Medicinal Plants: Sustainable Scope to Nutraceuticals

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Abstract Medicinal plants exhibit a broad range of potential for nutraceuticals, presenting a diverse assortment of bioactive compounds that confer notable health advantages beyond fundamental nourishment. These chemical compounds, which encompass polyphenols, flavonoids, alkaloids, terpenoids, and essential oils, demonstrate a wide range of biological activities, including antioxidant, anti-inflammatory, antimicrobial, and anticancer effects. The potential applications of nutraceuticals derived from medicinal plants exhibit promising prospects, encompassing disease prevention and management as well as the promotion of overall well-being. Additionally, the accessibility and affordability of these natural sources, coupled with their potential synergistic effects, render them appealing alternatives to traditional pharmaceuticals. However, it is imperative to address challenges pertaining to standardization, quality control, and regulatory frameworks in order to fully harness the potential of medicinal plants as valuable sources of nutraceuticals. The primary objective of this chapter is to investigate the extent of nutraceuticals obtained from medicinal plants and their importance in enhancing human welfare, while also acknowledging the obstacles and future prospects in the field of nutraceutical research.

Keywords Medicinal plants · Nutraceutical · Bioactive compounds · Phytochemicals · Health benefits · Herbal nutraceuticals

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1 Introduction

Medicinal plants, scientifically referred to as herbal medicines or botanical drugs, encompass plant organisms or specific plant components that possess bioactive compounds exhibiting therapeutic attributes. The aforementioned bioactive compounds, namely alkaloids, flavonoids, terpenoids, and phenolic compounds, possess the capacity to elicit physiological and pharmacological responses within the human organism. Medicinal plants possess the potential to be utilized either in their unaltered state or subjected to processing techniques to yield diverse formulations such as extracts, powders, tinctures, or essential oils, all of which serve medicinal objectives (Farzaneh et al. 2015). Medicinal plants have been employed for numerous centuries as a primary reservoir of traditional remedies and therapeutic methodologies. Throughout diverse cultural and societal contexts, indigenous populations have historically utilized the medicinal attributes of botanical organisms to address physical and mental afflictions, as well as to promote general health and vitality. The abundant biodiversity present on earth presents a valuable collection of plant species harbouring bioactive compounds that exhibit promising medicinal properties (Velu et al. 2018).

In the past few decades, there has been a notable increase in scientific attention towards the study of medicinal plants and their potential as nutraceuticals. This heightened emphasis arises from the escalating cognizance of the constraints and adverse reactions associated with synthetic pharmaceuticals, coupled with the expanding acknowledgment of the significance of proactive healthcare. Medicinal plants present a highly encouraging pathway for the advancement of naturally-derived, non-toxic, and environmentally-friendly therapeutic substances (Ruchi 2017). The extent of nutraceuticals derived from medicinal plants is expansive and includes a diverse array of bioactive compounds, including polyphenols, flavonoids, alkaloids, terpenoids, and essential oils (Fig. 1). These compounds have exhibited diverse biological activities, encompassing antioxidant, anti-inflammatory, antimicrobial, anticancer, and immune-modulatory effects. They have the potential to mitigate and regulate chronic ailments such as cardiovascular disorders, diabetes, neurodegenerative conditions, and cancer. Furthermore, these entities exhibit characteristics that augment cognitive performance, enhance gastrointestinal well-being, and fortify immune response (Velu et al. 2018).

Nutraceuticals from medicinal plants have numerous advantages. First and foremost, these compounds are derived from natural sources, which may render them comparatively safer and more easily tolerated than their synthetic counterparts. Moreover, the extensive presence of botanical species in various geographical areas enhances their accessibility and affordability in comparison to conventional pharmaceuticals. Moreover, the combined impacts of various bioactive compounds found in medicinal plants may offer amplified therapeutic advantages (Srivastava et al. 2015).

Numerous medicinal plants have been acknowledged for their potential as nutraceuticals. Some examples of scientifically recognized substances are turmeric (*Curcuma longa*), which contains curcumin with strong anti-inflammatory and

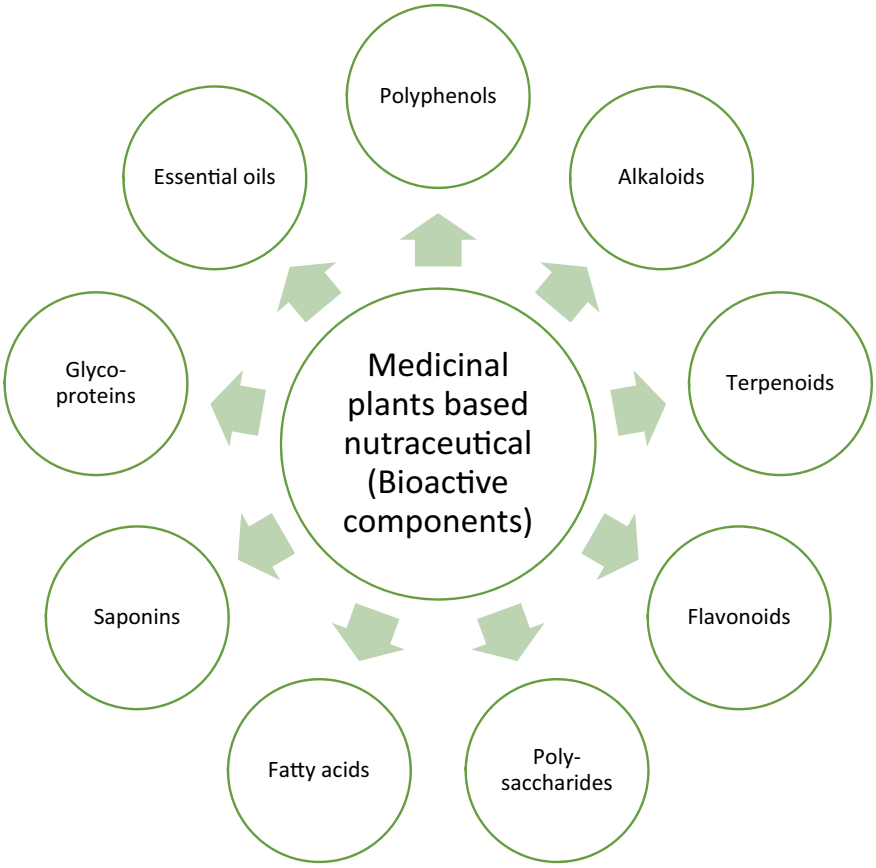

Fig. 1 Medicinal plants possesses bioactive components which may act as nutraceutical

antioxidant characteristics; garlic (*Allium sativum*), known for its ability to combat microbes and promote cardiovascular health; and green tea (*Camellia sinensis*), which is abundant in polyphenols that have been shown to have anticancer and neuroprotective properties. These plants have undergone thorough scientific investigation, and their nutraceutical constituents are currently accessible in diverse formats, including supplements, extracts, and functional foods. Ajanaku et al. (2022) Despite the enormous promise that medicinal plants have as sources of nutraceuticals, there are still a number of difficulties. The implementation of standardized extraction methodologies, rigorous quality control measures, and meticulous dose optimization are imperative in order to guarantee the uniformity and dependability of products. Furthermore, it is imperative to establish regulatory frameworks that guarantee the safety, effectiveness, and accurate labelling of nutraceutical products derived from medicinal plants.

The word Nutraceuticals refer to bioactive compounds obtained from natural origins, such as medicinal plants, which offer health advantages that extend beyond fundamental nutrition. The neologism "nutraceutical" is a portmanteau of the terms "nutrition" and "pharmaceutical," which aptly captures their shared function in bolstering well-being and mitigating ailments. These compounds have the potential to be extracted from various food sources, such as concentrated extracts, and can also be incorporated into dietary supplements, functional foods, or beverages. The objective of this chapter is to present a comprehensive examination of medicinal plants and their nutraceutical potential. This chapter is mainly emphasised on the extensive array of bioactive compounds present in medicinal plants, elucidates their mechanisms of action, and examines their potential implications in the fields of healthcare and nutrition. Additionally, it also highlights the necessity of interdisciplinary collaborations in order to optimize the complete potential of medicinal plants for the advancement of human health and well-being (Benković 2019; Thaur and Belwal 2022).

2 Components of Medicinal Plants as Nutraceuticals

The pant components which work as Nutraceuticals can be delineated into distinct categories and few are:

2.1 Polyphenols

Polyphenols encompass a wide array of chemical compounds that are abundantly present in various fruits, vegetables, grains, and herbs. They demonstrate antioxidant and anti-inflammatory characteristics and contribute to a range of health advantages, such as promoting cardiovascular health, enhancing cognitive function, and aiding in cancer prevention. Polyphenols exert their effects through the process of free radical scavenging, which involves the removal of unstable molecules that can cause damage to cells. Additionally, they contribute to the reduction of oxidative stress, a condition characterized by an imbalance between the production of reactive oxygen species and the body's ability to neutralize them. Furthermore, polyphenols play a role in regulating signalling pathways that are implicated in inflammation and the growth of cells (Pandey et al. 2011). Polyphenols, such as resveratrol found in grapes and berries, quercetin present in onions and apples, and catechins abundant in green tea, are notable examples.

2.2 Alkaloids

They are class of organic compounds that contain nitrogen and are commonly present in various plant species. These entities demonstrate a wide range of biological activities, encompassing antimicrobial, analgesic, and anti-inflammatory properties. Alkaloids have the capability to engage with cellular receptors and enzymes, thereby exerting an influence on processes such as neurotransmission, cell signalling, and immune responses (Yan et al. 2021). Instances of alkaloids encompass caffeine (found in coffee and tea), morphine (derived from the opium poppy), and vincristine (obtained from the Madagascar periwinkle) (Fu et al. 2002).

2.3 Carotenoids

They are organic compounds that function as pigments, contributing to the visually striking colours observed in various fruits and vegetables. They exhibit antioxidant properties and are renowned for their involvement in ocular health and immune system functionality. Carotenoids possess the ability to effectively eliminate free radicals, safeguard cells against oxidative harm, and uphold the structural soundness of the retina. Carotenoids, such as beta-carotene found in carrots and sweet potatoes, lycopene present in tomatoes, and lutein found in leafy greens and egg yolks, serve as notable examples (Wang et al. 2021).

