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Review

Edible and Medicinal Plants as Nutraceuticals: A Comprehensive Pharmacognostic Review

Isha Dhiman*, Jeewanjot Singh

Desh Bhagat University, Mandi Gobindgarh, Punjab, India

*Corresponding author: Isha Dhiman, ishadhiman042@gmail.com

Abstract

Curative and nutritional resources have been discovered in medicine and edible plants. It is an extensive pharmacognostic study of edible, nutraceutical and medicinal plants in relation to its historical aspect, classification, composition of the phytochemicals, pharmacological activity and the research methodology that is currently being carried out. It also discusses the problem of standardization, regulatory problems and safety and makes prospects based on nutraceutical innovation and drug discovery. Considerable phytoconstituents such as polyphenols, flavonoids, terpenoids, alkaloids, and vitamins are studied in light of their nutraceutical worth. Bioactive compounds and their health benefits of some of the plants were discussed which include turmeric (*Curcuma longa*), garlic (*Allium sativum*), green tea (*Camellia sinensis*), ginger (*Zingiber officinale*), amla (*Phyllanthus emblica*) and soy *(Glycine max*). The paper has found out that pharmacognosy has been the focus of discovery, authentication and standardization of the nutraceuticals, linguistic knowledge and modern scientific innovation.

Keywords

Medicinal plants, Nutraceuticals, Phytochemicals, Pharmacological, Polyphenols

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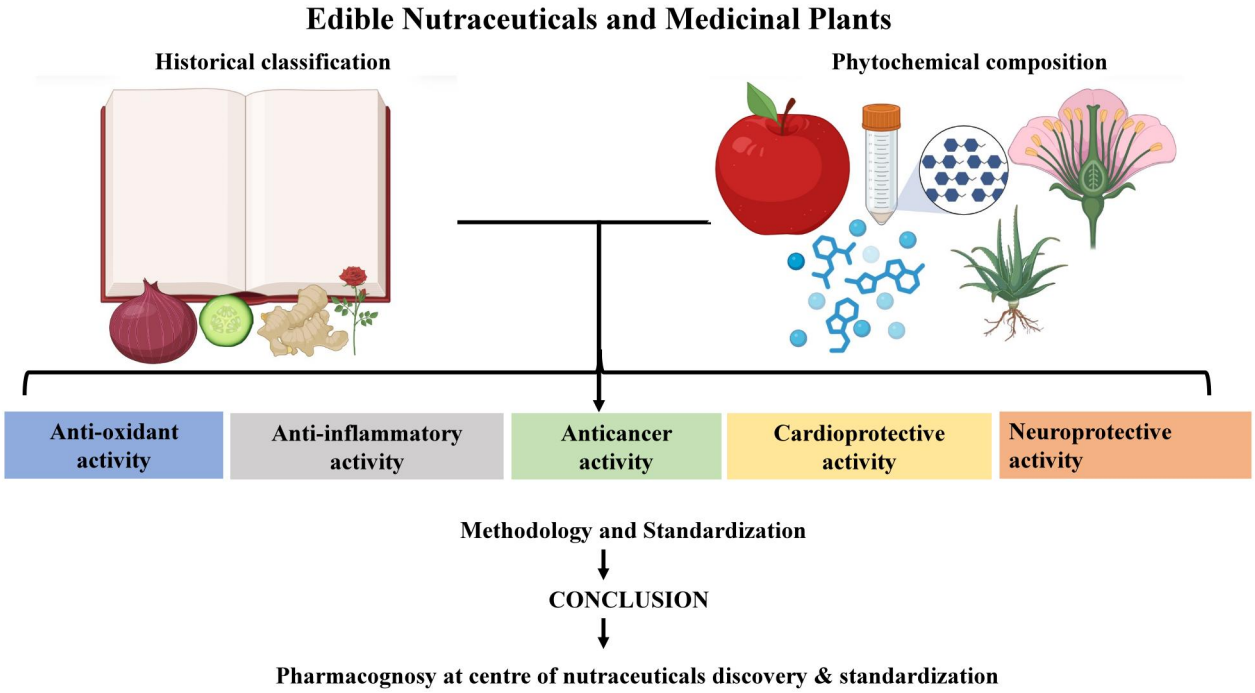
Graphical Abstract



1. Introduction

Nutraceuticals as a concept have entered the realm of nutrition, medicine, and pharmacology as an efficient intermediary. Nutraceuticals are a heterogeneous category of products whose source is mainly natural that can be vegetable in nature but may also contain bioactive substances, which may help to promote health and reduce the risk of disease [1]. The mechanism of action of nutraceuticals is numerous and it promotes general well-being and prevention of chronic diseases by enhancing the natural defense mechanisms of the body unlike the synthetic pharmaceuticals which are specifically developed to treat a certain illness. The increase in chronic diseases in our lifestyle such as cardiovascular diseases, diabetes, obesity and cancer in the world has aided the quest in the preventive and safer health interventions [2].

Phytochemicals (polyphenols, flavonoids, terpenoids, alkaloids and glycosides) are ubiquitous and are highly abundant in plants and have anti-oxidant, anti-inflammatory, and immunomodulatory activity [3]. These natural products assist in maintaining physiology balance, in addition to decreasing oxidative stress and in managing cellular signaling pathways that affect the formation of the disease. Edible foods, including turmeric, garlic and ginger, are good examples of foods with medicinal values [4]. They not only possess the nutrients necessary but they also contain the bioactive compounds which prevent or reduce the disease by the constant intake. This duality in property is a sign of this anti-catabolic activity to depict the increased significance of plant-based nutraceuticals in the contemporary preventive medicine [5].

Pharmacognosy is a scientific examination of natural drugs obtained by plants or other sources that is a crucial ground of nutraceutical examinations. It provides methodology of identifying, authenticating, standardizing, and assessing bioactive plants of medicinal and edible plants. The pharmacognostic analysis is useful to determine the purity, safety, and effectiveness of nutraceutical product [6]. In addition, pharmacognosy bridges between the traditional knowledge system and the current biomedical studies and in the process, ancient knowledge on how plants can be used as a healing agent is translated into evidence-based and tested nutraceuticals that could be used globally [7].

2. Historical Background

The influences of various plants upon the body were studied by early man and he instructed himself what was safe to eat and what possessed medicinal power. This body of empirical knowledge gradually got organized into systems of medicine, some of which continue to thrive to this day. Ayurveda is a concept that cannot be divided as it is one of the oldest ancient medical traditions in the world [8]. The nutraceutical philosophy is in Ayurvedic philosophy “Let food be thy medicine, and medicine be thy food”. The plants used in this regime, such as turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), and amala (*Phyllanthus emblica*) are also eaten and used as a remedy to normalize the body doshas of Vata, Pitta, and Kaph. It is said that these herbs maintain the entire body alive and do not allow it to be diseased because of the replenishing and revitalizing qualities of these herbs [9].

Traditional medicinal plants (TCM) has also given much emphasis on balance and the equilibrium of Yin and Yang, and food and herbs may serve as a supplement method of ensuring health [10]. Edible plants such as green tea (*Camellia sinensis*), ginseng (*Panax ginseng*), and soy (*Glycine max*) are long used to keep and regulate the functions of the organs [11]. The Unani system of medicine which has got its origin in Greco-Arabic traditions also gives great importance to the role of diet to maintain the balance of four humors of the body: blood, phlegm, yellow bile, and black bile [12]. Foods and herbs are classified based on their temperament and are used respectively to restore the humors. Every one of these classical systems is cognizant of the central role of diet in health and that a food can be both preventive and curative [13].

The transition of medicine to food was a natural process since ancient physicians discovered plants that nourished the body and at the same time cured some diseases. This ancient wisdom has been scientifically verified in the present age and this has resulted in the formal study of nutraceutical [14]. One such intriguing area is the use of food as medicine a concept that is still evolving today that the traditional ethnobotanical knowledge is being merged with contemporary knowledge of pharmacology [15]. It is the basis of the contemporary nutraceutical market that is planning to construct standardized, evidence-based products synthesizing the nutritional as well as medicinal qualities of plant [16].

3. Structured Methodology

The scientific information about edible and medicinal plants that may have a nutraceutical possibility and their pharmacological activity were collected and evaluated in the organized manner. The following major scientific databases, PubMed, Scopus, Web of Science, and Google Scholar identified peer-reviewed documents that were relevant and on which the research was performed with the publications being dated 2020-2026. The combination of keywords used to design the search strategy are nutraceuticals, phytoconstituents, plant-based nutraceuticals, edible medicinal plants, pharmacological activity, polyphenols, flavonoids, terpenoids, alkaloids, anti-oxidant, anti-inflammatory, anticancer, and pharmacognosy. The articles and reviews included in the studies were peer reviewed and reported a phytochemical composition, pharmacological activities or nutraceutical applications based on credible experimental or clinical evidence and were written in English. Articles written in non-English, an abstract of a conference, editorials and studies with nothing based on synthetic drugs were eliminated. After the screening of the titles, abstracts, and complete texts, approximately 55 studies were selected as relevant. The data were acquired on the sources of plants, phytoconstituents, pharmacological effects, the mechanisms of action, and their traditional applications and were evaluated and organized qualitatively through the nutraceutical typing and pharmacognostic principles.

4. Nutraceuticals Classification

There are multiple ways of classifying nutraceuticals. The nutraceuticals may be classified into various categories by considering their source, chemical structure or their mechanism of action [17]. The source-based and the functional mechanism-based systems are the most popular two classification systems as shown in Table 1.

Table 1. Classification of nutraceuticals on the basis of source and mechanism of action.

