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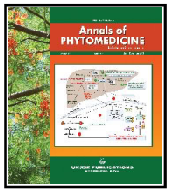

Review Article : Open Access

Exploring the holistic potential of medicinal plants for improving human health

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Abstract

Medicinal plants have been an integral part of traditional medicine systems for centuries, offering a wide array of therapeutic benefits. This review aims to explore the holistic potential of medicinal plants in improving human health. It addresses the need to investigate the diverse medicinal properties of plants and their application in modern healthcare. While there is a growing interest in herbal medicine, some notable herbs gaining popularity include turmeric, celebrated for its anti-inflammatory prowess; ginger, renowned for aiding digestion and combating nausea; and echinacea, often used to bolster the immune system during cold and flu seasons. Garlic is valued for heart health, peppermint soothes digestive discomfort, and lavender offers relaxation benefits. A comprehensive assessment of the current state of knowledge and research gaps is essential to fully harness the benefits of these natural remedies. There is a significant research gap in understanding the comprehensive scope of their medicinal properties. This review aims to address these gaps by providing a comprehensive overview of the holistic potential of medicinal plants. The review will explore the safety and efficacy of herbal medicines, highlighting the importance of evidence-based practices. The potential synergistic effects of combining different medicinal plants and their integration into modern healthcare systems will also be discussed. This review will encompass a wide range of medicinal plants from various cultural backgrounds, emphasizing their holistic potential for improving human health. It will provide a comprehensive overview of the current state of knowledge and research on medicinal plants, with a focus on their phytochemical composition, therapeutic properties, and safety considerations.

1. Introduction

"Herba", the Latin word, and "herbe", an ancient French word, are the origins of "herb", an English term. In modern times, plant components such as stem, fruit, stigma, bark, seed, leaf, flower, root, and non-woody plants can be considered herbs (Mohammed, 2019). Here is proof that herbal medicine has been used for more than 4000 years by Indian Vaids, Unani Hakims, and European and Mediterranean cultures (Petrovska, 2012). As per a World Health Organization (WHO) report, worldwide, around 80 per cent of people are dependent on herbal remedies for their basic medical requirements. According to the WHO, about 21,000 species of plants can be used as therapeutic plants. According to research, dependency on plants and plant extracts is greater than 75 per cent of the world's population for their medical necessities (Ogbu and Arah, 2016). Medicinal plants, is regarded as a crucial source for strengthening the body. With significant roles in India's heritage and good health, there exists a traditional history of herbs and spices used for understanding the value of food and its connection to health. Herbs are becoming more crucial economically since they are used in a variety of items, including food, medicine, perfumes, and cosmetics (Essa *et al.,* 2023).

The medicinal plant's usage is found to be relatively beneficial, with little or no adverse effects. The most significant benefit is that these treatments work in harmony with nature. Herbal medicines can be utilized by individuals of all ages and genders, according to the golden rule (Reddy, 2022). As per ancient scholars, herbs are the best solutions for a wide range of issues related to health. They conducted significant investigation and testing so as to achieve trustworthy results for the numerous medicinal plants efficacy (Haddad *et al*., 2020). Because the vast majority of drugs developed through this mechanism, do not have harmful adverse reactions; herbal medicine is gaining popularity across the world. Examples of how herbs and spices are used in Ayurveda for health benefits include turmeric for jaundice, mace for stomach infections, basil for heart protection, cinnamon for circulation enhancement, and ginger, which is the all-purpose drug, especially for nausea and indigestion. Tulsi, aloe, turmeric, neem and ginger are medicinal plants that can aid in numerous ailments treatment. It was found that the use of herbs and spices affects how much dietary flavonoid is consumed. High flavonoid content foods include chamomile, licorice, onions, rosemary, sage, and thyme. Apparently, these herbs and spices may also provide a fair amount of nutrients, like iron. As per the report, an adult in India is thought to be able to consume up to 4 g of turmeric per day, which might give 80-200 mg of the bioactive compound curcumin per day.

The review covers various aspects related to herbs, including their rich nutritional profile, potential to aid in digestive improvement, immune system stimulation, and their association with a reduced risk of chronic illnesses like heart disease, diabetes, and certain malignancies and highlights the advantages of combining probiotics with herbs to support different aspects of health and well-being. Furthermore, the review aims to explore the global market of herbal products, emphasizing their extensive influence across various sectors

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of society, economics, and ecology. It discusses the historical use of herbal products in different civilizations and their significance as traditional medicines and supplements. In addition to the benefits, the abstract addresses the issue of adulteration in herbal products, discussing the challenges faced by the herbal industry in combating this problem. Adulteration in herbal products can endanger consumers and diminish the credibility of herbal cures, resulting in potential health risks and decreased confidence in herbal products. Overall, the objective of the abstract is to provide readers with a comprehensive overview of the benefits of herbs, the potential of combining herbs with probiotics, the global impact of herbal products, and the challenges associated with adulteration in the herbal industry.