2.4 Terpenoids

The other name for them as isoprenoids, encompass a vast array of chemical compounds that are abundantly present in various plant species. These compounds include essential oils and plant resins. These entities exhibit antimicrobial, anti-inflammatory, and anticancer characteristics. Terpenoids elicit their effects via diverse mechanisms, including the modulation of cellular signalling pathways, inhibition of enzyme activity, and interaction with cellular membranes. Terpenoids are a class of organic compounds that can be found in various natural sources. Some notable examples of terpenoids include limonene, which is commonly found in citrus fruits, menthol, which is abundant in peppermint, and curcumin, which is present in turmeric (Jahangeer et al. 2021).

2.5 Omega-3 Fatty Acids

Omega-3 fatty acids are a class of necessary polyunsaturated fatty acids that can be found in various sources such as fish, flaxseeds, chia seeds, and walnuts. These entities are renowned for their advantageous impact on cardiovascular health, cognitive function, and reduction of inflammation. The actions of omega-3 fatty acids are exerted through their influence on the function of cell membranes, gene expression, and pathways related to inflammation (Jaca et al. 2020).

3 Relationship Between Nutraceutical and Medicinal Plants

The interconnection and symbiotic nature of the relationship between nutraceuticals and medicinal plants is evident. Nutraceuticals are derived from botanical sources and harness their bioactive compounds to confer health advantages that extend beyond fundamental nutrition (Gossell-Williams et al. 2006). Here are several fundamental elements of their relationship:

- ***Source of Bioactive Compounds***: Medicinal plants are the predominant origin of bioactive compounds, which are utilized in the development of nutraceutical products. The presence of bioactive compounds, including polyphenols, flavonoids, terpenoids, alkaloids, and various others, plays a significant role in the therapeutic attributes exhibited by medicinal plants. Nutraceuticals employ various methods such as extraction, concentration, or isolation to augment the potency and bioavailability of bioactive compounds within the ultimate product.
- ***Therapeutic Potential***: Medicinal plants possess a lengthy historical record of traditional utilization due to their medicinal attributes, and their bioactive compounds have undergone extensive scientific examination to explore their potential health advantages. Nutraceuticals utilize bioactive compounds to effectively leverage the therapeutic capabilities of medicinal plants in a concentrated and standardized manner. This facilitates precise and efficient utilization of the bioactive compounds, promoting diverse aspects of physical and mental wellness.
- ***The preventive and wellness approach***: its encompasses the utilization of both medicinal plants and nutraceuticals in the context of promoting health and preventing diseases. Medicinal plants have been utilized in traditional medicine systems due to their inherent preventive and therapeutic attributes. In a similar vein, nutraceuticals obtained from botanical sources present a proactive methodology towards health by furnishing an array of bioactive constituents that bolster diverse physiological processes, stimulate antioxidant and anti-inflammatory responses, and augment general state of being. The synergistic blend of bioactive compounds found in nutraceuticals derived from medicinal plants facilitates a comprehensive approach to preventive healthcare.

- ***Research and innovation***: this domain are driven by the correlation between nutraceuticals and medicinal plants. Scientists and researchers engage in the exploration of medicinal plants in order to discern and describe bioactive compounds, examine their mechanisms of action, and assess their effectiveness and safety. This information is subsequently utilized in the advancement of nutraceutical products, wherein particular bioactive compounds are chosen, enhanced, and structured to generate products with precise health advantages.
- ***Integration of Traditional and Modern Knowledge***: The incorporation of botanical resources in nutraceutical products facilitates the amalgamation of indigenous wisdom and contemporary scientific investigations. Traditional medicine systems possess a profound comprehension of the therapeutic attributes exhibited by medicinal plants, as well as their synergistic effects when combined and the suitable methods of administration. This knowledge is integrated with scientific progress, encompassing phytochemical analysis, pharmacological investigations, and clinical trials, in order to substantiate and broaden the traditional applications of medicinal plants. Nutraceuticals originating from botanical sources serve as a scientific link connecting traditional and contemporary knowledge, offering empirically supported uses for their biologically active constituents.

4 Scope of Medicinal Plants as Nutraceuticals

The scope of medicinal plants is extensive and encompasses various aspects of human health and well-being as nutraceuticals. Several crucial elements encompass the scope of medicinal plants, including:

- ***Medicinal plants*** have long been a fundamental component of traditional and indigenous medical practices worldwide. Indigenous communities possess a wealth of knowledge regarding the traditional utilization of medicinal plants, which has been transmitted across generations. The exploration and conservation of this traditional knowledge is imperative in order to comprehend the therapeutic capabilities of medicinal plants (Karunamoorthi et al. 2013).
- ***Drug Discovery and Development***: Medicinal plants have been extensively utilized as a valuable reservoir of primary compounds for the advancement of contemporary pharmaceutical drugs. Numerous pharmacologically significant compounds, such as acetylsalicylic acid (commonly known as aspirin) and morphine, can be traced back to their botanical sources. The investigation of plant biodiversity and the extraction of bioactive compounds present potential avenues for the identification and advancement of innovative pharmaceuticals to address a range of illnesses (Prasathkumar et al. 2021).
- ***Medicinal plants*** are of considerable importance in the realm of complementary and alternative medicine (CAM) modalities. A significant number of individuals are inclined towards natural and holistic healthcare methods, resulting in the incorporation of medicinal plants into complementary and alternative medicine (CAM)

practices such as herbal medicine, Ayurveda, traditional Chinese medicine, and naturopathy (Yuan et al. 2016).

- ***The nutraceutical industry*** has experienced a significant increase in attention regarding the utilization of botanical medicines. Nutraceuticals are biologically active compounds obtained from botanical sources that confer health advantages surpassing fundamental nutritional requirements. Medicinal plants are employed in the manufacturing of dietary supplements, functional foods, and fortified beverages, providing consumers with a natural and comprehensive method for enhancing health and well-being (Bommakanti et al. 2023).
- ***Preventive Healthcare and Health Promotion***: Medicinal plants possess the capacity to contribute to preventive healthcare through the provision of naturally occurring compounds that facilitate the enhancement of overall health and well-being. The bioactive constituents found within medicinal plants demonstrate antioxidant, anti-inflammatory, immunomodulatory, and antimicrobial characteristics, thereby bolstering the body's innate defence mechanisms and aiding in the prevention of chronic ailments (Sofowora et al. 2013).
- ***Sustainable agriculture and conservation***: The practice of cultivating and responsibly harvesting medicinal plants can yield favourable outcomes for agricultural methodologies and the preservation of the environment. The incorporation of botanical species with medicinal properties into agroforestry systems, the advocacy for sustainable cultivation techniques, and the conservation of plant biodiversity all contribute to the maintenance of ecological equilibrium and the safeguarding of traditional knowledge (Chen et al. 2016).

5 Mechanisms Involve in Use of Medicinal Plants as Nutraceuticals

Multiple mechanisms contribute to the health-promoting properties and therapeutic effects of medicinal plants when they are used as nutraceuticals. These mechanisms are based on the bioactive chemicals found in medicinal plants and their interactions with the individuals physiology. Following are several fundamental mechanisms implicated in the utilization of medicinal plants as nutraceuticals:

- **Antioxidant activity**: Medicinal plants harbour bioactive constituents, including polyphenols, flavonoids, and carotenoids, that demonstrate antioxidative characteristics. These chemical compounds exhibit scavenging properties towards free radicals and reactive oxygen species (ROS) within the biological system, thereby inhibiting oxidative harm to cellular structures and tissues. They have the ability to contribute electrons or hydrogen atoms in order to stabilize free radicals and prevent cellular damage caused by oxidative stress. Antioxidants also have a role in the regeneration of naturally occurring antioxidants, such as glutathione, and can influence the activity of antioxidant enzymes, including superoxide dismutase (SOD) and catalase (CAT) (Salehi et al. 2020).

- ***Anti-inflammatory activity***: Medicinal plants harbour a diverse array of phytochemical compounds that exhibit anti-inflammatory properties. For example, the presence of polyphenols, terpenoids, and alkaloids in plants has been observed to possess inhibitory effects on pro-inflammatory enzymes, specifically cyclooxygenase-2 (COX-2) and lipoxygenase (LOX). Additionally, these compounds have been found to decrease the production of pro-inflammatory cytokines, such as interleukin-1β (IL-1β) and tumour necrosis factor-alpha (TNF-α). The aforementioned compounds have the ability to modulate the signalling of nuclear factor-kappa B (NF-κB), a crucial pathway implicated in the process of inflammation, by impeding its activation and the subsequent expression of genes responsible for pro-inflammatory mediators (Roy et al. 2022).
- ***Enzyme activity regulation***: Certain bioactive compounds found in medicinal plants have the ability to modulate the activity of enzymes that participate in various metabolic processes. As an illustration, specific compounds possess the ability to hinder enzymes accountable for the degradation of carbohydrates, thereby resulting in enhanced regulation of blood glucose levels. Various compounds have the potential to stimulate enzymes that play a role in detoxification processes, thereby promoting hepatic function and facilitating overall detoxification (Mihailovic et al. 2021).
- ***Cellular signalling***: These pathways can be modulated by medicinal plants, leading to interactions with specific pathways implicated in the development and progression of diseases. An illustration of this would be the observation that curcumin derived from turmeric has demonstrated the ability to regulate various signalling pathways, such as the mitogen-activated protein kinase (MAPK) pathway, phosphoinositide 3-kinase/protein kinase B (PI3K/Akt) pathway, and NF-κB pathway. These signalling pathways are of utmost importance in the regulation of cellular processes such as cell viability, proliferation, programmed cell death, and immune response. Through the modulation of these biological pathways, medicinal plants have the ability to elicit therapeutic effects in a wide range of diseases (Lu et al. 2023).
- ***Regulation of gut microbiota***: It is influenced by the presence of bioactive compounds found in medicinal plants, which have the ability to impact the composition and functionality of the gut microbiota. As an illustration, specific polyphenols and dietary fibers exhibit prebiotic properties by stimulating the proliferation of advantageous bacteria, such as *Bifidobacterium* and *Lactobacilli*. The aforementioned advantageous microorganisms generate short-chain fatty acids (SCFAs) via the process of fermentation, thereby supplying energy to the cells in the colon and regulating immune responses. Medicinal plants may exhibit antimicrobial properties against pathogenic bacteria, including Escherichia coli and Salmonella, thereby contributing to the preservation of a balanced gut microbial ecosystem (Milutinović et al. 2021).
- ***Neuroprotective Effects***: Certain botanical species possess bioactive constituents that exhibit neuroprotective attributes, thereby facilitating the maintenance of cerebral well-being and cognitive performance. These compounds have the potential to augment synaptic plasticity, shield neurons against oxidative stress, and

mitigate inflammation within the brain. The investigation of nutraceuticals derived from these plants is currently underway to assess their potential efficacy in the prevention of neurodegenerative disorders, including Alzheimer's disease and Parkinson's disease (Shoaib et al. 2023).