Category	Examples of sources	Major bioactive compounds	Primary mechanisms / health benefits	References
Plant-based Nutraceuticals	Turmeric, Green tea	Polyphenols, Flavonoids, Terpenoids,	Anti-oxidant, anti-inflammatory, cardioprotective, anticancer.	[18]
Animal-based Nutraceuticals	Fish oil, Dairy, Egg	Omega-3 fatty acids, Peptides, Collagen, Chondroitin	Cardioprotective, joint health, skin elasticity.	[19]
Microbial-based Nutraceuticals	Probiotics	Enzymes and Probiotic cultures	Balances gut microbiota and modulates immune response.	[20]
Anti-oxidant Nutraceuticals	Green tea, Amla	Vitamin C, Catechins	Neutralize free radicals, reduce oxidative stress.	[21]
Anti-inflammatory Nutraceuticals	Turmeric, Ginger	Curcumin, Gingerols	Decreases inflammatory cytokines, relieves chronic inflammation.	[22]
Immunomodulatory Nutraceuticals	Mushrooms, Echinacea	β-glucans, Alkylamides	Boost immune defense, regulate cytokine activity.	[23]
Antidiabetic Nutraceuticals	Fenugreek, Bitter melon	Saponins, Polypeptides	Enhance insulin sensitivity.	[24]
Neuroprotective Nutraceuticals	Turmeric, Green tea	Curcumin, EGCG	Protect neurons.	[25]

4.1 Classification on the Basis of the Source

4.1.1 Plant-Based Nutraceuticals

Plant-based nutraceuticals are edible and medicinal plants that are being combined as a rapidly growing field of medicine and nutrition . These are sources of bioactive rich plants that are of use other than just nutrition and they help in preventing diseases and promoting health [26]. The pharmacological potential of phytoconstituents is based on a large variety of different phytoconstituents, such as polyphenols, flavonoids, alkaloids, terpenoids, saponins, dietary fibers, and essential micronutrients [27]. Some typical edible plants, including turmeric (*Curcuma longa*), garlic (*Allium sativum*), ginger (*Zingiber officinale*), and green tea (*Camellia sinensis*) have anti-oxidant, anti-inflammatory, antimicrobial, cardioprotective, and immunomodulatory properties [28,29]. Standardization, authentication and quality control of plant materials are essential in pharmacognostic viewpoint to make sure that the materials are safe, effective as well as reproducible [30]. Their nutraceutical use has been increased by the efforts of the technology in the areas of extraction, phytochemical profiling, and enhancing bioavailability [31]. Although these advantages are prospective, there are difficulties in the variability of plant sources, absence of harmonization of regulations and insufficient clinical validation. The sustainable development of the plant-based nutraceuticals is based on the integration of the traditional knowledge with the new scientific approaches [32].

4.1.2 Animal-Based Nutraceuticals

Animal-derived nutraceuticals are also used to supplement edible and medicinal vegetation with highly bioactive compounds that are highly bioavailable. These are fish oils containing omega-3 fatty acids, connective tissues containing collagen and gelatin, cartilage containing glucosamine and chondroitin and bioactive (merit) peptides found in milk and eggs [33]. Honey, propolis, and royal jelly which are bee products have anti-oxidant and immunomodulatory effects [34]. Nutraceuticals derived out of the sea also help in cardiovascular, anti-inflammatory and neuroprotective properties, e.g.-Fish oil and omega-3-fatty acids can be used in the prevention of cardiovascular diseases [35]. Collagen peptides-strengthen the skin and skin joints. Chondroitin and glucosamine-enhance the process of cartilage and osteoarthritis symptoms [36].

4.1.3 Microbial-Based Nutraceuticals

Microbial-based nutraceuticals are a novel and inherent group of functional ingredients which supplements edible and medicinal plant nutraceuticals. These are probiotics (*Lactobacillus*, *Bifidobacterium* and *Saccharomyces* species), prebiotic fermentation products and postbiotics [37]. Prebiotics (inulin, fructooligosaccharides)-Stimulates the proliferation of beneficial microorganisms of the intestine. Enzymes (amylase, protease) of the microorganisms help in the digestion and absorption of food [38,39]. They play a role in the regulation of intestinal microbiota, improved absorption of nutrients, immunologic homeostasis, and gastrointestinal health. Fermentation by microbes also enhances bioavailability and biotransformation of plant-derived phytoconstituents which increases therapeutic efficacy. Strain specificity, viability, standardization and safety assessment are key parameters in terms of pharmacognostics [40]. Microbial-based nutraceuticals used in the prevention of diseases as a component of preventive health will hold synergistic potential when incorporated with plant-based bioactive [41].

4.2 Classification According to Mechanism of Action

4.2.1 Anti-Oxidant Nutraceuticals

Antioxidant nutraceuticals are produced by edible and medicinal plants, which are very important in the inhibition of oxidative stress related to chronic and degenerative diseases. These nutraceuticals contain bioactive phytochemicals including polyphenolic, flavonoid, carotenoid, phenolic acid, vitamins C and E as well as selenium. The usual sources of plants are *Curcuma longa*, *Camellia sinensis*, *Emblica officinalis*, *Vitis vinifera* and *Ocimum sanctum* [42,43]. They play their antioxidant roles in several different ways such as scavenging free radicals, decreasing the reactive oxygen species, increasing the activity of endogenous antioxidants such as superoxide dismutase, catalase and glutathione peroxidase, and inhibiting lipid peroxidation and DNA damage [44]. The compounds also regulate the oxidative stress and inflammatory pathways, which preserve cell integrity and function. Pharmacognostically, the antioxidant properties of these plants are related to appropriate botanical identification, extraction, phytochemical standardization, and bioavailability. Frequent use of nutraceuticals containing antioxidants can be used to protect the cells, control the immune system, and promote health [45,46].

4.2.2 Anti-Inflammatory Nutraceuticals

The use of nutraceutical anti-inflammatory agents in the prevention and treatment of chronic inflammatory diseases is crucial because of the sources used in the manufacturing of these products which are edible plants and medicinal plants [47]. These nutraceuticals are bioactive phytoconstituents including polyphenols, flavonoids, terpenoids, alkaloids, and compounds of sulfur which inhibit enzymes like cyclooxygenase (COX) and lipoxygenase (LOX), and suppress nuclear factor-κB (NF-κB) and pro-inflammatory cytokines [48-50]. Another group of plant source of anti-inflammatory and

antioxidant effects are known to be *Curcuma longa*, *Zingiber officinale*, *Camellia sinensis*, *Ocimum sanctum*, and *Allium sativum* [51]. These compounds minimize oxidative stress, as well as immune reactions and tissue injury by regulating the signaling pathways implicated in inflammation [52]. To achieve safety, efficacy, and consistency of anti-inflammatory nutraceutical products, pharmacognostically, proper identification, standardization, and quality control of plant materials should be conducted. There are also immune modulating nutraceuticals such as some vitamins, amino acids and carbohydrates, which play a role in regulating the immune system and have been reported to lower the chances of having osteoporosis among others [46,53].

4.2.3 Immunomodulatory Nutraceuticals

Some vitamins, amino acids and some carbohydrates, which are categorized as immunomodulatory nutraceuticals have a major role of improving immune defense and also maintaining immune homeostasis, and also help in the prevention of various disorders such as osteoporosis [54]. Bioactive phytoconstituents found in nutraceuticals derived out of edible and medicinal plants are polysaccharides, flavonoids, alkaloids, terpenoids, and phenolic compounds that mediate the regulation of the innate and adaptive immune responses [55]. The typical ones are *Curcuma longa*, *Withania somnifera*, *Tinospora cordifolia*, *Ocimum sanctum*, and *Allium sativum* which possess immunostimulatory, anti-inflammatory, and antioxidant effects. The mechanisms of action of these compounds include activation of immune cells (macrophages, T-lymphocytes, and natural killer cells), control of cytokine secretion (interleukins and interferons), and control of signaling pathways nuclear factor-kappa B and mitogen activated kinase (NF-κB and MAPK) [18,54,56]. They also lower the oxidative stress, boost the production of antibodies and contribute to keeping the immune balance by mitigating excessive inflammatory responses [57].

4.2.4 Cardioprotective Nutraceuticals

The cardioprotective nutraceuticals found in edible and medicinal plants are significant in the cardiovascular maintenance of lipid metabolism, oxidative stress, and inflammation. Examples include omega-3 fatty acids found in fish oil, garlic, cocoa, and flavonoids found in green tea. Examples of plants that are rich in bioactive phytoconstituents include flavonoids, polyphenols, carotenoids, phytosterols and dietary fibers which are found in plants like garlic, green tea, turmeric, fenugreek and berries [58]. These compounds have cardioprotective effects by various mechanisms, such as the lowering of serum cholesterol and triglycerides by inhibition of HMG-CoA reductase and enhancement of lipid metabolism, prevention of platelet aggregation by inhibition of thromboxane production, and antioxidant activity which lessens oxidative stress and vascular endothelium protection [59]. They also stimulate vasodilation and raising nitric oxide (NO) and decrease inflammation through NF-κB pathways and inhibit atherosclerotic plaque development. They also enhance the endothelial performance and maintain blood pressure [60,61]. These plant sources need to be identified, standardized and assessed in quality to guarantee safety, efficacy and consistency of cardioprotective nutraceutical preparations.

4.2.5 Antidiabetic Nutraceuticals

Andtidiabetic nutraceuticals possess bioactive phytoconstituents in the form of polyphenols, flavonoids, alkaloids, terpenoids and dietary fibers [62]. Plants that are commonly studied are *Momordica charantia*, *Trigonella foenum-graecum*, *Gygenema sylvestre*, *Cinnamomum* species, and *Syzygium cumini* [63]. They act by several mechanisms to reduce glucose absorption, such as improving insulin secretion by the pancreatic β-cells, enhancing insulin sensitivity by activating signaling pathways, including AMPK and PI3K/Akt, and blocking carbohydrate-digesting enzymes, including 8-amylase and 8-glucosidase [64,65]. They also stimulate glucose uptake in peripheral tissues by enhancing GLUT-4 translocation, decrease hepatic gluconeogenesis and aid in the preservation of β-cells against oxidative stress by acting as antioxidants [65,66]. Also, the compounds regulate inflammatory processes and lipid metabolism, which contributes to the total glycemic control. The standards of pharmacognostic and quality control are necessary to guarantee the safety, efficacy and reproducibility of plant-based antidiabetic nutraceuticals in the prevention and adjunctive management of diabetes [67].

4.2.6 Neuroprotective Nutraceuticals

The antioxidant neuroprotective nutraceuticals of edible and medicinal plants are critical in the maintenance of cognitive and prevention of neurodegenerative diseases [68]. Bioactive phytochemicals, including polyphenols, flavonoids, alkaloids, and terpenoids, are found in plants like *Curcuma longa*, *Withania somnifera*, *Bacopa monnieri* and *Camellia sinensis* and have anti-oxidant, anti-inflammatory and anti-apoptotic effects [69]. These compounds have neuroprotective effects in various ways such as reduction of oxidative stress, inhibition of neuroinflammation by suppression of signaling pathway including NF-κB and pro-inflammatory cytokines and inhibition of neuronal apoptosis by regulating proteins such as Bcl-2, Bax and caspases [70,71]. They also enhance the rate of mitochondrial activities, neurotransmitter homeostasis (e.g. acetylcholine and dopamine), and signaling pathways involved in neuronal survival such as MAPK and PI3K/Akt pathways [72,73]. Also, they assist in the inhibition of protein aggregation as well as excitotoxicity, which are major characteristics of neurodegenerative disorders. Pharmacognostically, identification, standardization, and quality control of such plant-based nutraceuticals are very important to ensure

uniformity, safety and efficacy of such nutraceuticals in enhancing the health of the brain and well-being of the neural system [74].

