovation while ensuring safety and effectiveness.

In summary, incorporating medicinal plants into our diets offers great potential for improving public health. Continued research and collaboration will be essential for accessing their benefits in future dietary practices.

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CHAPTER TWO

FUNCTIONAL FOOD FORTIFIED WITH ACTIVE INGREDIENT OF MEDICINAL PLANTS

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Abstract

Functional foods act as a bridge between traditional nutrition and modern medicine, offering preventative and therapeutic effects. Unlike dietary supplements, functional foods are consumed as part of a regular diet and are often fortified or naturally enriched with bioactive compounds. The use of medicinal plants in functional foods is deep-rooted in traditional medicinal systems of different countries like 'Indian Ayurveda', 'Siddha', 'Tibetan SOWA-RIGPA', 'Traditional Chinese Medicine', and 'Unani', which emphasize the therapeutic potential of natural ingredients. As prevalence of lifestyle-related diseases like diabetes, obesity, mental health issues and cardiovascular diseases has been increased, functional foods have emerged as a preferred choice for health-conscious individuals. The integration of bioactive compounds from medicinal plants ensures that these products provide targeted health benefits while adhering to the natural and sustainable ethos of modern consumers.

Keywords; Biofortification, Golden rice, food fortification, nutrient quality,

Introduction

Foods that have nutrients added to food that don't exist in the food naturally are referred to as fortified foods. These foods are designed to enhance