- ***Cardiovascular health*** can be enhanced by the consumption of specific medicinal plants containing bioactive compounds. For example, bioactive compounds such as polyphenols and omega-3 fatty acids have been shown to possess properties that can potentially contribute to the reduction of blood pressure, the decrease of cholesterol levels, and the enhancement of blood vessel function. These effects are associated with a reduction in the likelihood of developing cardiovascular diseases, such as hypertension and atherosclerosis (Awuchi et al. 2022).
- ***Immune modulation***: The regulation of immune function is achieved through the modulation of immune responses by medicinal plants, which exert their effects by influencing the activity of immune cells and the production of cytokines. For instance, the presence of compounds in Echinacea, including polysaccharides and alkamides, has demonstrated the ability to augment the functionality of natural killer (NK) cells, macrophages, and dendritic cells. Additionally, they have the ability to induce the synthesis of cytokines, such as interferons (IFNs) and interleukins (ILs), which are pivotal in the regulation of the immune system and the protection against infections (Di-Sotto et al. 2020).

Hence, the mechanisms implicated in the utilization of medicinal plants as nutraceuticals exhibit a wide range of diversity and interconnections. The bioactive compounds found within these plants engage in interactions with diverse physiological processes, thereby facilitating the promotion of well-being and the prevention of diseases. These mechanisms play a role in enhancing the efficacy of nutraceuticals obtained from medicinal plants and their ability to promote general wellness and address specific health conditions.

6 Nutraceutical Potential of Medicinal Plants

The use of plant-based medicines for the treatment of various ailments is practiced from ancient times such as Ayurveda, Unani, and Siddha, and has been part of human culture. Plant-based medication are the basis of the modern pharmaceuticals and search for novel and functional extracts from medicinal plants are in central attraction in recent years because of the presence of diverse bioactive compounds such as alkaloids, terpenoids, glycosides, steroids, flavonoids, and phenolic compounds. These bioactive molecules are reported to have several beneficial effects in lowering the risk of diseases caused by reactive oxygen species (ROS) through different mechanisms of action such as scavenging free radicals, quenching ROS, inhibiting oxidative enzymes. The bioactive compounds present in these plants contribute to their nutraceutical properties, which encompass a range of health benefits (Table 1). The mechanisms of action elucidate the specific ways in which these medicinal plants

exert their effects on the body. Following are some kye potential of medicinal plants explored as nutraceuticals.

6.1 Antioxidant and Anti-inflammatory Properties

Medicinal plants have been widely acknowledged for their antioxidative and anti-inflammatory characteristics. The observed characteristics can be primarily ascribed to the existence of diverse bioactive compounds, including polyphenols, flavonoids, terpenoids, and alkaloids. These compounds function as antioxidants and regulate inflammatory pathways (Adegbola et al. 2017). Few instances of botanical specimens recognized for their antioxidative and anti-inflammatory attributes are.

- ***Turmeric (Curcuma longa)***: Curcumin, the primary bioactive compound found in turmeric, exhibits robust antioxidative and anti-inflammatory characteristics. It aids in the scavenging of free radicals, mitigates oxidative stress, and hampers the activity of inflammatory enzymes and molecules. Turmeric has been employed in traditional medicine for its potential to mitigate symptoms associated with inflammation, arthritis, and diverse chronic ailments.
- ***Zingiber officinale***, commonly known as ginger, is a plant species that possesses gingerol and its associated compounds. These bioactive constituents have been found to possess potent antioxidant properties, as well as exhibit anti-inflammatory effects. The bioactive compounds have the ability to hinder the synthesis of pro-inflammatory molecules and regulate the signalling pathways implicated in inflammation. Ginger has historically been utilized for its documented anti-inflammatory attributes and is recognized for its potential to alleviate symptoms associated with osteoarthritis and gastrointestinal inflammation.
- ***Camellia sinensis***, commonly known as Green Tea, is a beverage that contains a high concentration of catechins, specifically epigallocatechin gallate (EGCG). These catechins exhibit strong antioxidant properties and have been found to possess anti-inflammatory effects. The inhibitory effects of EGCG on oxidative stress and inflammation are achieved through the blockade of signalling pathways associated with inflammation. The consumption of green tea has been correlated with a decreased likelihood of developing chronic inflammatory conditions, such as cardiovascular diseases and specific types of cancer.
- ***Rosmarinus officinalis***, commonly known as rosemary, is a plant species that possesses the phenolic compound called rosmarinic acid. This compound is renowned for its notable antioxidant and anti-inflammatory characteristics. According to researchers, it has been observed that the substance aids in the scavenging of free radicals, the suppression of inflammatory enzymes, and the inhibition of the release of pro-inflammatory molecules. The application of rosemary extract has demonstrated encouraging results in mitigating inflammation and oxidative stress in diverse experimental models.

Table 1 List of medicinal plants and its nutraceutical potential, with specific bioactive compounds, and mechanisms of action (Pandey et al. 2011)

Medicinal plant	Bioactive compounds	Nutraceutical potential	Mechanisms of action
Aloe vera	Aloin, Polysaccharides	Anti-inflammatory, Wound healing	Inhibition of pro-inflammatory mediators, Promotion of tissue regeneration, Modulation of immune response
Ashwagandha (Withania somnifera)	Withanolides, Alkaloids	Adaptogenic, Stress reduction	Modulation of stress hormones, Antioxidant activity, Anti-inflammatory effects
Bilberry (Vaccinium myrtillus)	Anthocyanins, Flavonoids	Antioxidant, Eye health	Scavenging of free radicals, Protection of retinal cells, Improvement of blood flow
Black cohosh (Actaea racemosa)	Triterpene glycosides	Menopause symptoms relief	Estrogenic activity, Regulation of hormone levels
Chamomile (Matricaria chamomilla)	Apigenin, Chamazulene	Calming, Sleep aid	Modulation of GABA receptors, Anti-anxiety effects, Anti-inflammatory properties
Cinnamon (Cinnamomum verum)	Cinnamaldehyde, Polyphenols	Blood sugar regulation	Insulin sensitization, Inhibition of glucose absorption, Antioxidant activity
Cranberry (Vaccinium macrocarpon)	Proanthocyanidins, Flavonoids	Urinary tract health	Inhibition of bacterial adhesion, Anti-inflammatory effects, Antioxidant properties
Echinacea (Echinacea purpurea)	Alkamides, Polysaccharides	Immune support	Activation of immune cells, Enhancement of cytokine production, Antioxidant effects
Grape seeds (Vitis vinifera)	Proanthocyanidins	Antioxidant, Anticancer, Cardiovascular health	Scavenging free radicals, Inhibiting tumor growth, Improving blood flow, Protecting cardiovascular system

(continued)

Table 1 (continued)

Medicinal plant	Bioactive compounds	Nutraceutical potential	Mechanisms of action
Garlic (Allium sativum)	Allicin, Sulfur compounds	Cardiovascular health, Immune support	Antioxidant activity, Cholesterol reduction, Immune modulation, Antiplatelet effects
Ginger (Zingiber officinale)	Gingerol, Shogaol	Digestive health, Anti-inflammatory	Anti-nausea, Inhibition of inflammatory pathways, Antioxidant properties
Ginkgo biloba	Flavonoids, Terpenoids	Cognitive function, Circulation	Antioxidant activity, Improvement of cerebral blood flow, Neuroprotective effects
Green tea (Camellia sinensis)	Catechins, EGCG	Antioxidant, Weight management	Scavenging of free radicals, Promotion of thermogenesis, Modulation of metabolism
Hawthorn (Crataegus spp.)	Flavonoids, Procyanidins	Cardiovascular health	Vasodilation, Improvement of cardiac function, Antioxidant effects
Licorice (Glycyrrhiza glabra)	Glycyrrhizin, Flavonoids	Digestive health, Anti-inflammatory	Anti-ulcer, Modulation of immune response, Antioxidant properties
Milk thistle (Silybum marianum)	Silymarin, Flavonolignans	Liver health, Detoxification	Antioxidant activity, Promotion of liver cell regeneration, Anti-inflammatory effects
Peppermint (Mentha piperita)	Menthol, Menthone	Digestive health, Soothing	Anti-spasmodic, Alleviation of gastrointestinal discomfort, Anti-inflammatory properties
Saw palmetto (Serenoa repens)	Fatty acids, Phytosterols	Prostate health	Inhibition of enzyme 5-alpha-reductase, Anti-inflammatory effects
St. John's wort (Hypericum perforatum)	Hypericin, Hyperforin	Mood support, Depression	Serotonin modulation, Inhibition of reuptake, Anti-inflammatory properties

(continued)

Table 1 (continued)

Medicinal plant	Bioactive compounds	Nutraceutical potential	Mechanisms of action
Turmeric (Curcuma longa)	Curcumin, Curcuminoids	Anti-inflammatory, Antioxidant	Inhibition of inflammatory pathways, Scavenging of free radicals, Modulation of gene expression
Valerian (Valeriana officinalis)	Valerenic acid, Valepotriates	Sleep aid, Anxiety relief	Modulation of GABA receptors, sedative effects, Anti-Anxiety properties
Wheatgrass (Triticum aestivum)	Chlorophyll, Antioxidants	Detoxification, Digestive health	Supporting detoxification processes, Aiding digestion

- ***Allium sativum***, commonly known as garlic, is a plant species that is rich in sulfur compounds. One notable compound found in garlic is allicin, which exhibits properties of being an antioxidant and anti-inflammatory agent. The aforementioned compounds exhibit free radical scavenging properties, mitigate oxidative stress, and impede the functionality of pro-inflammatory enzymes. The potential anti-inflammatory effects of garlic supplementation have been extensively investigated in the context of cardiovascular diseases and rheumatoid arthritis.
- ***Bauhinia purpurea L***: It has many bioactive compounds like flavonoids, alkaloids, steroids, triterpenoids, fatty alcohol, acid, and aster, glycerol's, and phenols chromone. The antioxidant activity was measured by 2,2-diphenyl-1-picrylhydroxyl solution (DPPH) radical scavenging assay and the in vitro studies showed considerably antioxidant activity, mainly based a scavenging of oxygen radicals. These flavonoids mainly inhibit of low-density lipoproteins oxidation, likely due to their reductive capacity and protein-binding properties. Hence *Bauhinia purpurea* are to be claimed as good antioxidant properties.