4.2.7 Anticancer Nutraceuticals

Anticancer nutraceuticals such as edible and medicinal products have a major role in trying to prevent cancer and adjunct therapy [75]. They have anticancer effects associated with oxidative stress, DNA damage inhibition, inhibiting cell proliferation by regulating cell signaling pathways, including PI3K/Akt and MAPK, and causing apoptosis by regulating proteins such as p53, Bax, and caspases [76-78]. They also trigger cell cycle arrest, prevent angiogenesis through downregulation of VEGF and possess anti-inflammatory effects through inhibition of NF-κB and COX-2 [77]. Moreover, they regulate the epigenetic activities and suppress the metastasis. Plant sources need to be properly standardized and controlled in terms of quality to guarantee their bioavailability and therapeutic efficacy. The compounds are also chemoprotective as observed with lycopene (tomatoes), genistein (soy), and sulforaphane (broccoli) [79].

5. Aspects of Edible and Medicinal Plant Pharmacognostics

The scientific validation of edible and medicinal plants as nutraceuticals consists of a thorough inspection of their morphology, anatomy, chemistry, and quality control parameters in order to be sure of authenticity and efficacy [80]. Plant materials can be identified using morphological and microscopic characteristics as the first line. Morphological examination is the external examination of plant parts, including their size, shape, color, odor, and texture of the parts, like leaves, roots, stems, flowers, or seeds [81]. Microscopic analysis is more detailed and examines such features of cells and tissues that are unique to a particular species. Trichomes, vascular bundles, stomata, and secretory structures are used as diagnostic features [82]. In order to illustrate this fact, the rhizome of *Curcuma longa* is characterized by its orange-yellow color and oleoresin cells, whereas the rhizomes of *Zingiber officinale* are characterized by parenchymatous tissue stuffed with starch grains and oil globules [82,83].

In addition to anatomy, phytochemical constituents are the basis of the nutraceutical value of a plant. The sources of the biological activities that make plants therapeutically relevant are due to secondary metabolites, which include alkaloids, flavonoids, tannins, terpenoids, and glycosides [84].As an example, alkaloids have various physiological effects, such as analgesic effects, as well as cardiovascular effects [85]. Flavonoids have been known to have anti-oxidant and anti-inflammatory effects [86]. Tannins contain astringent, antimicrobial, and anti-oxidant action. Terpenes and essential oils are known to have anti-inflammatory, anticancer, and antimicrobial properties, whereas the glycosides can control heart and metabolic activities [87,88].

Another important element of pharmacognosy in the development of nutraceuticals is quality control and standardization. Phytochemical composition may vary due to harvesting, soil nature, climate, and processing techniques, and consequently, efficacy [89]. The use of specific marker compounds and methodologies of analysis, such as chromatography, spectroscopy, and DNA barcoding, to ensure the uniformity of the products, is called standardization. Further, the pharmacognostic quality regulation identifies the level of purity through the analyzing nature of contaminants, including heavy metals, pesticides, the presence of microbial load, and adulterants [90,91]. The reason behind these astringent tests is to make sure that nutraceuticals are safe, authentic and effective and that scientific integrity is upheld and so does consumer confidence [16] as speculated in Figure 1.

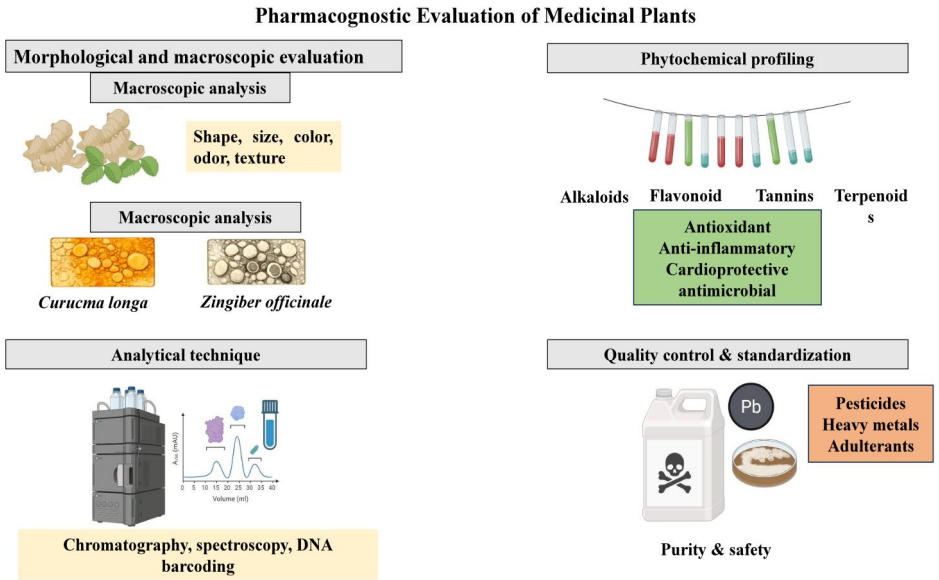


Figure 1. Illustration of aspects of edible and medicinal plant pharmacognostic.

6. Major Phytoconstituents with Nutraceutical Potential

Phytochemical compounds of the edible and medicinal plants are largely involved in their biological effect and health effects. It is these bioactive substances that render plant-based foods and herb products have a nutraceutical potential [92]. These significant groups of phytoconstituents are polyphenols, flavonoids, terpenoids, alkaloid, glycoside, and essential micro-nutrients such as vitamins and minerals [93]. Each of these groups has a special role in health support and prevention of diseases and is likely to act in a coordinated manner to enhance the treatment.

Phenolic acids, tannins, lignans, and stilbenes counter free radicals and reactive forms of oxygen and hence prevent oxidative damage to biomolecules, including proteins, lipids, and DNA [94]. The anti-oxidant defense is capable of preventing chronic diseases such as cardiovascular diseases, diabetes, and neurodegenerative disorders. Further, the polyphenols are known to regulate the activity of proteins (enzymes), inhibit inflammation, and regulate cellular signal transduction of apoptosis and cancer progression. Foods that are rich in polyphenols, e.g., green tea, grapes, berries, and olive oil, are commonly correlated with morbidity reduction and longer lifespan [95-97].

Another significant group of nutraceutical compounds is the flavonoid, subclass of polyphenols. Fruits, vegetables, tea, and wine contain these pigments in abundance, and they are the ones that give these substances their bright colors. Flavonoid structures are phenolic ring and hydroxyl group-containing compounds, which then aid their anti-oxidant properties. They have great diversity in their biological activities, such as free radical scavenging, metal ion chelation, anti-inflammatory, and vascular activity [98,99]. Epidemiological research associates a low level of cardiovascular diseases, hypertension, and some forms of cancer with a flavonoid-rich diet. Flavanoids aslo exert neuroprotective action by improving cerebral blood flow and safeguard neurons against oxidative stress [100,101].

Terpenoids are the source of the aroma and taste of a lot of spices and herbs, and they play a major role in their pharmacology. Terpenoids have been known to have anti-inflammatory effects, anticancer effects, antimicrobial effects, and hepatoprotective effects [102]. As an illustration, the diterpenoid curcumin, present in turmeric, has the anti-inflammatory property of potency, whereas the ginsenosides in *Panax ginseng* are adaptogens, which enable the body to resist stress and exhaustion [103,104]. Alkaloids are nitrogen containing substances and are characterized by their strong biological activities, and in most cases, they affect the central nervous system and metabolism [105]. On the one hand, some alkaloids are lethal at large doses, but on the other hand, there are various ones that could be used in treatment in moderate doses. An example of this type of use would be the case of caffeine, which is a weak stimulant that improves wakefulness and mental abilities, or berberine of the Berberis species, which has exhibited hypoglycemic and lipid-lowering effects. Alkaloids have a broad range of biological activity, including antimicrobial and cardiotonic properties, and this is due to their structural diversity [106-108].

The glycosides are drugs where a sugar molecule is connected to a non-sugary compound, which usually gives the drug a better solubility and bioavailability. Such pharmacological variability in cardiac glycosides includes digitoxin and saponins that are present in soy and quinoa [109]. Saponin, especially, has been of interest to nutraceutical agents with its effects of lowering cholesterol, increasing immunity, and anticancer properties. The glycosides are amphiphilic, and, as such, the interaction with cell membranes affects their permeability and signaling [109,110]. Finally, vitamins and minerals have irreplaceable roles in sustaining cellular metabolism and the well-being of the body as shown in Figure 2. Vitamins C and E are natural anti-oxidants that supplement the activity of polyphenols and flavonoids. Various enzymatic reactions use minerals such as selenium, zinc, magnesium, and iron as cofactors. The combination of these micronutrients synergizes with phytochemicals to improve the nutraceuticals of edible plants, which creates a concerted defense network that promotes human health [111].

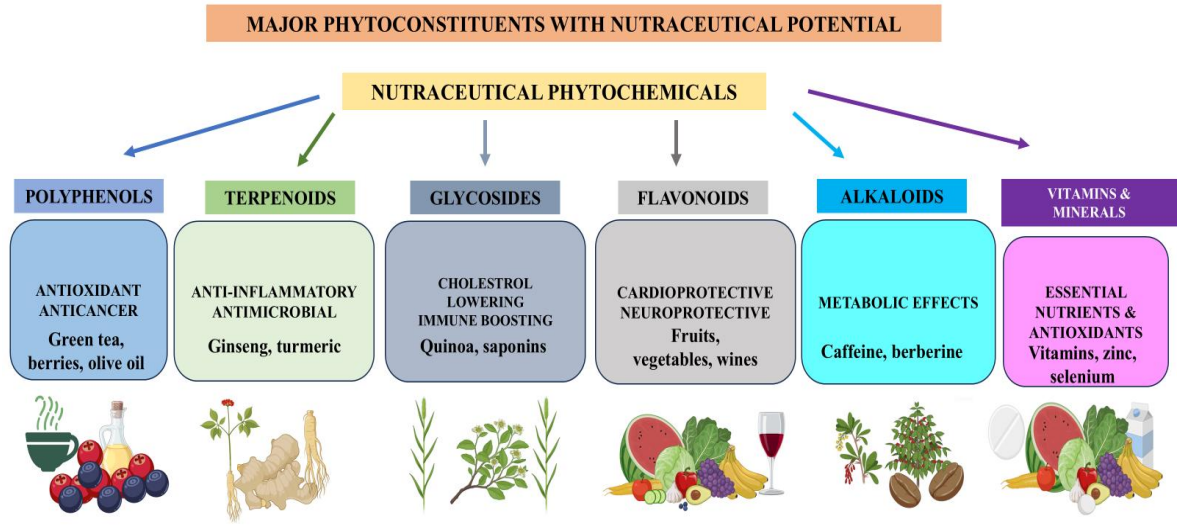


Figure 2. Classification of nutraceuticals according to their major phytochemical activity.