6.2 Anti-cancer Properties

The potential anti-cancer properties of medicinal plants have garnered considerable attention. Numerous compounds derived from plants demonstrate diverse mechanisms of action that possess the ability to impede the proliferation and metastasis of cancer cells, trigger apoptosis (programmed cell death), and hinder angiogenesis (the process of forming new blood vessels to tumors) (Macharia et al. 2022). Here are several instances of botanical specimens recognized for their anti-carcinogenic attributes:

- ***Taxus brevifolia***, commonly known as the Pacific Yew Tree, has been recognized for its medicinal properties. Taxol, a compound extracted from the bark of this tree, has been extensively utilized as a chemotherapeutic agent in the treatment of

various forms of cancer. Taxol exerts its inhibitory effects on cell division through the process of microtubule stabilization, resulting in the arrest of the cell cycle and induction of apoptosis.

- ***Camptotheca acuminata* (Happy Tree)**: *Camptothecin*, derived from the bark and leaves of Camptotheca acuminata, has demonstrated potent anti-neoplastic properties against a diverse range of malignancies. The compound acts as a potent inhibitor of topoisomerase I, an essential enzyme in the processes of DNA replication and repair. This inhibition disrupts the normal functioning of DNA, resulting in DNA damage and subsequent cell death.
- ***Vinca rosea***, commonly known as Madagascar Periwinkle, is a plant species that has been extensively studied for its medicinal properties. One of the notable findings is the presence of Vinca alkaloids, specifically vincristine and vinblastine, which have shown significant potential in the field of cancer treatment. These alkaloids, extracted from the Madagascar Periwinkle, have been utilized in various therapeutic approaches aimed at combating cancerous cells. These compounds disrupt the process of microtubule assembly during cellular division, resulting in the cessation of the cell cycle and programmed cell death, also known as apoptosis.
- ***Curcuma longa***, commonly known as Turmeric, contains curcumin, a bioactive compound that has demonstrated anti-cancer properties in numerous preclinical and clinical investigations. It has the ability to modulate various signalling pathways implicated in the growth, proliferation, and survival of cancer cells. Curcumin demonstrates antioxidant, anti-inflammatory, and anti-angiogenic characteristics, and it has the ability to trigger apoptosis and hinder metastasis.
- ***Viscum album (European Mistletoe)***: Extracts derived from Viscum album, commonly known as European mistletoe, have been employed as adjunctive interventions in the field of cancer therapy. The extract containing mistletoe lectins has demonstrated immunomodulatory properties by enhancing the immune system's anticancer response. Additionally, they have the ability to impede cellular proliferation and trigger programmed cell death.
- ***Camellia sinensis (Green Tea)***: Green tea is known to possess polyphenolic compounds, specifically epigallocatechin gallate (EGCG), that demonstrate anticancer properties. Epigallocatechin gallate (EGCG) has the ability to regulate signalling pathways associated with cellular proliferation, inflammatory responses, and the formation of new blood vessels (angiogenesis). Additionally, it exhibits antioxidant properties and has the ability to trigger programmed cell death in cancer cells.

It is imperative to acknowledge that although these botanical specimens exhibit encouraging anti-neoplastic characteristics, additional scientific investigations and clinical trials are requisite to substantiate their efficacy and ascertain their safety in the context of oncological therapy. Furthermore, the utilization of plant-derived anti-cancer compounds in conjunction with traditional cancer therapies is frequently employed to augment their effectiveness and mitigate adverse reactions. The literature reports showed that there is high correlation between antioxidant activity and

phenolics content. Antioxidants have been scientifically proven to be the most efficient method for mitigating the detrimental impacts induced by free radicals, as they possess the ability to scavenge or facilitate the decomposition of these radicals. The use of herbal extracts and phytochemicals with antioxidant activity can be extremely beneficial in the treatment of a wide range of disease and disorders. They show antiallergic, anti-inflammatory, antimicrobial and anticancer activity (Greenwell et al. 2015).

6.3 Cardiovascular Health Benefits

The potential cardiovascular health benefits of medicinal plants have been acknowledged as well. These entities possess bioactive compounds that exhibit potential in promoting cardiovascular well-being, regulating blood pressure, diminishing cholesterol levels, and mitigating the risk of cardiovascular ailments (Rastogi et al. 2016). Presented below are several instances of botanical species renowned for their therapeutic properties in relation to cardiovascular health:

- ***Allium sativum***, commonly known as garlic, is a plant species that possesses sulfur compounds, including allicin. Extensive research has demonstrated the diverse cardiovascular effects associated with these sulfur compounds. Allicin exhibits antiplatelet characteristics, indicating its ability to impede platelet aggregation, consequently mitigating the likelihood of thrombus formation. Garlic additionally demonstrates vasodilatory properties, facilitating the relaxation and dilation of blood vessels, thereby potentially contributing to the reduction of blood pressure. Furthermore, garlic exhibits lipid-modulating properties, as it is capable of diminishing overall cholesterol, low-density lipoprotein cholesterol, and triglyceride concentrations, while concurrently elevating high-density lipoprotein cholesterol levels. The synergistic impact of these combined factors contributes to the potential cardiovascular advantages of garlic (Papu et al. 2014).
- **Hawthorn (Crataegus spp.)**: Hawthorn comprises a variety of flavonoids, procyanidins, and other bioactive constituents that possess antioxidative characteristics and have the potential to enhance cardiovascular well-being. Studies have demonstrated that the presence of flavonoids in hawthorn extracts can effectively augment the flow of blood in the coronary arteries, enhance the contractile function of the heart, and diminish resistance in the peripheral blood vessels. These physiological responses contribute to enhancing the overall performance of the cardiac system and mitigating symptoms associated with heart failure. Hawthorn has been found to potentially exhibit antihypertensive properties, which could contribute to the reduction of blood pressure through the relaxation of blood vessels (Rastogi et al. 2016).
- ***Camellia sinensis***, commonly known as Green Tea, is a beverage that contains a significant amount of polyphenolic compounds, specifically catechins. Among

these compounds, the most prevalent and extensively researched is epigallocatechin gallate (EGCG). Epigallocatechin gallate (EGCG) demonstrates notable antioxidant and anti-inflammatory characteristics, thereby potentially safeguarding against oxidative stress-induced damage and mitigating inflammation within blood vessels. The consumption of green tea catechins has been linked to enhancements in lipid profiles, as they possess the ability to reduce levels of total cholesterol and LDL cholesterol. Green tea exhibits vasodilatory properties, which contribute to the improvement of endothelial function and the facilitation of optimal blood circulation (Hodgson et al. 2010).

- **Ginkgo (*Ginkgo biloba*)**: Extracts derived from Ginkgo leaves consist of flavonoids, terpenoids, and various other compounds that contribute to the cardiovascular effects exhibited by this plant. *Ginkgo biloba* demonstrates antioxidant characteristics, which contribute to the mitigation of oxidative stress and the preservation of blood vessel integrity. It additionally enhances blood flow through the process of vasodilation and the augmentation of microcirculation. *Ginkgo biloba* has been extensively researched for its potential therapeutic effects in the management of peripheral arterial disease (PAD), specifically in alleviating symptoms like intermittent claudication. This is believed to be achieved through the enhancement of blood circulation to the extremities. Furthermore, it has been suggested that ginkgo biloba may potentially enhance endothelial function, a critical factor in the maintenance of optimal blood vessel health (Šamec et al. 2022).
- **Turmeric**, scientifically known as *Curcuma longa*, contains curcumin, an active compound that has shown promising cardiovascular advantages. The substance demonstrates anti-inflammatory and antioxidant characteristics, which have the potential to mitigate inflammation and oxidative stress in blood vessels. Studies have demonstrated that curcumin possesses the ability to impede the synthesis of inflammatory molecules implicated in the development of atherosclerosis, thus potentially diminishing the likelihood of plaque formation. It has the potential to enhance endothelial function, a critical factor in maintaining optimal blood vessel dilation and function (Singletary 2020).
- ***Bauhinia purpurea***, (commonly known as bitter melon) extract may mitigate risk factors for congestive heart disease. Researchers investigated the antihyperlipidemic activity of an ethanolic extract derived from the unripe pods and desiccated leaves of B. purpurea in Albino rats. The extract was subjected to a comparative analysis with the standard lipid-lowering pharmaceutical agent known as atorvastatin. The investigators induced hyperlipidemia in the rodents by introducing a high-fat diet comprising of cholesterol, sodium cholate, and coconut oil into their standard nutrition. The extract was orally administered at a dosage of 300 mg/kg/day for a period of 30 days. The researchers noted a slight elevation in body weight subsequent to the administration of the extract. Nevertheless, the researchers also observed a noteworthy increase in the concentration of high-density lipoprotein cholesterol (HDL-C) in the blood serum, as well as a reduction in total cholesterol, low-density lipoprotein (LDL), and triglyceride levels. The atherogenic index, a significant parameter for assessing congestive heart disease, exhibited a decrease

upon administration of this dosage of the extract. The outcomes of this study indicate that the ethanolic extract derived from B. purpurea exhibited antihyperlipidemic properties in the rats that were subjected to experimentation. The extract yielded a lipid profile that exhibited positive characteristics, including elevated levels of HDL-C (which is considered advantageous) and decreased levels of total cholesterol, LDL, and triglycerides (Lakshmi et al. 2011).

6.4 Neuroprotective Properties

The neuroprotective properties of medicinal plants have been extensively investigated, focusing on their potential to safeguard and maintain the integrity and functionality of the nervous system. These plants possess a diverse range of bioactive compounds that demonstrate antioxidant, anti-inflammatory, and neuro-regenerative properties, thereby contributing to their neuroprotective mechanisms. Here are several instances of botanical species recognized for their neuroprotective attributes in the field of medicine:

- ***Ginkgo biloba***, commonly known as Ginkgo, is a plant species that produces leaf extracts rich in flavonoids, terpenoids, and various other compounds. These compounds have been scientifically demonstrated to exhibit neuroprotective properties. Ginkgo biloba demonstrates antioxidative characteristics, which contribute to the mitigation of oxidative stress and the preservation of neuronal cells by preventing damage. Additionally, it exhibits anti-inflammatory properties by suppressing the synthesis of pro-inflammatory molecules that may contribute to neurodegenerative mechanisms. According to researchers, there is evidence suggesting that Ginkgo has the potential to augment cognitive function, enhance memory, and mitigate age-related cognitive decline (Nowak et al. 2021).
- ***Bacopa monnieri***, commonly referred to as Bacopa, is a botanical species recognized for its medicinal properties in Ayurvedic medicine. It has been historically utilized for its potential to enhance cognitive function. The substance comprises various compounds, notably bacosides, which have demonstrated neuroprotective properties. Bacopa demonstrates antioxidant properties, thereby mitigating oxidative stress and safeguarding neuronal cells against potential harm. Additionally, it exerts modulation on neurotransmitter systems and augments the transmission of nerve impulses, potentially contributing to its neuroprotective and cognitive-enhancing characteristics (Abdul-Manap et al. 2019).
- ***Curcumin***, the bioactive constituent found in *Curcuma longa*, has exhibited neuroprotective properties in diverse preclinical and clinical investigations. The substance exhibits antioxidant and anti-inflammatory characteristics, which contribute to the mitigation of oxidative stress and inflammation within the cerebral region. Curcumin additionally demonstrates neuro-regenerative properties through its facilitation of neurogenesis and enhancement of neuronal viability. Extensive research has been conducted to investigate the potential therapeutic

advantages of this substance in the context of neurodegenerative disorders, including Alzheimer's disease and Parkinson's disease (Kulkarni et al. 2010).