7. The Selected Nutraceuticals: Edible and Medicinal Plants

A diverse array of edible and medicinal plants are currently being well known in their nutraceutical potential, with special reference to turmeric, garlic, green tea, ginger, amla and soy, each of which has its own set of bioactive compounds and health properties. Curcumin, which is the main active ingredient of Turmeric (*Curcuma longa*), is recognized as a powerful anti-inflammatory, anti-oxidant, and anti-cancer compound used in the traditional Indian medicine. Curcumin also regulates actions of several molecular targets, such as transcription factors and inflammatory mediators, and neurologically inhibits (NF-κB), which in turn decreases production of pro-inflammatory cytokines; Curcumin assists in digestion, liver functionality, and immunity, and emergent information suggests its use in arthritis and metabolic syndrome as well as neurodegenerative diseases [112-114]. Garlic (*Allium sativum*) has been appreciated due to its cardioprotective and antimicrobial properties, which are largely attributed to sulfur-based compounds like allicin, allialyl sulfide, and ajoene, which reduce cholesterol and blood pressure, platelet aggregation, improve endothelial activity, and microorganismal infection besides reducing oxidative stress [115,116]. Green tea (*Camellia sinensis*) contains catechins and more so epigallocatechin gallate (EGCG), which is a strong anti-oxidant linked with lower tendency towards cardiovascular diseases, obesity and some cancers by controlling cell proliferation, apoptosis, and angiogenesis [64,117]. Ginger (*Zingiber officinale*) contains anti-oxidant, anti-inflammatory and antimicrobial effects of gingerols, shogaols and other like compounds. Amla (*Phyllanthus emblica*) which is among the richest sources of vitamin C in nature, has excellent anti-oxidant, immunomodulatory, hepatoprotective, hypolipidemic, antidiabetic as well as anti-aging properties [118,119]. Soy (*Glycine max*) is a good source of quality protein and isoflavones like genistein and daidzein which are phytoestrogens and help to maintain hormonal balance especially among post-menopausal women [120] as shown in Table 2.

Table 2. Selected edible and medicinal plants with nutraceutical potential.

Plant (Scientific Name)	Common Name	Major Bioactive Compound	Pharmacological Activity / Health Benefit	Traditional Use / System	Reference
Curcuma longa	Turmeric	Curcumin	Anti-inflammatory, anti-oxidant, anticancer	Ayurveda – anti-arthritic and wound healer	[112-114]
Allium sativum	Garlic	Allicin	Cardioprotective, antihyperlipidemic	Unani and folk medicine – heart tonic	[115,116]
Camellia sinensis	Green Tea	Catechins (EGCG)	Anti-oxidant, anti-cancer, neuroprotective	Traditional Chinese Medicine – detoxifying beverage	[64,117]
Zingiber officinale	Ginger	Gingerols, Shogaols	Digestive aid, anti-nausea, anti-inflammatory	Ayurveda – digestive stimulant	[118]
Phyllanthus emblica	Amla / Indian Gooseberry	Ascorbic acid, Polyphenols	Immunomodulatory, anti-oxidant, hepatoprotective	Ayurveda – rejuvenator (Rasayana)	[119]
Glycine max	Soybean	Isoflavones (Genistein, Daidzein)	Phytoestrogenic, cardioprotective, anticancer	Traditional Asian diets – hormone balance	[120]
Withania somnifera	Ashwagandha	Withanolides	Adaptogenic, anti-stress, neuroprotective	Ayurveda – Rasayana tonic	[121]
Tinospora cordifolia	Guduchi	Alkaloids, Diterpenoids	Immunomodulatory, antipyretic	Ayurveda – immune enhancer	[121]
Ocimum sanctum	Holy Basil (Tulsi)	Eugenol, Rosmarinic acid	Anti-oxidant, antidiabetic, anti-stress	Ayurveda – sacred adaptogen	[122]

8. Pharmacological Activities and Health Activities

Edible and medicinal plant based nutraceuticals are a potent convergence of nutrition and therapy, which presents a wide range of biological actions that improve health and diminish the risk of disease. They have applications in the domain of anti-oxidant, anti-inflammatory, cardioprotective, antidiabetic, neuroprotective, and anticancer, which makes them useful substances of preventive care [2]. The most basic of these properties is anti-oxidant activity, which is best characterized. Environmental stressors and normal metabolic processes produce reactive oxygen species (ROS), which may cause cellular damage and may increase aging and the progression of chronic diseases [123]. Plant phytochemicals like polyphenols, flavonoids, carotenoids, vitamins, are effective scavengers of these free radicals, inhibitors of lipid peroxidation of cellular membranes and structural and functional integrity of biomolecules [124].

Many degenerative disorders such as arthritis, diabetes, cardiovascular diseases and cancer are based on chronic inflammation. Bioactive compounds such as curcumin, quercetin and resveratrol inhibit important inflammatory mediators such as cyclooxygenase (COX), lipoxygenase (LOX) and tumor necrosis factor-alpha (TNF-α), thus delaying the onset of the disease and enhancing the overall body health [125]. Cardioprotective effects of nutraceuticals are attained by decrease of oxidative stresses, enhancement of endothelial activities, modulation of lipid metabolism and platelet aggregation. Garlic, green tea, and soy have proved to lower lipids and reduce thrombosis, whereas polyphenols

stimulate the production of nitric oxide, which leads to the vasodilation and proper circulation. Numerous vegetable extracts also regulate glycemia by enhancing the sensitivity of insulin and inhibiting the activity of carbohydrate-digestive enzymes (as α-amylase and α-glucosidase) [126,127].

Flavonoids, terpenoids and alkaloids prevent diabetic complications. Moreover, there is an increasing body of evidence that suggests neuroprotective effects of nutraceuticals, in which compounds such as curcumin, Epigallocatechin-3-Gallate (EGCG), and resveratrol have a protective effect on neurons, lessen oxidative damage, regulate neurotransmission, and prevent the formation of amyloid plaques [128]. Lastly, their anticancer effects include the control of cell cycle, induction of apoptosis, prevention of angiogenesis, and the control of signaling pathways like MAPK, PI3K/Akt, and NF-κB. High-phytochemical diets are thus closely linked with lower rates of cancer occurrence making nutraceuticals a promising natural chemopreventive agent [129,130].

9. Current Methodologies in Nutraceutical Studies

The scope of nutraceutical research has been greatly widened by the progress in science and technology. The modern methods are not only to isolate the bioactive compounds of plants but also to increase their bioavailability, stability, and clinical efficacy by using new delivery systems and sustainable production mechanisms [131]. The ultimate potential of nanotechnology for nutraceutical formulation is one of the most promising things to take place in this area. Most of the plant-derived compounds, like curcumin and resveratrol, have low solubility, low absorption, and are easily metabolized [132]. Nanocarriers, e.g., liposomes, polymeric nanoparticles, and nanoemulsions, offer the solution to the above-mentioned problem as these bioactives can be encapsulated by them, avoid degradation, and delivered to specific tissues. This results in improved pharmacokinetics, improved bioavailability and augmented therapeutic effects [133].

The other current direction that is emerging is the use of green extraction processes in the derivation of phytoconstituents in a green manner. Normal solvent extraction products are normally toxic and they use much power inevitably putting safety and biodiversity balance at risk. A list of green technologies that decrease solvent use, preserve thermolabile molecules and increase yield during solvent extraction of molecules includes supercritical fluid extraction, microwave-assisted, and ultrasound-assisted [134,135]. These natural processes are in line with the world trend towards sustainable production of nutraceuticals.

Moreover, clinical validation is a critical aspect of determining the effectiveness and safety of nutraceuticals. Although in vitro and animal research can offer early information on the biological processes, clinical trials are needed to convert the information into human use [136]. Increased use of randomized controlled trials on the health benefits of plant-based nutraceuticals and their impact on cardiovascular health, metabolic disorders, and cognitive functioning has been observed within recent years [137]. This kind of evidence-based validation does not only increase consumer confidence; it also makes it easier to get regulatory approval and be accepted in the market. Together, these new methods of research represent the paradigm shift from the traditional practices of empirical research to the scientifically rigorous and technologically sophisticated development of nutraceuticals, and thus, the modern quality and efficacy standards of plant-derived products are met [138].

10. Challenges and Limitation

Although there has been increasing commercial interest in nutraceuticals, there are various challenges that constrain their standardization, regulations, safety and clinical acceptance. The problem of lack of standardization of plant-based nutraceuticals is a significant one. Phytochemical content of plants changes depending on genetic content, geographical area, soil type, farming, harvesting, and processing after harvesting [139,140]. Additional changes in extraction, storage, and manipulation also influence concentration and stability of bioactive compounds and create inconsistency between batches and the possibility of contamination. To solve this issue, there is a necessity of rigorous pharmacognostic analysis and using chemical markers as an authentication and quality control means. The other important issue is that of regulatory ambiguity since nutraceuticals tend to be in the middle between food and pharmaceuticals [141]. They do not have to go through rigorous clinical trials like the drugs and thus products with unproven health claims find their way into the market. This destroys consumer confidence and brings out the issue of more harmonized regulatory structures. Toxicity and safety problems are still present. Nutraceuticals have the potential of producing adverse effects despite being considered as natural and safe because of contamination, over intake or interaction with conventional drug [75]. It is therefore important to ensure Good Manufacturing Practices (GMP) and to run toxicological tests. Lastly, there is a lack of innovation and medical acceptance due to limited clinical evidence and intellectual property limitations. These issues need to be dealt with by effective research, regulation, and shared models that will allow the responsible development of nutraceuticals [139].

11. Future Perspectives

The future of nutraceuticals obtained in edible and medicinal plants is bright due to the global trend towards preventative or holistic health. Increased recognition of the relationship between nutrition and health coupled with rising demand of natural substitutes to synthetic drugs would ensure further growth of the industry. To achieve this

potential, though, will involve the incorporation of pharmacognosy, sophisticated analytical sciences, biotechnology, and intensive clinical research. Plant identification, standardization, and phytochemical profiling will continue to play a key role in the development of nutraceuticals by means of pharmacognosy. The use of advanced methods like DNA barcoding, metabolomic fingerprinting and chemometric analysis will enable the improvement of authentication, quality control and the identification of new bioactive compounds. The use of biotechnology and nanotechnology will also enhance bioavailability and selective delivery of plant compounds, e.g. nano-encapsulated polyph phenols and liposomal preparations, and will increase efficacy and minimize adverse effects. Mainstream medical acceptance requires well-designed and large-scale clinical trials based on evidence. Also, artificial intelligence, bioinformatics, and network pharmacology will serve to expedite the development of formulations and explain multi-target effects. The harmonized regulatory frameworks, quality assurance and ethical trade practices will be the pillar of sustained growth. They can be instrumental in preventive healthcare and functional nutrition in the context of scientific rigor, transparency, and collaboration of nutraceuticals.

12. Conclusion

Since time immemorial, edible and medicinal plants have been the sources of food and medicine. Phytochemical investigation, morphological recognition and proper pharmacognostic expertise are all useful in the development of safe, effective, and evidence-based nutraceuticals. Anti-oxidant, anti-inflammatory, cardioprotective, antidiabetic, neuroprotective and anticancer activities are the key roles played by major phytoconstituents that include polyphenols, flavonoids, terpenoids, alkaloids and glycosides. The traditional knowledge with subsequent scientific validation used widely such as turmeric, garlic, green tea, ginger, amla, and soy are examples of how traditional knowledge can result in effective natural remedies.

Although the future of nutraceuticals is still promising, there are still issues of phytochemical variability, non-standardization, inadequate clinical data, and regulation changes. To be safe, effective, and acceptable internationally, quality control should be reinforced, global standards should be used and human clinical trials should be conducted on a large scale. Nutraceutical development will remain centred on pharmacognosy which is backed up by the new advanced technologies, including nanotechnology, metabolomics, and bioinformatics. With the increasing demand of natural health solutions, edible and medicinal plants will continue to play a crucial role in sustainable, holistic and scientifically based nutraceuticals. To summarize, applying the traditional knowledge to the contemporary pharmacognostic studies helps to emphasize the unity of food and medicine and provide a sustainable solution to prevention-oriented healthcare and long-term health condition.

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Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this review article. All the authors have read and approved the final manuscript.

Generative AI Statement

The authors declare that no Gen AI was used in the creation of this manuscript.

References

[1] Rusciano D, Bagnoli P. The controversial role of nutraceuticals vs. drugs in proliferative retinopathies. Frontiers in Neuroscience, 2025, 19, 1727089. DOI: 10.3389/fnins.2025.1727089

[2] Jain N, Radhakrishnan A, Kuppusamy G. Review on nutraceuticals: Phase transition from preventive to protective care. Journal of Complementary and Integrative Medicine, 2022, 19(3), 553-570. DOI: 10.1515/jcim-2022-0026

[3] Sharma S, Sharma U, Dangi N, Gupta MK, Agrawal A, Mali SN, et al. A comprehensive review on immunoregulatory effects of phytochemicals. Current Drug Discovery Technologies, 2025, 22(3), e15701638326442. DOI: 10.2174/0115701638326442241118053543

[4] Chang X, Zhang T, Zhang W, Zhao Z, Sun J. Natural drugs as a treatment strategy for cardiovascular disease through the regulation of oxidative stress. Oxidative Medicine and Cellular Longevity, 2020, 2020, 5430407. DOI: 10.1155/2020/5430407

[5] Vlaicu PA, Untea AE, Varzaru I, Saracila M, Oancea AG. Designing nutrition for health-incorporating dietary by-products into poultry feeds to create functional foods with insights into health benefits, risks, bioactive compounds, food component functionality and safety regulations. Foods, 2023, 12(21), 4001. DOI: 10.3390/foods12214001

[6] Huang L, Xiao P, Guo L, Gao W. Molecular pharmacognosy. Science China Life Sciences, 2010, 53(6), 643-652. DOI: 10.1007/s11427-010-4006-4

[7] Patwardhan B, Aswar U. Harnessing the potential of ethnopharmacology for future medicines. Journal of Ethnopharmacology, 2025, 353(Pt A), 120359. DOI: 10.1016/j.jep.2025.120359
[8] Nedungadi P, Salethoor SN, Puthiyedath R, Nair VK, Kessler C, Raman R. Ayurveda research: Emerging trends and mapping to sustainable development goals. Journal of Ayurveda and Integrative Medicine, 2023, 14(6), 100809. DOI: 10.1016/j.jaim.2023.100809
[9] Wijewardhana U, Jayasinghe M, Wijesekara I, Ranaweera K. Zingiber officinale, phyllanthus emblica, cinnamomum verum, and curcuma longa to prevent type 2 diabetes: An integrative review. Current Diabetes Reviews, 2023, 19(8), e241122211183. DOI: 10.2174/1573399819666221124104401
[10] Zhao X, Tan X, Shi H, Xia D. Nutrition and traditional chinese medicine (TCM): A system's theoretical perspective. European Journal of Clinical Nutrition, 2021, 75(2), 267-273. DOI: 10.1038/s41430-020-00737-w
[11] Kim IS, Kim CH, Yang WS. Physiologically active molecules and functional properties of soybeans in human health-a current perspective. International Journal of Molecular Sciences, 2021, 22(8), 4054. DOI: 10.3390/ijms22084054
[12] Nasir F, Itrat M, Shahabuddin F, Nikhat S. Effective management of type-2 diabetes mellitus with Unani medications: A case report. Advances in Mind-Body Medicine, 2024, 38(4), 8-13.
[13] López-Rodríguez R, Domínguez L, Fernández-Ruiz V, Cámara M. Extracts rich in nutrients as novel food ingredients to be used in food supplements: A proposal classification. Nutrients, 2022, 14(15), 3194. DOI: 10.3390/nu14153194
[14] Rizvi SAA, Einstein GP, Tulp OL, Sainvil F, Branly R. Introduction to traditional medicine and their role in prevention and treatment of emerging and re-emerging diseases. Biomolecules, 2022, 12(10), 1442. DOI: 10.3390/biom12101442
[15] Johnson R, Fiddler T, Pirozek J, Gordon J, Sodhi S, Poirier J, et al. Traditional medicine and type 2 diabetes in first nations patients. Canadian Journal of Diabetes, 2022, 46(1), 53-59. DOI: 10.1016/j.jcjd.2021.05.007
[16] Sadgrove NJ. Honest nutraceuticals, cosmetics, therapies, and foods (NCTFs): Standardization and safety of natural products. Critical Reviews in Food Science and Nutrition, 2022, 62(16), 4326-4341. DOI: 10.1080/10408398.2021.1874286
[17] Essa MM, Bishir M, Bhat A, Chidambaram SB, Al-Balushi B, Hamdan H, et al. Functional foods and their impact on health. Journal of Food Science and Technology, 2023, 60(3), 820-834. DOI: 10.1007/s13197-021-05193-3
[18] Kulkarni A, Kulkarni CC, Pradeep SR, Poyya J, Kudva AK, Radhakrishnan V, et al. Role of anti-inflammatory and antioxidant properties of natural products in curing cardiovascular diseases. Current Issues in Molecular Biology, 2025, 47(11), 955. DOI: 10.3390/cimb47110955
[19] Hoti G, Matencio A, Rubin Pedrazzo A, Cecone C, Appleton SL, Khazaei Monfared Y, et al. Nutraceutical concepts and dextrin-based delivery systems. International Journal of Molecular Sciences, 2022, 23(8), 4102. DOI: 10.3390/ijms23084102
[20] Liu Y, Wang J, Wu C. Modulation of gut microbiota and immune system by probiotics, pre-biotics, and post-biotics. Frontiers in Nutrition, 2021, 8, 634897. DOI: 10.3389/fnut.2021.634897
[21] Jain DP, Pancholi SS, Patel R. Synergistic antioxidant activity of green tea with some herbs. Journal of Advanced Pharmaceutical Technology & Research, 2011, 2(3), 177-183. DOI: 10.4103/2231-4040.85538
[22] Ballester P, Cerdá B, Arcusa R, Marhuenda J, Yamedjeu K, Zafrilla P. Effect of ginger on inflammatory diseases. Molecules, 2022, 27(21), 7223. DOI: 10.3390/molecules27217223
[23] Skarzynski DJ, Szóstek-Mioduchowska AZ, Rebordão MR, Jalali BM, Piotrowska-Tomala KK, Leciejewska N, et al. Neutrophils, monocytes and other immune components in the equine endometrium: Friends or foes? Theriogenology, 2020, 150, 150-157. DOI: 10.1016/j.theriogenology.2020.01.018
[24] Zhou Y, Xu B. New insights into anti-diabetes effects and molecular mechanisms of dietary saponins. Critical Reviews in Food Science and Nutrition, 2023, 63(33), 12372-12397. DOI: 10.1080/10408398.2022.2101425
[25] Chen Y, Liu Z, Gong Y. Neuron-immunity communication: Mechanism of neuroprotective effects in EGCG. Critical Reviews in Food Science and Nutrition, 2024, 64(25), 9333-9352. DOI: 10.1080/10408398.2023.2212069
[26] Le Bloch J, Rouault M, Iriantsoa V, Michelet O. Polyphenols in human nutrition: European regulations and potential classification as a novel food or food additive. Journal of Agricultural and Food Chemistry, 2024, 72(48), 26936-26942. DOI: 10.1021/acs.jafc.4c08435
[27] Riaz M, Khalid R, Afzal M, Anjum F, Fatima H, Zia S, et al. Phytobioactive compounds as therapeutic agents for human diseases: A review. Food Science & Nutrition, 2023, 11(6), 2500-2529. DOI: 10.1002/fsn3.3308
[28] Kaushik P, Gahalayan A, Parashar S, Rani M, Khurana N, Dogra S, et al. Exploring the multifaceted health benefits of natural dietary sources: Antimicrobial, antioxidant, anticancer, and antidiabetic properties. Recent Patents on Biotechnology, 2025. DOI: 10.2174/0118722083375459250801073140
[29] Ballester P, Cerdá B, Arcusa R, García-Muñoz AM, Marhuenda J, Zafrilla P. Antioxidant activity in extracts from *Zingiberaceae* family: Cardamom, turmeric, and ginger. Molecules, 2023, 28(10), 4024. DOI: 10.3390/molecules28104024
[30] Osman A, Chittiboyina AG, Avula B, Ali Z, Adams SJ, Khan IA. Quality consistency of herbal products: Chemical evaluation. Progress in the Chemistry of Organic Natural Products, 2023, 122, 163-219. DOI: 10.1007/978-3-031-26768-0_2
[31] Nicolescu A, Babotă M, Barros L, Rocchetti G, Lucini L, Tanase C, et al. Bioaccessibility and bioactive potential of different phytochemical classes from nutraceuticals and functional foods. Frontiers in Nutrition, 2023, 10, 1184535. DOI: 10.3389/fnut.2023.1184535
[32] Chen G, Carcea M. Editorial: Advances and trends in nutraceutical and functional plant-based food. Frontiers in Nutrition, 2023, 10, 1168826. DOI: 10.3389/fnut.2023.1168826
[33] Jeyachandran S, Aman M. Valorisation of fish scales and bones: A sustainable source of bioactive proteins and collagen for nutraceuticals. Bioresources and Bioprocessing, 2025, 12(1), 141. DOI: 10.1186/s40643-025-00970-w
[34] El-Seedi HR, Eid N, Abd El-Wahed AA, Rateb ME, Afifi HS, Algethami AF, et al. Honey bee products: Preclinical and clinical studies of their anti-inflammatory and immunomodulatory properties. Frontiers in Nutrition, 2021, 8, 761267. DOI: 10.3389/fnut.2021.761267
[35] Elbandy M. Anti-inflammatory effects of marine bioactive compounds and their potential as functional food ingredients in the prevention and treatment of neuroinflammatory disorders. Molecules, 2022, 28(1), 2. DOI: 10.3390/molecules28010002
[36] Brito R, Costa D, Dias C, Cruz P, Barros P. Chondroitin sulfate supplements for osteoarthritis: A critical review. Cureus, 2023, 15(6), e40192. DOI: 10.7759/cureus.40192