- ***Withania somnifera***, commonly known as Ashwagandha, is a botanical species recognized for its adaptogenic properties. It has been extensively utilized in traditional Ayurvedic medicine to promote holistic wellness, encompassing various aspects such as brain health. The substance in question comprises bioactive compounds, specifically withanolides, which have demonstrated neuroprotective properties. Ashwagandha demonstrates notable antioxidant properties, thereby mitigating oxidative stress and providing neuroprotection to brain cells. Additionally, it exhibits anti-inflammatory characteristics and has the ability to regulate neurotransmitter systems, which may enhance cognitive abilities and mitigate neurodegenerative processes (Bhatnagar et al. 2009).
- ***Hericium erinaceus***, commonly referred to as Lion's Mane Mushroom, is a species of fungi that has gained recognition for its purported neuroprotective properties in the field of medicine. The substance comprises hericenones and erinacines, which have demonstrated the ability to induce the synthesis of nerve growth factor (NGF). Nerve Growth Factor (NGF) is an essential factor in the promotion, sustenance, and viability of neuronal cells. The consumption of Lion's Mane has been suggested to potentially have a positive impact on cognitive function, promote the regeneration of nerves, and provide protection against neurodegenerative disorders (Lakhanpal and Rana 2005; Spelman et al. 2017).
- ***Bauhinia purpurea***, are prescribed for various nervous-related disorders, including convulsions, delirium, asthma and anti-inflammatory agents. Current study reveals the first evidence that Bauhinia purpurea (stem bark) has antiamnesic effect on scopolamine induced amnesia in rats (Abdelghany et al. 2022).

6.5 Others

Medicinal plants provide a significant reservoir of nutraceuticals that have been extensively studied for their therapeutic properties in diverse medical conditions. Plants bioactive compounds, owing to its anti-inflammatory and wound-healing characteristics, has exhibited potential in the management of ulcers, cutaneous inflammation, and gastrointestinal disorders. Similarly, some bioactive compound, demonstrates significant anti-inflammatory and antioxidant properties, thus presenting itself as a promising contender for the treatment of ulcerative colitis, wound healing, and various inflammatory disorders such as glandular swelling, stomach tumors, dysentery, piles, lymph node swelling and enlargement, inflammatory swelling, hemorrhage-bleeding, as well as cold and cough symptoms. Medicinal plant based nutraceutical compounds can also help to cure from ulcer, wound, glandular swelling, stomach tumor, diarrhoea, dysentery, amoebic dysentery, ano-rectal, piles, lymph nodes swelling, lymph node enlargement, inflammatory swelling and hemorrhage-bleeding, cold and cough. Few examples of these plants are listed below:

- **Aloe Vera (*Aloe barbadensis*)**: The gel derived from Aloe vera contains a variety of bioactive compounds, such as polysaccharides, lectins, and anthraquinones, which are responsible for its therapeutic properties. Research has demonstrated the presence of anti-inflammatory, antimicrobial, and wound-healing properties. Aloe vera gel has been found to exhibit properties that can potentially induce collagen synthesis, facilitate angiogenesis, and augment the migration and proliferation of dermal cells, thereby potentially facilitating the process of wound healing. Furthermore, it demonstrates anti-ulcerogenic characteristics and has the potential to mitigate gastric inflammation and facilitate the regeneration of gastric ulcers (Hęś et al. 2019).
- ***Turmeric***, scientifically known as *Curcuma longa*, encompasses curcumin, a polyphenolic compound renowned for its robust anti-inflammatory, antioxidant, and antimicrobial attributes. Curcumin possesses the ability to regulate various signalling pathways implicated in the processes of inflammation and wound healing. It has the potential to mitigate inflammation by suppressing the activity of pro-inflammatory molecules and enzymes. Curcumin additionally facilitates wound healing through augmentation of collagen synthesis, angiogenesis, and tissue regeneration. Moreover, extensive research has been conducted to investigate the potential anti-neoplastic properties of the substance in different types of malignancies, such as gastric neoplasms (Jyotirmayee et al. 2022).
- ***Calendula (Calendula officinalis)***: Calendula exhibits characteristics of anti-inflammatory, antimicrobial, and wound-healing properties. The therapeutic effects of this substance can be attributed to the presence of flavonoids, triterpenoids, and polysaccharides. The anti-inflammatory properties of calendula extracts are attributed to their ability to suppress the activity of pro-inflammatory cytokines and enzymes. Additionally, they demonstrate antimicrobial properties against a range of pathogens, thereby aiding in the prevention of wound infections. The wound healing properties of calendula are attributed to its ability to enhance fibroblast proliferation, stimulate collagen synthesis, and promote re-epithelialization. Moreover, scientific studies have demonstrated that it exhibits anticancer properties and has the potential to impede the growth of tumors (Ahmad et al. 2022).
- ***Psidium guajava (Guava)***: The leaves of Guava are rich in bioactive compounds such as tannins, flavonoids, and essential oils. These compounds exhibit antimicrobial, anti-inflammatory, and gastroprotective properties. The antimicrobial properties of guava leaf extracts have been observed to exhibit efficacy against a range of bacteria and parasites commonly linked to diarrhoea and dysentery, such as Escherichia coli and Entamoeba histolytica. The growth and activity of these pathogens can be suppressed, leading to a reduction in diarrhoea. The anti-inflammatory properties of guava leaves have been observed, suggesting their potential for reducing inflammation in the gastrointestinal tract (Díaz-de-Cerio et al. 2017)
- ***Terminalia chebula***, commonly known as Haritaki, is a botanical species that has been extensively utilized in the field of Ayurveda for the treatment of diverse gastrointestinal ailments. The substance in question comprises bioactive

compounds, namely tannins, chebulic acid, and chebulinic acid, which are responsible for its therapeutic attributes. Haritaki demonstrates antimicrobial properties against a diverse array of bacteria and parasites, encompassing those responsible for inducing diarrhea and dysentery. It has the potential to mitigate diarrhea and facilitate the restoration of regular gastrointestinal motility. Haritaki exhibits antioxidant and anti-inflammatory properties, potentially contributing to its gastroprotective characteristics (Bulbul et al. 2022).

- ***Azadirachta indica (Neem)***: Neem, scientifically known as *Azadirachta indica*, is a botanical species that has been historically employed for its notable antimicrobial, anti-inflammatory, and wound-healing attributes. Neem is comprised of bioactive compounds, namely nimbin, nimbidin, and quercetin, which exhibit antimicrobial properties against various microorganisms including bacteria, fungi, and parasites. Additionally, it demonstrates anti-inflammatory properties through the inhibition of pro-inflammatory cytokines and enzymes. The topical application of neem oil or creams derived from neem has been found to have beneficial effects on wound healing, infection prevention, and inflammation reduction (Alzohairy 2016).
- ***Glycyrrhiza glabra***, commonly known as licorice, has been historically employed for its therapeutic properties in treating ulcers. The substance under consideration comprises glycyrrhizic acid, a compound that has demonstrated inhibitory effects on the proliferation of Helicobacter pylori, a bacterium frequently linked to gastric ulcers. Licorice additionally demonstrates anti-inflammatory properties and has the potential to mitigate inflammation within the gastrointestinal tract. Moreover, licorice has been employed for the alleviation of symptoms associated with gastritis and gastric mucosal injury (Sharma et al. 2018).
- ***Centella asiatica (Gotu kola)***: Gotu kola has been historically utilized for its potential wound-healing attributes. The presence of triterpenoids in this substance is hypothesized to augment the process of collagen synthesis and stimulate the proliferation of fibroblasts, the cellular entities accountable for the reparative process of wound healing. Gotu kola exhibits potential anti-inflammatory properties, which contribute to the mitigation of edema and facilitation of wound and ulcer healing (Belwal et al. 2019).
- ***Plantago*** *ovata*, commonly known as Psyllium husk, is a plant material that exhibits a high concentration of soluble fiber. It has been historically utilized for its advantageous impact on gastrointestinal well-being. It exhibits the ability to undergo hydration and transform into a viscoelastic material, thereby aiding in the regulation of gastrointestinal transit. Psyllium husk is frequently employed as a bulk-forming cathartic agent for the management of diarrhoea and to facilitate the establishment of regularity in gastrointestinal motility. It may also potentially offer alleviation from inflammatory bowel conditions, such as ulcerative colitis (Khan et al. in 2021).
- ***Matricaria chamomilla***, commonly referred to as Chamomile, is recognized for its renowned effects on promoting relaxation and providing a soothing sensation. The substance comprises a diverse array of bioactive compounds, such as chamazulene, flavonoids, and terpenoids, which exhibit notable anti-inflammatory

and anti-ulcer properties. Chamomile has been historically employed for the alleviation of gastrointestinal ailments, including stomach ulcers, gastric inflammation, and gastrointestinal spasms. It has been suggested that it could potentially alleviate symptoms of diarrhoea and facilitate the regeneration of gastrointestinal tissues (Gupta et al. 2010).

- ***Terminalia arjuna***, also known as Arjuna, is a botanical specimen widely employed in the field of Ayurvedic medicine due to its recognized therapeutic properties in promoting cardiovascular well-being. The substance in question is comprised of bioactive compounds, specifically flavonoids and tannins, which exhibit properties associated with antioxidation and protection of the cardiovascular system. Studies have demonstrated that Arjuna exhibits anti-inflammatory properties, enhances cardiac function, lowers blood pressure, and improves overall cardiovascular well-being. The utilization of this intervention has shown potential advantages in the management of cardiovascular disorders, including hypertension, heart failure, and coronary artery disease (Jain et al. 2009).
- ***Asparagus racemosus linn* (shatavari)**: It is a botanical species recognized for its diverse pharmacological attributes, encompassing antioxidative, anti-stress, anti-ulcer, and wound healing properties. The antioxidant properties of *Asparagus racemosus* have received considerable scientific interest in recent years due to their potential as natural substitutes for synthetic additives. A scientific investigation was carried out by researchers to examine the presence of antioxidant compounds in the methanolic extract of *Asparagus racemosus* roots and their capacity to eliminate reactive oxygen species (ROS) and free radicals in a controlled environment. Furthermore, the study revealed that the methanolic extract derived from the roots of *Asparagus racemosus* exhibits a substantial abundance of antioxidant compounds. These compounds demonstrated the capacity to efficiently counteract diverse reactive oxygen species (ROS) and free radicals in an in vitro setting. Additionally, a distinct investigation carried out by Researchers assessed the efficacy of the root extract on lung cancer cells. The findings indicate that *Asparagus racemosus* exhibits potential as a viable candidate for the advancement of novel plant-derived therapeutic medications aimed at addressing lung cancer. Hence, *Asparagus racemosus* (shatavari) contains antioxidant capabilities which may be an safe alternative for treatment of pulmonary disorders (Goyal et al. 2003).
- ***Glycyrrhiza glabra***: It is, commonly referred to as liquorice, is a herb species that possesses a multitude of bioactive compounds. The primary constituents responsible for its distinctively sweet taste are triterpene saponins. Furthermore, the plant contains phenolic compounds. The volatile constituents present in liquorice comprise geraniol, pentanol, hexanol, teroinen-4-ol, and α-terpineol. Additionally, it exhibits a high concentration of propionic acid, benzoic acid, furfuraldehyde, 2,3-butanediol, furfuryl formate, maltol, 1-methyl-2-formylpyrrole, and trimethylpyrazine. The utilization of liquorice extracts is prevalent in the food and pharmaceutical sectors, along with their incorporation in the manufacturing of functional foods and food supplements. It is additionally employed as a traditional Chinese medicinal remedy for the management of diverse ailments, encompassing gastrointestinal disorders, cough, bronchitis, arthritis, gastritis, peptic

ulcers, respiratory infections, and tremors. Moreover, liquorice is utilized as a flavour enhancer and natural sweetening agent in diverse food commodities including American-style tobacco, chewing gum, confectioneries, baked goods, frozen desserts, and carbonated beverages. It is also employed in the manufacturing of beer and fire extinguishers, as well as serving as a skin depigmentation agent. Studies have shown that *G. glabra* can reduce microsomal lipid peroxidation and has strong scavenging action against DPPH radicals, suggesting that it has antioxidant potential. The presence of phenolic compounds in liquorice is known to exert a protective effect on biological systems by mitigating oxidative stress and potentially mitigating skin damage (Pastorino et al. 2018).

- ***Premna integrifolia***: It is used in treating fever, colic, diarrhoea, dysentery, urine retention, flatulence, dyspepsia and rheumatism. Premnine, ganikarine and premnazole alkaloids. In a research it has been found that the roots of *P. integrifolia*, whereas the flavanoids luteolin, sterol and triterpene are present in the leaves. It also contains iridoid glycosides and several diterpenoids. The methanol extracts of *P. integrifolia* leaves, was found to have high antiradical capacities and reducing power and has significant potential for use as natural antioxidants. The antioxidant and radical scavenging activities were investigated by using reducing power and 2,2-diphenyl-2- picrylhydrazyl hydrate (DPPH) assays. Moreover, it exhibits analgesic, antinociceptive, antiarthritic, antibacterial, anticancer, antitumor, cytotoxic, tumor-suppressing, and anti-inflammatory characteristics. Additionally, the administration of *P. integrifolia* and atorvastatin exhibited notable efficacy in preventing the elevation of serum cholesterol, triglyceride, and LDL levels when compared to the nicotine control group. The HDL level exhibited a significant increase in both the treated and standard groups when compared to the Nicotine control group. Based on the aforementioned findings, it is evident that *P. integrifolia* exhibits significant efficacy as an anti-hyperlipidemic agent. It can also be employed in a traditional manner for the treatment of diverse ailments such as rheumatism, asthma, dropsy, cough, fever, boils, and scrofulous diseases (Mali 2016).

7 Importance of Medicinal Plants in Nutraceuticals

The role of medicinal plants in nutraceuticals is extensive and multifaceted. There are several primary factors that contribute significantly to the pivotal role of medicinal plants in the advancement and application of nutraceuticals:

Rich Source of Bioactive Compounds: Medicinal plants serve as an extensive and varied repository of bioactive compounds, encompassing phytochemicals, antioxidants, polyphenols, flavonoids, terpenoids, and alkaloids. These compounds exhibit diverse health-enhancing characteristics and contribute to the therapeutic capabilities of nutraceuticals. The distinctive chemical composition of medicinal plants offers a diverse array of bioactive molecules that can be extracted, refined, and integrated into nutraceutical formulations.

- Traditional Knowledge and Ethnopharmacology: It encompass the utilization of medicinal flora that has been practiced for an extended period within traditional medical frameworks, including Ayurveda, Traditional Chinese Medicine, and Indigenous healing methodologies. The aggregation of traditional knowledge offers valuable perspectives on the potential therapeutic applications of botanical species. Ethnopharmacological investigations facilitate the identification of botanical specimens possessing distinct therapeutic attributes, elucidate the underlying mechanisms by which these properties are manifested, and provide guidance for their utilization in the development of nutraceutical preparations. The integration of traditional knowledge with contemporary scientific research facilitates the identification of novel bioactive compounds and improves the efficacy of nutraceutical interventions.
- Holistic Approach to Health: The utilization of medicinal plants provides a comprehensive and integrated approach to promoting health and well-being. In contrast to traditional pharmaceuticals that frequently focus on singular symptoms or illnesses, medicinal plants encompass a multitude of bioactive compounds that possess the potential for synergistic impacts on diverse physiological systems. Nutraceuticals originating from botanical sources possess the capacity to enhance general welfare, rectify fundamental irregularities, and facilitate optimal health by providing nourishment to the body and its physiological mechanisms.
- Disease prevention and health promotion: Extensive research has been conducted on the potential of bioactive compounds found in medicinal plants for the prevention and management of various diseases. Nutraceuticals derived from botanical sources have the potential to exert preventive effects through their antioxidant, anti-inflammatory, and immune-modulating properties. They play a role in mitigating the likelihood of developing chronic ailments, such as cardiovascular diseases, diabetes, neurodegenerative disorders, and specific forms of cancer. Through the integration of botanical species with medicinal properties into nutraceutical formulations, individuals have the opportunity to actively promote and enhance their overall health and well-being.
- Natural and sustainable methodologies: Medicinal flora provide a natural and sustainable approach to promoting health and well-being. In contrast to synthetic pharmaceuticals, which frequently exhibit accompanying adverse reactions, nutraceuticals sourced from medicinal plants are regarded as safe and well-tolerated when administered appropriately. Furthermore, the cultivation and sustainable harvesting of medicinal plants play a crucial role in promoting environmental conservation, preserving biodiversity, and implementing sustainable agricultural practices.
- Personalized Nutrition: Personalized nutrition approaches are founded upon the utilization of medicinal plants. Various botanical species possess distinct bioactive compounds that exhibit diverse physiological effects on human health. Through comprehensive analysis of an individual's distinct health requirements, genetic predispositions, and biochemical indicators, customized nutraceutical suggestions can be formulated to maximize health outcomes. Medicinal plants possess a wide

array of bioactive compounds that can be selectively combined or tailored to meet specific individual needs.

Hence, medicinal plants are of significant importance in the advancement and application of nutraceuticals. They function as a plentiful reservoir of bioactive substances, provide valuable traditional knowledge and ethnopharmacological perspectives, advocate for a comprehensive approach to well-being, assist in the prevention of diseases and the promotion of health, offer a natural and sustainable methodology, and enable the implementation of individualized nutritional strategies. The integration of botanical species with medicinal properties into nutraceutical compositions amplifies their therapeutic efficacy and aids individuals in attaining an optimal state of health and overall well-being (Srivastava et al. 2018).

8 Applications of Medicinal Plant-Based Nutraceuticals

- ***Human Health and Disease Management***: The utilization of nutraceuticals derived from medicinal plants plays a crucial role in the prevention and management of diverse chronic diseases in human health. The bioactive compounds found in the subject's composition, namely polyphenols, alkaloids, and terpenoids, exhibit characteristics of being antioxidants, anti-inflammatory agents, and anti-carcinogens. These nutraceuticals have the potential to serve as supplementary therapies to bolster conventional treatments and enhance overall well-being (Devaraj et al. 2021).
- ***Nutritional supplements***: Medicinal plant-derived nutraceuticals are recognized as valuable reservoirs of vital nutrients, encompassing vitamins, minerals, and dietary fibers. Nutritional supplements are formulated to effectively target and rectify specific nutrient deficiencies, thereby enhancing overall well-being. Illustrative instances encompass botanical extracts abundant in vitamins C and E, omega-3 fatty acids obtained from botanical origins, and plant-derived protein supplements (Ruchi 2017).
- ***Traditional Medicine***: Medicinal plants have been employed in traditional medicine systems across various cultures for an extended period of time. Nutraceuticals derived from these botanical sources persistently find application in traditional medicinal practices on a global scale. In Ayurvedic practice, formulations frequently incorporate plant-derived nutraceuticals with the aim of reinstating equilibrium and fostering well-being. Traditional Chinese Medicine utilizes herbal preparations as therapeutic interventions for a multitude of health conditions (Ruchi 2017).
- ***Cosmeceuticals***: Medicinal plant-derived nutraceuticals are widely employed in the cosmetics sector due to their potential advantages in promoting skin and hair well-being. Skincare products, hair care formulations, and anti-aging treatments often utilize plant extracts that contain bioactive compounds such as polyphenols,

flavonoids, and essential oils. These nutraceuticals exhibit antioxidant, moisturizing, and anti-inflammatory properties, thereby contributing to enhanced skin tone, texture, and overall appearance (Carvalho et al. 2016).