[37] Balthazar CF, Guimarães JF, Coutinho NM, Pimentel TC, Ranadheera CS, Santillo A, et al. The future of functional food: Emerging technologies application on prebiotics, probiotics and postbiotics. Comprehensive Reviews in Food Science and Food Safety, 2022, 21(3), 2560-2586. DOI: 10.1111/1541-4337.12962
[38] Kumari A, K GR, Sudhakaran VA, Warrier AS, Singh NK. Unveiling the health benefits of prebiotics: A comprehensive review. Indian Journal of Microbiology, 2024, 64(2), 376-388. DOI: 10.1007/s12088-024-01235-4
[39] Assan D, Kuebutornye FKA, Hlordzi V, Chen H, Mraz J, Mustapha UF, et al. Effects of probiotics on digestive enzymes of fish (finfish and shellfish); Status and prospects: A mini review. Comparative Biochemistry and Physiology Part B: Biochemistry & Molecular Biology, 2022, 257, 110653. DOI: 10.1016/j.cbpb.2021.110653
[40] Alharbi NA. Polyphenol metabolites in fermented foods: Biotransformation, bioavailability, and functional roles. Frontiers in Nutrition, 2026, 13, 1767453. DOI: 10.3389/fnut.2026.1767453
[41] Elazzazy AM, Baeshen MN, Alasmi KM, Alqurashi SI, Desouky SE, Khattab SMR. Where biology meets engineering: Scaling up microbial nutraceuticals to bridge nutrition, therapeutics, and global impact. Microorganisms, 2025, 13(3), 566. DOI: 10.3390/microorganisms13030566
[42] Liu RH. Health-promoting components of fruits and vegetables in the diet. Advances in Nutrition, 2013, 4(3), 384s-392s. DOI: 10.3945/an.112.003517
[43] Gawish AS, ElMofty MS, Jambi S, Felemban D, Ragheb YS, Elsayed SA. Phytotherapy in periodontics as an effective and sustainable supplemental treatment: A narrative review. Journal of Periodontal & Implant Science, 2024, 54(4), 209-223. DOI: 10.5051/jpis.2301420071
[44] Engwa GA, EnNwekegwa FN, Nkeh-Chungag BN. Free radicals, oxidative stress-related diseases and antioxidant supplementation. Alternative Therapies, Health and Medicine, 2022, 28(1), 114-128.
[45] Al-Khayri JM, Sahana GR, Nagella P, Joseph BV, Alessa FM, Al-Mssallem MQ. Flavonoids as potential anti-inflammatory molecules: A review. Molecules, 2022, 27(9), 2901. DOI: 10.3390/molecules27092901
[46] Basak S, Gokhale J. Immunity boosting nutraceuticals: Current trends and challenges. Journal of Food Biochemistry, 2022, 46(3), e13902. DOI: 10.1111/jfbc.13902
[47] Cuevas-Cianca SI, Romero-Castillo C, Gálvez-Romero JL, Juárez ZN, Hernández LR. Antioxidant and anti-inflammatory compounds from edible plants with anti-cancer activity and their potential use as drugs. Molecules, 2023, 28(3), 1488. DOI: 10.3390/molecules28031488
[48] Mukhopadhyay N, Shukla A, Makhal PN, Kaki VR. Natural product-driven dual COX-LOX inhibitors: Overview of recent studies on the development of novel anti-inflammatory agents. Heliyon, 2023, 9(3), e14569. DOI: 10.1016/j.heliyon.2023.e14569
[49] Dey R, Dey S, Samadder A, Saxena AK, Nandi S. Natural inhibitors against potential targets of cyclooxygenase, lipoxygenase and leukotrienes. Combinatorial Chemistry & High Throughput Screening, 2022, 25(14), 2341-2357. DOI: 10.2174/1386207325666210917111847
[50] Fik-Jaskółka M, Mittova V, Motsonelidze C, Vakhania M, Vicidomini C, Roviello GN. Antimicrobial metabolites of Caucasian medicinal plants as alternatives to antibiotics. Antibiotics (Basel), 2024, 13(6), 487. DOI: 10.3390/antibiotics13060487
[51] Ayustaningwarno F, Anjani G, Ayu AM, Fogliano V. A critical review of ginger's (*Zingiber officinale*) antioxidant, anti-inflammatory, and immunomodulatory activities. Frontiers in Nutrition, 2024, 11, 1364836. DOI: 10.3389/fnut.2024.1364836
[52] Luan R, Ding D, Yang J. The protective effect of natural medicines against excessive inflammation and oxidative stress in acute lung injury by regulating the Nrf2 signaling pathway. Frontiers in Pharmacology, 2022, 13, 1039022. DOI: 10.3389/fphar.2022.1039022
[53] Inchingolo AD, Inchingolo AM, Malcangi G, Avantario P, Azzollini D, Buongiorno S, et al. Effects of resveratrol, curcumin and quercetin supplementation on bone metabolism-a systematic review. Nutrients, 2022, 14(17), 3519. DOI: 10.3390/nu14173519
[54] Medoro A, Davinelli S, Colletti A, Di Micoli V, Grandi E, Fogacci F, et al. Nutraceuticals as modulators of immune function: A review of potential therapeutic effects. Preventive Nutrition and Food Science, 2023, 28(2), 89-107. DOI: 10.3746/pnf.2023.28.2.89
[55] Gasmi A, Shanaida M, Oleshchuk O, Semenova Y, Mujawdiya PK, Ivankiv Y, et al. Natural ingredients to improve immunity. Pharmaceuticals (Basel), 2023, 16(4), 528. DOI: 10.3390/ph16040528
[56] Singh G, Sharma V, Udeh BN. Medicinal plants and lead phytomolecules as immunomodulators: An updated review. BioMed Research International, 2026, 2026, 6998034. DOI: 10.1155/bmri/6998034
[57] Anand S, Bharadvaja N. Potential benefits of nutraceuticals for oxidative stress management. Revista Brasileira de Farmacognosia, 2022, 32(2), 211-220. DOI: 10.1007/s43450-022-00246-w
[58] Siroma TK, Machate DJ, Zorgetto-Pinheiro VA, Figueiredo PS, Marcelino G, Hiane PA, et al. Polyphenols and ω-3 PUFAs: Beneficial outcomes to obesity and its related metabolic diseases. Frontiers in Nutrition, 2021, 8, 781622. DOI: 10.3389/fnut.2021.781622
[59] Djuricic I, Calder PC. Omega-3 (n-3) fatty acid-statin interaction: Evidence for a novel therapeutic strategy for atherosclerotic cardiovascular disease. Nutrients, 2024, 16(7), 962. DOI: 10.3390/nu16070962
[60] Drenjančević I, Pitha J. Omega-3 polyunsaturated fatty acids-vascular and cardiac effects on the cellular and molecular level (narrative review). International Journal of Molecular Sciences, 2022, 23(4), 2104. DOI: 10.3390/ijms23042104
[61] Brosolo G, Da Porto A, Marcante S, Picci A, Capilupi F, Capilupi P, et al. Omega-3 fatty acids in arterial hypertension: Is there any good news? International Journal of Molecular Sciences, 2023, 24(11), 9520. DOI: 10.3390/ijms24119520
[62] Fernandes I, Oliveira J, Pinho A, Carvalho E. The role of nutraceutical containing polyphenols in diabetes prevention. Metabolites, 2022, 12(2), 184. DOI: 10.3390/metabo12020184
[63] Cortez-Navarrete M, Pérez-Rubio KG, Escobedo-Gutiérrez MJ. Role of fenugreek, cinnamon, *Curcuma longa*, berberine and *Momordica charantia* in type 2 diabetes mellitus treatment: A review. Pharmaceuticals (Basel), 2023, 16(4), 515. DOI: 10.3390/ph16040515
[64] Nguyen NH, Pham THT, Nguyen NTT, Bui VKH, Van Vo G. Herbal medicine in diabetes treatment: An updated strategy with flavonoid compounds in preclinical and clinical studies. Chemistry & Biodiversity, 2025, 22(10), e02806. DOI: 10.1002/cbdv.202402806

[65] Chauhan S, Singh AP, Rana AC, Kumar S, Kumar R, Singh J, et al. Natural activators of ampk signaling: Potential role in the management of type-2 diabetes. Journal of Diabetes & Metabolic Disorders, 2023, 22(1), 47-59. DOI: 10.1007/s40200-022-01155-4
[66] Singh JK, Chakraborty S, Nagpal M, Aggarwal G. Herbal approach for diabetic cure and futuristic dimension. Current Drug Research Reviews, 2023, 15(3), 207-221. DOI: 10.2174/2589977515666230217114449
[67] Jiao X, Liu X, Cao Q, Deng Z. Plant-based supplements in enhancing exercise performance and recovery. Frontiers in Nutrition, 2025, 12, 1699642. DOI: 10.3389/fnut.2025.1699642
[68] Marino A, Battaglini M, Moles N, Ciofani G. Natural antioxidant compounds as potential pharmaceutical tools against neurodegenerative diseases. ACS Omega, 2022, 7(30), 25974-25990. DOI: 10.1021/acsomega.2c03291
[69] Singh J, Kumar D. *In vivo* and *in vitro* perspectives in Parkinson's disease: Mechanisms and the role of phytomedicine. Journal of Food and Drug Analysis, 2025, 33(3), 193-212. DOI: 10.38212/2224-6614.3557
[70] Bhat KMR, Upadhya R, Adiga S, Kumar SEP, Manjula SD, Acharya N, et al. Regulation of chronic neuroinflammation through dietary herbal products. Frontiers in Nutrition, 2025, 12, 1487786. DOI: 10.3389/fnut.2025.1487786
[71] Aggarwal A, Rajalekshmi R, Aggarwal A, Agrawal DK. Plants, pills, and the brain: Exploring phytochemicals and neurological medicines. International Journal of Plant, Animal and Environmental Sciences, 2025, 15(3), 90-114. DOI: 10.26502/ijpaes.4490180
[72] Li RL, Wang LY, Duan HX, Zhang Q, Guo X, Wu C, et al. Regulation of mitochondrial dysfunction induced cell apoptosis is a potential therapeutic strategy for herbal medicine to treat neurodegenerative diseases. Frontiers in Pharmacology, 2022, 13, 937289. DOI: 10.3389/fphar.2022.937289
[73] Qiao J, Wang C, Chen Y, Yu S, Liu Y, Yu S, et al. Herbal/natural compounds resist hallmarks of brain aging: From molecular mechanisms to therapeutic strategies. Antioxidants (Basel), 2023, 12(4), 920. DOI: 10.3390/antiox12040920
[74] Xiang L, Wang Y, Liu S, Liu B, Jin X, Cao X. Targeting protein aggregates with natural products: An optional strategy for neurodegenerative diseases. International Journal of Molecular Sciences, 2023, 24(14), 11275. DOI: 10.3390/ijms241411275
[75] Puri V, Nagpal M, Singh I, Singh M, Dhingra GA, Huanbutta K, et al. A comprehensive review on nutraceuticals: Therapy support and formulation challenges. Nutrients, 2022, 14(21), 4637. DOI: 10.3390/nu14214637
[76] Vrânceanu M, Galimberti D, Banc R, Dragoş O, Cozma-Petruţ A, Hegheş SC, et al. The anticancer potential of plant-derived nutraceuticals via the modulation of gene expression. Plants (Basel), 2022, 11(19), 2524. DOI: 10.3390/plants11192524
[77] Alharbi KS, Almalki WH, Makeen HA, Albratty M, Meraya AM, Nagraik R, et al. Role of medicinal plant-derived nutraceuticals as a potential target for the treatment of breast cancer. Journal of Food Biochemistry, 2022, 46(12), e14387. DOI: 10.1111/jfbc.14387
[78] Trivedi A, Hasan A, Ahmad R, Siddiqui S, Srivastava A, Misra A, et al. Flavonoid myricetin as potent anticancer agent: A possibility towards development of potential anticancer nutraceuticals. Chinese Journal of Integrative Medicine, 2024, 30(1), 75-84. DOI: 10.1007/s11655-023-3701-5
[79] Sailo BL, Liu L, Chauhan S, Girisa S, Hegde M, Liang L, et al. Harnessing sulforaphane potential as a chemosensitizing agent: A comprehensive review. Cancers (Basel), 2024, 16(2), 244. DOI: 10.3390/cancers16020244
[80] Sarma ND, Monagas M, Giancaspro G, Brinckmann JA, Harnly J, Kababick J, et al. Compendial perspectives on botanical identity testing. Journal of Natural Products, 2026, 89(2), 339-351. DOI: 10.1021/acs.jnatprod.5c01200
[81] Shabana, Barkatullah, Nafees M. Pharmacognostic standardization of *Xanthium spinosum* L. Through scanning electron microscopy and analytical techniques. Microscopy Research and Technique, 2022, 85(12), 3736-3754. DOI: 10.1002/jemt.24224
[82] Öztürk Ş, Ergen Akçin Ö. Microscopic analysis of anatomical and taxonomic characteristics in some centaurea species. Microscopy Research and Technique, 2026, 89(2), 243-259. DOI: 10.1002/jemt.70068
[83] Tian WW, Liu L, Chen P, Yu DM, Li QM, Hua H, et al. *Curcuma longa* (turmeric): From traditional applications to modern plant medicine research hotspots. Chinese Medical Journal, 2025, 20(1), 76. DOI: 10.1186/s13020-025-01115-z
[84] Elshafie HS, Camele I, Mohamed AA. A comprehensive review on the biological, agricultural and pharmaceutical properties of secondary metabolites based-plant origin. International Journal of Molecular Sciences, 2023, 24(4), 3266. DOI: 10.3390/ijms24043266
[85] Amssayef A, Eddouks M. Alkaloids as vasodilator agents: A review. Current Pharmaceutical Design, 2023, 29(24), 1886-1895. DOI: 10.2174/1381612829666230809094313
[86] Rathee P, Chaudhary H, Rathee S, Rathee D, Kumar V, Kohli K. Mechanism of action of flavonoids as anti-inflammatory agents: A review. Inflammation & Allergy-Drug Targets, 2009, 8(3), 229-235. DOI: 10.2174/187152809788681029
[87] Maugeri A, Lombardo GE, Cirmi S, Süntar I, Barreca D, Laganà G, et al. Pharmacology and toxicology of tannins. Archives of Toxicology 2022, 96(5), 1257-1277. DOI: 10.1007/s00204-022-03250-0
[88] de Sousa DP, Damasceno ROS, Amorati R, Elshabrawy HA, de Castro RD, Bezerra DP, et al. Essential oils: Chemistry and pharmacological activities. Biomolecules, 2023, 13(7), 1144. DOI: 10.3390/biom13071144
[89] Raudone L, Savickiene N. Phytochemical profiles of plant materials: From extracts to added-value ingredients. Plants (Basel), 2024, 13(7), 964. DOI: 10.3390/plants13070964
[90] Lindenmaier MP, Bernart MW, Brinckmann JA. Advanced methodologies for the quality control of herbal supplements and regulatory considerations. Phytochemical Analysis, 2025, 36(8), 2417-2433. DOI: 10.1002/pca.70000
[91] Amir M, Zafar A, Ahmad R, Ahmad W, Sarafroz M, Khalid M, et al. Quality control standardization, contaminant detection and *in vitro* antioxidant activity of *Prunus domestica* Linn. Fruit. Plants (Basel), 2022, 11(5), 706. DOI: 10.3390/plants11050706
[92] El-Saadony MT, Saad AM, Mohammed DM, Alkafaas SS, Abd El-Mageed TA, Fahmy MA, et al. Plant bioactive compounds: Extraction, biological activities, immunological, nutritional aspects, food application, and human health benefits-a comprehensive review. Frontiers in Nutrition, 2025, 12, 1659743. DOI: 10.3389/fnut.2025.1659743
[93] Pathaw N, Devi KS, Sapam R, Sanasam J, Monteshori S, Phurailatpam S, et al. A comparative review on the anti-nutritional factors of herbal tea concoctions and their reduction strategies. Frontiers in Nutrition, 2022, 9, 988964. DOI: 10.3389/fnut.2022.988964
[94] Muscolo A, Mariateresa O, Giulio T, Mariateresa R. Oxidative stress: The role of antioxidant phytochemicals in the prevention and treatment of diseases. International Journal of Molecular Sciences, 2024, 25(6), 3264. DOI: 10.3390/ijms25063264