- ***Functional Foods and Nutraceutical Beverages***: Medicinal plant-derived nutraceuticals are integrated into functional foods and beverages to augment their nutritional composition and confer targeted health advantages. Functional foods encompass a range of fortified consumables, such as breakfast cereals, energy bars, and yogurts, which are enriched with nutraceuticals derived from plants. Nutraceutical beverages may comprise of botanical extracts or herbal infusions that exhibit potential health benefits (Pinela et al. 2016).
- ***Animal Nutrition and Feed Additives***: Nutraceuticals derived from botanical sources are employed in animal nutrition to enhance animal well-being, growth, and productivity. These nutraceuticals may comprise of botanical extracts, volatile compounds, or distinct phytochemicals possessing antimicrobial, anti-inflammatory, or growth-stimulating attributes. They function as organic substitutes for synthetic feed additives, promoting the implementation of sustainable and environmentally-friendly farming methods (Hajam et al. 2020).
- ***Agricultural Applications***: Medicinal plant-derived nutraceuticals exhibit potential in agricultural settings as biopesticides and plant growth promoters. Medicinal plants, such as Azadirachta indica (neem) or Chrysanthemum cinerariifolium (pyrethrum), contain bioactive compounds that demonstrate insecticidal, antifungal, or herbicidal activities. These naturally occurring alternatives mitigate dependence on artificial pesticides and facilitate the adoption of ecologically sustainable agricultural methods (Tlak et al. 2021).
- ***Environmental Sustainability and Biodiversity Conservation***: The cultivation and utilization of medicinal plants for nutraceutical purposes have the potential to make a positive impact on environmental sustainability and biodiversity conservation. The conservation of medicinal plant biodiversity can be effectively ensured by implementing sustainable practices, such as organic farming, responsible harvesting, and cultivation of endangered or threatened species. This methodology facilitates the sustainable preservation of botanical species with medicinal properties and ensures the conservation of natural habitats (Chen et al. 2016).

9 Challenges and Opportunities in Using Medicinal Plants for Nutraceuticals

9.1 Challenges

Using medicinal plants for nutraceuticals poses challenges in terms of quality control, standardization, efficacy determination, regulatory framework, sustainability, intellectual property rights etc. Piccolella et al. (2019). Some are listed below:

- ***Phytochemical diversity***: Medicinal plants exhibit a wide range of chemical constituents, encompassing alkaloids, flavonoids, terpenoids, and phenolic compounds. Nevertheless, the chemical composition of these plants exhibits considerable variation contingent upon factors including plant species, geographical location, climatic conditions, soil characteristics, and the timing of harvest. The presence of variability presents a significant obstacle in maintaining uniform levels of bioactive compounds in nutraceutical products derived from medicinal plants.
- ***Quality control and authentication***: The assessment and verification of the quality and genuineness of medicinal plant materials utilized in nutraceuticals are of utmost importance in ensuring their safety and effectiveness. The phenomena of adulteration, substitution, or misidentification of plant species can manifest, resulting in discrepancies in the composition and potency of the ultimate products. The implementation of rigorous quality control measures, such as accurate botanical authentication, comprehensive chemical profiling, and standardized active constituent analysis, is imperative in order to guarantee product uniformity and establish consumer confidence.
- ***Safety considerations***: Although medicinal plants are generally regarded as safe for consumption, certain plants may contain toxic compounds or have the potential to interact with medications. Evaluating the safety profile of medicinal plants and their bioactive constituents is of utmost importance in order to identify potential hazards and establish appropriate dosage guidelines. Moreover, the existence of impurities such as metallic elements with high atomic mass, chemical substances used for pest control, or microscopic disease-causing organisms in botanical specimens can potentially endanger human well-being if adequate measures are not implemented for regulation.
- ***Variability in standardized regulations***: The regulations pertaining to the manufacturing, labelling, and promotion of nutraceutical products derived from medicinal plants exhibit heterogeneity across various countries and regions. The lack of standardized norms and regulations can pose difficulties for manufacturers, leading to variations in product quality, safety, and effectiveness. The implementation of uniform regulations and guidelines is imperative to guarantee the efficacy and safety of nutraceuticals derived from medicinal plants.

9.2 Opportunities

The use of medicinal plants as a source of nutraceuticals opens up a number of promising avenues. Nutraceuticals are bioactive compounds obtained from food sources that exhibit physiological benefits surpassing their fundamental nutritional value. Medicinal plants, due to their wide array of bioactive compounds, present a bountiful reservoir of natural constituents for the advancement of nutraceutical research and development (Sen et al. 2011). Below are several potential avenues for harnessing the potential of medicinal plants in the development of nutraceuticals:

- ***Phytochemical characterization***: The field of phytochemical characterization has witnessed significant progress due to the development and application of advanced analytical techniques, including chromatography, spectroscopy, and mass spectrometry. These techniques enable the thorough determination and measurement of bioactive compounds found in medicinal plants. Thorough phytochemical characterization enhances the process of selecting suitable plant species, guarantees consistent levels of essential compounds, and aids in identifying the most effective extraction and processing techniques for nutraceutical manufacturing.
- ***Pharmacological Research***: The implementation of meticulous pharmacological examinations, encompassing both preclinical and clinical trials, yields scientific substantiation regarding the effectiveness and safety of nutraceuticals derived from medicinal plants. These investigations provide clarification on the mechanisms by which bioactive compounds exert their effects, explore their potential for therapeutic applications, and examine potential interactions with other substances. Pharmacological research additionally contributes to the establishment of optimal dosage regimens, the identification of target populations, and the investigation of potential synergistic effects with other medications or therapies.
- ***Bioavailability augmentation***: Numerous bioactive compounds found in medicinal plants exhibit suboptimal bioavailability, indicating limited absorption and utilization within the human body. Techniques such as nanotechnology, liposomal encapsulation, microencapsulation, or complexation with specific carriers can be employed to improve the solubility, stability, and bioavailability of these compounds. Enhanced bioavailability facilitates the transportation of the active components to their designated locations within the body, thereby augmenting the efficacy of nutraceutical interventions.
- ***Sustainable cultivation and sourcing***: The utilization of medicinal plants can exert stress on natural resources and ecosystems. By advocating for sustainable cultivation methodologies, such as organic farming, agroforestry, and the cultivation of endangered species, we can effectively guarantee the continued accessibility of medicinal plants in the long run, all the while mitigating any potential adverse effects on the environment. Furthermore, the endorsement of fair trade principles and ethical sourcing has the potential to positively impact the conservation of traditional knowledge and the welfare of indigenous communities engaged in the growth and collection of medicinal flora.
- ***Synergistic combinations***: Medicinal plants frequently possess numerous bioactive compounds that have the potential to demonstrate synergistic effects when employed collectively. Exploring the synergistic interactions among various plant constituents can potentially result in the creation of nutraceutical formulations that exhibit heightened effectiveness and a wider range of health advantages. Many micronutrient serving as phytochemicals also act in synergies for long lasting effects (Singh et al. 2022).
- ***Personalized nutrition and precision medicine***: Medicinal plants possess a broad spectrum of bioactive compounds that exhibit various health-promoting properties. The concept of personalized nutrition and precision medicine endeavours to customize nutraceutical interventions by considering individual genetic

variations, health status, and specific requirements. The integration of genetic profiling, biomarker analysis, and clinical data enables the identification of individuals who would derive the greatest advantages from particular medicinal plant-based nutraceuticals, thereby facilitating personalized and precisely targeted interventions.

10 Conclusion

Medicinal plants serve as a valuable reservoir of bioactive compounds that possess noteworthy nutraceutical properties. These plants exhibit a diverse array of health-promoting properties, encompassing antioxidant, anti-inflammatory, anticancer, cardiovascular, neuroprotective, and gastrointestinal effects. Nevertheless, the application of botanical species for their medicinal properties in the form of nutraceuticals poses certain obstacles, including the need for standardization, quality control measures, and adherence to regulatory guidelines. However, the continuous progress in technology, the synergy between traditional knowledge and modern science, personalized nutrition strategies, and the implementation of sustainable practices present potential avenues for addressing these obstacles. Through comprehensive study, quality control, and appropriate application, the nutraceutical potential of medicinal plants can be tapped to improve preventative medicine, supplementary therapies, and individualized diets.

References

Abdelghany AK, El-Nahass ES, Ibrahim MA, El-Kashlan AM, Emeash HH, Khalil F (2022) Neuroprotective role of medicinal plant extracts evaluated in a scopolamine-induced rat model of Alzheimer's disease. Biomark 27(8):773–783

Abdul-Manap AS, Vijayabalan S, Madhavan P, Chia YY, Arya A, Wong EH, Rizwan F, Bindal U, Koshy S (2019) Bacopa monnieri, a neuroprotective lead in Alzheimer disease: a review on its properties, mechanisms of action, and preclinical and clinical studies. Drug Tar Ins 13:1177392819866412

Adegbola P, Aderibigbe I, Hammed W, Omotayo T (2017) Antioxidant and anti-inflammatory medicinal plants have potential role in the treatment of cardiovascular disease: a review. Am J Cardio Dis 7(2):19

Ahmad W, Quazi J (2022) A review that on emphasizes the traditional uses and clinical potential calendula officinalis. Res J Pharma Dos Technol 14(4):342–348

Ajanaku CO, Ademosun OT, Atohengbe PO, Ajayi SO, Obafemi YD, Owolabi OA, Akinduti PA, Ajanaku KO (2022) Functional bioactive compounds in ginger, turmeric, and garlic. Front Nutr 9:1012023

Alzohairy MA (2016) Therapeutics role of Azadirachta indica (Neem) and their active constituents in diseases prevention and treatment. Evidence-Based Compl Alter Med 2016:11

Awuchi CG, Okpala COR (2022) Natural nutraceuticals, especially functional foods, their ma-jor bioactive components, formulation, and health benefits for disease prevention-an overview. J Food Bioact 19:97–123

Belwal T, Andola HC, Atanassova MS, Joshi B, Suyal R, Thakur S, Bisht A, Jantwal A, Bhatt ID, Rawal RS (2019) Gotu kola (*Centella asiatica*) in non-vitamin and non-mineral nutritional supplements. Acadamic, pp 265–275

Benković M (2019) Introduction to nutraceuticals and pharmaceuticals. In: Nutraceuticals and natural product pharmaceuticals. Acadamic, pp 1–31

Bhatnagar M, Sharma D, Salvi M (2009) Neuroprotective effects of Withania somnifera dunal: a possible mechanism. Neurochem Res 34:1975–1983

Bommakanti V, Puthenparambil Ajikumar A, Sivi CM, Prakash G, Mundanat AS, Ahmad F, Haque S, Prieto MA, Rana SS (2023) An overview of herbal nutraceuticals, their extraction, formulation, therapeutic effects and potential toxicity. Separations 10(3):177

Bulbul MRH, Chowdhury MNU, Naima TA, Sami SA, Imtiaj MS, Huda N, Uddin MG (2022) A comprehensive review on the diverse pharmacological perspectives of Terminalia chebula Retz. Heliy 8(2022):e10220