[95] Shanmugam G. Polyphenols: Potent protectors against chronic diseases. Natural Product Research, 2025, 39(23), 6941-6943. DOI: 10.1080/14786419.2024.2386402
[96] Oršolić N, Jazvinšćak Jembrek M. Molecular and cellular mechanisms of propolis and its polyphenolic compounds against cancer. International Journal of Molecular Sciences, 2022, 23(18), 10479. DOI: 10.3390/ijms231810479
[97] Meccariello R, D'Angelo S. Impact of polyphenolic-food on longevity: An elixir of life. An overview. Antioxidants (Basel), 2021, 10(4), 507. DOI: 10.3390/antiox10040507
[98] Charlton NC, Mastyugin M, Török B, Török M. Structural features of small molecule antioxidants and strategic modifications to improve potential bioactivity. Molecules, 2023, 28(3), 1057. DOI: 10.3390/molecules28031057
[99] Mucha P, Skoczyńska A, Małecka M, Hikisz P, Budzisz E. Overview of the antioxidant and anti-inflammatory activities of selected plant compounds and their metal ions complexes. Molecules, 2021, 26(16), 4886. DOI: 10.3390/molecules26164886
[100] Parmenter BH, Dalgaard F, Murray K, Marquis-Gravel G, Cassidy A, Bondonno CP, et al. Intake of dietary flavonoids and incidence of ischemic heart disease in the danish diet, cancer, and health cohort. European Journal of Clinical Nutrition, 2023, 77(2), 270-277. DOI: 10.1038/s41430-022-01226-y
[101] Bellavite P. Neuroprotective potentials of flavonoids: Experimental studies and mechanisms of action. Antioxidants (Basel), 2023, 12(2), 280. DOI: 10.3390/antiox12020280
[102] Kamran S, Sinniah A, Abdulghani MAM, Alshawsh MA. Therapeutic potential of certain terpenoids as anticancer agents: A scoping review. Cancers (Basel), 2022, 14(5), 1100. DOI: 10.3390/cancers14051100
[103] Uvaniskanova Z, Hafez-Ghoran S, Ikhlas Abdjan M, Mountessou BYG, Taktaz F, Mulya F, et al. Anti-inflammatory activity-guided isolation and *in silico* validation of turmeric (*Curcuma longa* L.) phytochemicals. Foods, 2025, 14(24), 4205. DOI: 10.3390/foods14244205
[104] Sutopo NC, Qomaladewi NP, Lee HW, Lee MS, Kim JH, Cho JY. Comprehensive understanding and underlying molecular mechanisms of the adaptogenic effects of *Panax ginseng*. Journal of Ginseng Research, 2025, 49(4), 356-365. DOI: 10.1016/j.jgr.2025.03.013
[105] Zhang Q, Jiang Q, Sa K, Liang J, Sun D, Li H, et al. Research progress of plant-derived natural alkaloids in central nervous system diseases. Phytotherapy Research, 2023, 37(11), 4885-4907. DOI: 10.1002/ptr.7955
[106] Abookleesh FL, Al-Anzi BS, Ullah A. Potential antiviral action of alkaloids. Molecules, 2022, 27(3), 903. DOI: 10.3390/molecules27030903
[107] Vital-Lopez FG, Doty TJ, Reifman J. When to sleep and consume caffeine to boost alertness. Sleep, 2024, 47(10), zsae133. DOI: 10.1093/sleep/zsae133
[108] Musazadeh V, Hamidi N, Noormohammadi M, Shidfar F. The effect of berberis (vulgaris and integerrima) on cardiovascular risk factors in patients with type 2 diabetes mellitus: A systematic review, meta-analysis, and GRADE assessment. Current Therapeutic Research-clinical and Experimental, 2025, 102, 100788. DOI: 10.1016/j.curtheres.2025.100788
[109] Timilsena YP, Phosanam A, Stockmann R. Perspectives on saponins: Food functionality and applications. International Journal of Molecular Sciences, 2023, 24(17), 13538. DOI: 10.3390/ijms241713538
[110] Jiang M, Hong C, Zou W, Ye Z, Lu L, Liu Y, et al. Recent advances in the anti-tumor activities of saponins through cholesterol regulation. Frontiers in Pharmacology, 2024, 15, 1469392. DOI: 10.3389/fphar.2024.1469392
[111] Zarbakhsh S. Effect of antioxidants on preimplantation embryo development *in vitro*: A review. Zygote, 2021, 29(3), 179-193. DOI: 10.1017/s0967199420000660
[112] Kumari N, Anand S, Shah K, Chauhan NS, Sethiya NK, Singhal M. Emerging role of plant-based bioactive compounds as therapeutics in Parkinson's disease. Molecules, 2023, 28(22), 7588. DOI: 10.3390/molecules28227588
[113] Shahrajabian MH, Sun W. The golden spice for life: Turmeric with the pharmacological benefits of curcuminoids components, including curcumin, bisdemethoxycurcumin, and demethoxycurcumins. Current Organic Synthesis, 2024, 21(5), 665-683. DOI: 10.2174/1570179420666230607124949
[114] Qin T, Chen X, Meng J, Guo Q, Xu S, Hou S, et al. The role of curcumin in the liver-gut system diseases: From mechanisms to clinical therapeutic perspective. Critical Reviews in Food Science and Nutrition, 2024, 64(24), 8822-8851. DOI: 10.1080/10408398.2023.2204349
[115] Abd El-Ghany WA. Potential effects of garlic (*Allium sativum* L.) on the performance, immunity, gut health, anti-oxidant status, blood parameters, and intestinal microbiota of poultry: An updated comprehensive review. Animals (Basel), 2024, 14(3), 498. DOI: 10.3390/ani14030498
[116] Dai X, Azi F, Alnadari F, Yu Z. Developing organosulfur compounds in *Allium* as the next-generation flavor and bioactive ingredients for food and medicine. Critical Reviews in Food Science and Nutrition, 2025, 65(33), 8406-8424. DOI: 10.1080/10408398.2025.2500674
[117] Farhan M. Green tea catechins: Nature's way of preventing and treating cancer. International Journal of Molecular Sciences, 2022, 23(18), 10713. DOI: 10.3390/ijms231810713
[118] Samanta S. Potential bioactive components and health promotional benefits of tea (*Camellia sinensis*). Journal of the American Nutrition Association, 2022, 41(1), 65-93. DOI: 10.1080/07315724.2020.1827082
[119] Pathak S, Pratap A, Sharma R, Jha MK. The *Phyllanthus emblica* fruits: A review on phytochemistry traditional uses, bioactive composition and pharmacological activities. Current Topics in Medicinal Chemistry, 2024, 24(22), 1917-1939. DOI: 10.2174/0115680266321320240708060327
[120] Intharuksa A, Arunotayanun W, Na Takuathung M, Chaichit S, Prasansuklab A, Chaikhong K, et al. Daidzein and genistein: Natural phytoestrogens with potential applications in hormone replacement therapy. International Journal of Molecular Sciences, 2025, 26(14), 6973. DOI: 10.3390/ijms26146973
[121] Vittal M, Vinciguerra M. Enhancing healthspan with ashwagandha (*Withania somnifera*): A comprehensive review of its multifaceted geroprotective benefits. Biogerontology, 2025, 26(5), 179. DOI: 10.1007/s10522-025-10320-0
[122] Arya R, Faruquee HM, Shakya H, Rahman SA, Begum MM, Biswas SK, et al. Harnessing the antibacterial, anti-diabetic and anti-carcinogenic properties of *Ocimum sanctum* Linn (Tulsi). Plants (Basel), 2024, 13(24), 3516. DOI: 10.3390/plants13243516
[123] Jomova K, Raptova R, Alomar SY, Alwasel SH, Nepovimova E, Kuca K, et al. Reactive oxygen species, toxicity, oxidative stress, and antioxidants: Chronic diseases and aging. Archives of Toxicology, 2023, 97(10), 2499-2574. DOI: 10.1007/s00204-023-03562-9

[124] Chaudhary P, Janmeda P, Docea AO, Yeskaliyeva B, Abdull Razis AF, Modu B, et al. Oxidative stress, free radicals and antioxidants: Potential crosstalk in the pathophysiology of human diseases. Frontiers in Chemistry, 2023, 11, 1158198. DOI: 10.3389/fchem.2023.1158198
[125] Bagherniya M, Mahdavi A, Abbasi E, Iranshahy M, Sathyapalan T, Sahebkar A. The effects of phytochemicals and herbal bio-active compounds on tumour necrosis factor-α in overweight and obese individuals: A clinical review. Inflammopharmacology, 2022, 30(1), 91-110. DOI: 10.1007/s10787-021-00902-y
[126] Giurranna E, Nencini F, Bettiol A, Borghi S, Argento FR, Emmi G, et al. Dietary antioxidants and natural compounds in preventing thrombosis and cardiovascular disease. International Journal of Molecular Sciences, 2024, 25(21), 11457. DOI: 10.3390/ijms252111457
[127] Kashtoh H, Baek KH. New insights into the latest advancement in α-amylase inhibitors of plant origin with anti-diabetic effects. Plants (Basel), 2023, 12(16), 2944. DOI: 10.3390/plants12162944
[128] Grabska-Kobyłecka I, Szpakowski P, Król A, Książek-Winiarek D, Kobyłecki A, Głąbiński A, et al. Polyphenols and their impact on the prevention of neurodegenerative diseases and development. Nutrients, 2023, 15(15), 3454. DOI: 10.3390/nu15153454
[129] Ahmed M. Targeting aging pathways with natural compounds: A review of curcumin, epigallocatechin gallate, thymoquinone, and resveratrol. Immunity & Ageing, 2025, 22(1), 28. DOI: 10.1186/s12979-025-00522-y
[130] Shimizu M, Weinstein IB. Modulation of signal transduction by tea catechins and related phytochemicals. Mutation Research, 2005, 591(1-2), 147-160. DOI: 10.1016/j.mrfmmm.2005.04.010
[131] Petrovic SM, Barbinta-Patrascu ME. Organic and biogenic nanocarriers as bio-friendly systems for bioactive compounds' delivery: State-of-the art and challenges. Materials (Basel), 2023, 16(24), 7550. DOI: 10.3390/ma16247550
[132] Chavda VP, Patel AB, Mistry KJ, Suthar SF, Wu ZX, Chen ZS, et al. Nano-drug delivery systems entrapping natural bioactive compounds for cancer: Recent progress and future challenges. Frontiers in Oncology, 2022, 12, 867655. DOI: 10.3389/fonc.2022.867655
[133] Dwivedi K, Sahoo A, Almalki WH, Almujri SS, Aodah A, Alruwaili NK, et al. Innovative nanocarrier systems for enhanced delivery of phyto-active compounds in cancer therapy. Nanomedicine (Lond), 2025, 20(1), 91-116. DOI: 10.1080/17435889.2024.2440301
[134] Hlatshwayo S, Thembane N, Krishna SBN, Gqaleni N, Ngcobo M. Extraction and processing of bioactive phytoconstituents from widely used South African medicinal plants for the preparation of effective traditional herbal medicine products: A narrative review. Plants (Basel), 2025, 14(2), 206. DOI: 10.3390/plants14020206
[135] Herzyk F, Piłakowska-Pietras D, Korzeniowska M. Supercritical extraction techniques for obtaining biologically active substances from a variety of plant byproducts. Foods, 2024, 13(11), 1713. DOI: 10.3390/foods13111713
[136] Evans M, Lewis ED, Antony JM, Crowley DC, Guthrie N, Blumberg JB. Breaking new frontiers: Assessment and re-evaluation of clinical trial design for nutraceuticals. Frontiers in Nutrition, 2022, 9, 958753. DOI: 10.3389/fnut.2022.958753
[137] Vashishat A, Patel P, Das Gupta G, Das Kurmi B. Alternatives of animal models for biomedical research: A comprehensive review of modern approaches. Stem Cell Reviews and Reports, 2024, 20(4), 881-899. DOI: 10.1007/s12015-024-10701-x
[138] Aleta A, Brighenti F, Jolliet O, Meijaard E, Shamir R, Moreno Y, et al. A need for a paradigm shift in healthy nutrition research. Frontiers in Nutrition, 2022, 9, 881465. DOI: 10.3389/fnut.2022.881465
[139] Gaur A, Singhal N, Vardhan H, Jain R, Bist Y, Wagri NK. Cultivation to consumption: Strengthening bacterial safety in plant-based nutraceuticals. Frontiers in Microbiology, 2025, 16, 1698580. DOI: 10.3389/fmicb.2025.1698580
[140] Afzal I, Haq MZU, Ahmed S, Hirich A, Bazile D. Challenges and perspectives for integrating quinoa into the Agri-food system. Plants (Basel), 2023, 12(19), 3361. DOI: 10.3390/plants12193361
[141] Noviana E, Indrayanto G, Rohman A. Advances in fingerprint analysis for standardization and quality control of herbal medicines. Frontiers in Pharmacology, 2022, 13, 853023. DOI: 10.3389/fphar.2022.853023