Carvalho IT, Estevinho BN, Santos L (2016) Application of microencapsulated essential oils in cosmetic and personal healthcare products–a review. Int J Cosm Sci 38(2):109–119

Chen SL, Yu H, Luo HM, Wu Q, Li CF, Steinmetz A (2016) Conservation and sustainable use of medicinal plants: problems, progress, and prospects. Chinese Med 11:1–10

Devaraj A, Mahalingam G (2021) Bioactive molecules from medicinal plants as functional foods (Biscuits) for the benefit of human health as antidiabetic potential. In: Bioactive compounds in nutraceutical and functional food for good human health

Di-Sotto A, Vitalone A, Di-Giacomo S (2020) Plant-derived nutraceuticals and immune system modulation: an evidence-based overview. Vaccines 8(3):468

Díaz-de-Cerio E, Verardo V, Gómez-Caravaca AM, Fernández-Gutiérrez A, Segura-Carretero A (2017) Health effects of Psidium guajava L. leaves: an overview of the last decade. Int J Mol Sci 18(4):897

Farzaneh V, Carvalho IS (2015) A review of the health benefit potentials of herbal plant infusions and their mechanism of actions. Indus Crops Prod 65:247–258

Fu PP, Yang YC, Xia Q, Chou MW, Cui YY, Lin G (2002) Pyrrolizidine alkaloids-tumorigenic components in Chinese herbal medicines and dietary supplements. J Food Drug Anal 10(4):198–211

Gossell-Williams M, Simon RE, West ME (2006) The past and present use of plants for medicines. West Indian Med J 55(4):217–218

Goyal RK, Singh J, Lal H (2003) Asparagus racemosus-an update. Indian J Med Sci 57(9):408–414

Greenwell M, Rahman PKSM (2015) Medicinal plants: their use in anticancer treatment. Int J Pharm Sci Res 6(10):4103

Gupta V, Mittal P, Bansal P, Khokra SL, Kaushik D (2010) Pharmacological potential of Matricaria recutita-a review. Int J Pharm Sci Drug Res 2(1):12–16

Hajam YA, Rai S, Kumar R, Bashir M, Malik JA (2020) Phenolic compounds from medicinal herbs: their role in animal health and diseases–a new approach for sustainable welfare and development. Plant Phenol Sustain Agri 1:221–239

Hęś M, Dziedzic K, Górecka D, Jędrusek-Golińska A, Gujska E (2019) Aloe vera (L.) Webb: natural sources of antioxidants–a review. Plant Foods Human Nutr 74:255–265

Hodgson JM, Croft KD (2010) Tea flavonoids and cardiovascular health. Mol Asp Med 31(6):495–502

Jaca A, Durão S, Harbron J (2020) Omega-3 fatty acids for the primary and secondary prevention of cardiovascular disease. South African Med J 110(12):1158–1159

Jahangeer M, Fatima R, Ashiq M, Basharat A, Qamar SA, Bilal M, Iqbal H (2021) Therapeutic and biomedical potentialities of terpenoids-a review. J Pure Appl Microbiol 15(2):471–483

Jain S, Yadav PP, Gill V, Vasudeva N, Singla N (2009) Terminalia arjuna a sacred medicinal plant: phytochemical and pharmacological profile. Phytochem Rev 8:491–502

Jyotirmayee B, Mahalik G (2022) A review on selected pharmacological activities of Curcuma longa L. Intern J Food Prop 25(1):1377–1398

Karunamoorthi K, Jegajeevanram K, Vijayalakshmi J, Mengistie E (2013) Traditional medicinal plants: a source of phytotherapeutic modality in resource-constrained health care settings. J Evidence-Based Comp Alter Med 18(1):67–74

Khan AW, Khalid W, Safdar S, Usman M, Shakeel MA, Jamal N, Prakash R, Jha MB, Shehzadi S, Khalid MZ, Shahid MK (2021) Nutritional and therapeutic benefits of Psyllium Husk (*Plantago ovata*). Acta Scient Microbiol 4(3):43–50

Kulkarni SK, Dhir A (2010) An overview of curcumin in neurological disorders. Indian J Pharm Sci 72(2):149

Lakhanpal TN, Rana M (2005). Medicinal and Nutraceutical genetic resources of mushrooms. Plant Gen Res–Characteriz Util 20:19, 1–17

Lakshmi BVS, Neelima N, Kasthuri N, Umarani V, Sudhakar M (2011) Antihyperlipidemic activity of Bauhinia purpurea extracts in hypercholesterolemic albino rats. Int J Pharmtech Res 3(3):1265–1272

Lu KH, Lu PWA, Lu EWH, Lin CW, Yang SF (2023) Curcumin and its analogs and carriers: potential therapeutic strategies for human osteosarcoma. Intern J Biological Sci 19(4):1241

Macharia JM, Mwangi RW, Rozmann N, Zsolt K, Varjas T, Uchechukwu PO, Wagara IN, Raposa BL (2022) Medicinal plants with anti-colorectal cancer bioactive compounds: potential game-changers in colorectal cancer management. Biomed Pharmacother 153:113383

Mali PY (2016) Pharmacological potentials of *Premna integrifolia* L. Anc Sci Life 35(3):132

Milutinović M, Dimitrijević-Branković S, Rajilić-Stojanović M (2021) Plant extracts rich in polyphenols as potent modulators in the growth of probiotic and pathogenic intestinal microorganisms. Front Nutr 8:688843

Nowak A, Kojder K, Zielonka-Brzezicka J, Wróbel J, Bosiacki M, Fabiańska M, Wróbel M, Sołek-Pastuszka J, Klimowicz A (2021) The use of *Ginkgo biloba* L. as a neuroprotective agent in the Alzheimer's disease. Front Pharmacol 12:775034

Pandey N, Meena RP, Rai SK, Pandey-Rai S (2011) Medicinal plants derived nutraceuticals: a re-emerging health aid. Int J Pharma Bio Sci 2(4):420–441

Papu S, Jaivir S, Sweta S, Singh BR (2014) Medicinal values of garlic (Allium sativum L.) in human life: an overview. Greener J Agricult Sci 4(6):265–280

Pastorino G, Cornara L, Soares S, Rodrigues F, Oliveira MBP (2018) Liquorice (Glycyrrhiza glabra): a phytochemical and pharmacological review. Phyto Res 32(12):2323–2339

Piccolella S, Crescente G, Candela L, Pacifico S (2019) Nutraceutical polyphenols: new analytical challenges and opportunities. J Pharma Biomed Anal 175:112774

Pinela J, Carocho M, Dias MI, Caleja C, Barros L, Ferreira IC (2016) Wild plant-based functional foods, drugs, and nutraceuticals. Wild Plants, Mushrooms Nuts: Funct Food Prop Appl 15:315–351

Prasathkumar M, Anisha S, Dhrisya C, Becky R, Sadhasivam S (2021) Therapeutic and pharmacological efficacy of selective Indian medicinal plants–a review. Phytomed plus 1(2):100029

Rastogi S, Pandey MM, Rawat AK (2016) Traditional herbs: a remedy for cardiovascular disorders. Phytomed 23(11):1082–1089

Roy A, Khan A, Ahmad I, Alghamdi S, Rajab BS, Babalghith AO, Alshahrani MY, Islam S, Islam MR (2022) Flavonoids a bioactive compound from medicinal plants and its therapeutic applications. BioMed Res Int 2022:1–9

Ruchi S (2017) Role of nutraceuticals in health care: a review. Int J Green Pharm 11(03):385–398

Salehi B, Azzini E, Zucca P, Maria-Varoni EV, Kumar AN, Dini L, Panzarini E, Rajkovic J, Valere-Tsouh-Fokou P, Peluso I, Mishra PA (2020) Plant-derived bioactives and oxidative stress-related disorders: a key trend towards healthy aging and longevity promotion. Appl Sci 10(3):947

Šamec D, Karalija E, Dahija S, Hassan ST (2022) Biflavonoids: important contributions to the health benefits of Ginkgo (*Ginkgo biloba* L.). Plant 11(10):1381

Sen S, Chakraborty R, De B (2011) Challenges and opportunities in the advancement of herbal medicine: India's position and role in a global context. J Herbal Med 1(3–4):67–75

Sharma V, Katiyar A, Agrawal RC (2018) Glycyrrhiza glabra: chemistry and pharmacological activity. Sweet 31:87–100

Shoaib S, Ansari MA, Fatease AA, Safhi AY, Hani U, Jahan R, Alomary MN, Ansari MN, Ahmed N, Wahab S, Ahmad W (2023) Plant-derived bioactive compounds in the management of neurodegenerative disorders: challenges, future directions and molecular mechanisms involved in neuroprotection. Pharmaceutics 15(3):749

Singh V, Thakur M, Rap MK, Prakash S (2022) Evaluation of in-vitro functional potential of developed synergistic Fe-Vit C rich powder for anemic adolescent girls. Indian J Agri Biochem 35(2):213–219

Singletary K (2020) Turmeric: potential health benefits. Nutr Today 55(1):45–56

Sofowora A, Ogunbodede E, Onayade A (2013) The role and place of medicinal plants in the strategies for disease prevention. African J Trad Compl Altern Med 10(5):210–229

Spelman K, Sutherland E, Bagade A (2017) Neurological activity of Lion's mane (*Hericium erinaceus*). J Restor Med 6(1):19–26

Srivastava AK (2018) Significance of medicinal plants in human life. Synth Med Agents Plants (Elsevier) 2018:1–24

Srivastava S, Sharma PK, Kumara S (2015) Nutraceuticals: a review. J Chronother Drug Deli 6:1–10

Thakur M, Belwal T (2022) Bioactive components: a sustainable system for good health and well-being, vol I. Springer, Singapore, p 609

Tlak-Gajger I, Dar SA (2021) Plant allelochemicals as sources of insecticides. Insects 12(3):189

Velu G, Palanichamy V, Rajan AP (2018) Phytochemical and pharmacological importance of plant secondary metabolites in modern medicine. Bioorganic Phase Nat Food: Overv 2018:135–156

Wang L, Shi Y, Wang R, Su D, Tang M, Liu Y, Li Z (2021) Antioxidant activity and healthy benefits of natural pigments in fruits: a review. Int J Mol Sci 22(9):4945

Yan Y, Li X, Zhang C, Lv L, Gao B, Li M (2021) Research progress on antibacterial activities and mechanisms of natural alkaloids: a review. Antibio 10(3):318

Yuan H, Ma Q, Ye L, Piao G (2016) The traditional medicine and modern medicine from natural products. Mol 21(5):559