Table 1: Nutritional profile of some common herbs

S.No.	Herbs	Nutritional profile	References
1.	*Ocimum basilicum*	• **Vitamins:** Rich in vitamin K, a good source of vitamin A and vitamin C.· • **Minerals:** Contains small amounts of calcium, potassium, and iron. • **Other nutrients:** Provides essential oils like eugenol, which has antioxidant properties.	Thakur and Thapa, 2023
2.	*Petroselinum crispum*	• **Vitamins:** High in vitamin K, a good source of vitamin C, and vitamin A. • **Minerals:** Contains notable amounts of potassium and folate. • **Other nutrients:** Rich in chlorophyll and volatile oils.	Boaghe *et al*., 2023 Scandar *et al*., 2023
3.	*Coriandrum sativum*	• **Vitamins:** Good source of vitamin K and vitamin A. • **Minerals:** Contains moderate amounts of potassium, calcium, and magnesium. • **Other nutrients:** Provides essential oils, including linalool and geranyl acetate.	
4.	*Thymus vulgaris*	• **Vitamins:** Contains vitamin K and vitamin C in smaller amounts. • **Minerals:** Good source of manganese and a moderate source of iron. • **Other nutrients:** Rich in volatile oils like thymol, which has antimicrobial properties.	Hossain *et al*., 2022
5.	*Origanum vulgare*	• **Vitamins:** Contains vitamin K, vitamin A, and small amounts of vitamin C. • **Minerals:** Good source of manganese and a moderate source of calcium and iron. • **Other nutrients:** High in antioxidants and essential oils such as carvacrol.	Martins *et al*., 2023
6.	*Mentha*	• **Vitamins:** Contains moderate amounts of vitamin A and vitamin C. • **Minerals:** Rich in potassium and a good source of calcium and iron. • **Other nutrients:** High in menthol and volatile oils, contributing to its characteristic flavor.	Fazal *et al*., 2023
7.	*Anethum graveolens*	• **Vitamins:** Good source of vitamin K and vitamin A. • **Minerals:** Contains moderate amounts of calcium, iron, and magnesium. • **Other nutrients:** Provides essential oils like d-carvone.	Giordano *et al*., 2022

2. Antioxidant potential of herbs and spices in modern medicine

Herbs are used as home cures in various sections of the nation. Indian cooking utilizes majority of these herbs and spices to add sensation of taste, many plants are used to honour kings all across the world as a sign of good fortune (A³tyn Twaruck, 2020). Modern pharmaceutical manufacturing currently relies heavily on medicinal herbs for basic ailments treatment including constipation, diarrhea,

hypertension, dysentery, low sperm count, and weak penile erections, as well as coated tongue, piles, menstrual disorders, leucorrhea, bronchial asthma and fevers. As these herbs, spices contain antioxidant, antibacterial, medicinal, and nutritional qualities, the variety of plants that may have antiphlogistic properties is astounding. Antiphlogistic elements that are natural included in herbs and spices, including capsaicin and curcumin (Zheng *et al.*, 2022). In a study, it was found that herbs provide defensive mechanism against both the risk factors, *i.e.,* oxidative damage and infection, for the onset and progression of cancer, and various pathological disorders because herbs and spices contains a variety of naturally occurring phenolic acids which are soluble in water and flavonoids, like quercetin and caffeic acid which are capable of scavenge reactive oxygen species and also contain lipid-soluble substances (Madani *et al*., 2023; Zafar *et al*., 2023). Although, the use of herbs has increased considerably since the past two decades, research on the topic is currently lacking (Ekor, 2014). The significance of several plants in terms of their medical properties have been summarized in Table 2.

Table 2: The significance of several plants in terms of their medical properties

Herbs	Phytoconstituents	Model	Dose or IC_{50}	Mechanism	Outcomes	References
Piper nigrum	Piperine	Analysis of RT-PCR and ELISA: Analgesic and cardiac dysrhythmia properties of piperine were studied on carrageenan-induced arthritis and acute paw pain in rat models.	20 and 100 mg/kg	Block the synthesis of crucial proinflammatory mediators, IL6 and PGE2, in IL1 β-stimulated human FLS Suppress phosphorylation of ERK1/2 blocked by IL1β.	Anti-inflammatory (AI)	Bang *et al.*, 2009
Ocimum tenuiflorum	Methyl cinnamate	Evaluation of methyl cinnamate (E-MC) E isomer's circulatory effects in rat isolated aortic rings.		Suppressed cholinergic induced contractions. E-Isomer of methyl cinnamate inhibits the recruitment of receptor operated Ca^{2+} channels (ROCCs) during contractile reactions.	Cardio protective (CP)	Vasconcelos-Silva *et al.*, 2014
Zingiber officinale	Gingerol shogaol	Detection of phytoconstituents [6]-gingerol, [8]-gingerol, [10]-gingerol and [6]-shogaol by DPPH.		Inhibition of cyclooxygenase, lipoxygenase, and arachidonic acid metabolites. Suppressed LPS induced PGE2 production in U937 cells. Attenuation of human polymorphonuclear neutrophils (PMN) ROS generation. Reduction of nitric oxide and PGE2 synthesis in mouse leukemic monocyte (RAW 264.7).	Anti-inflammatory (AI) and antioxidant (AO)	Dugasani *et al.*, 2010
Anethum graveolens	Phellandrene	The impact of extract of AGS (*Anethum graveolens* L. seeds) on mucosal deterioration and infection with reflux esophagitis suffering rats.	AGS (12.5, 25, 50 µg/ml) LPS. (1µg/ml)	Slowed down the generation of NO and inflammatory proteins (iNOS and COX2) expression. Inhibit factor for nuclear transfer which is related to signaling of NF-κB and cytokines (IL-1ß and TNF-α).	Anti-inflammatory (AI)	Nam *et al.*, 2021

				Triggering macrophage activation, which results in NO, TNF-, and IL-1 inflammatory mediator production, tissue damage, and inflammation.		
Linum usitatissimum	Alpha-linolenic acid	In rats, linolenic acid (ALA) intestinal absorption, followed by flaxseed oil administration in both emulsified and non-emulsified forms.	0-3 g	Suppression of platelet aggregation. Elevate plasma level.	Gastrointestinal (GI)	Couëdelo *et al*., 2011
Echinacea purpurea	Alkylamides	Anti-inflammatory capability in xylene induced mouse ear edoema, egg-white induced rat paw edoema, and cotton induced granuloma tissue proliferating inflammation in mice.	Low dose 3.75 µl essential oil/kg. Medium dose 7.5 µl essential oil/kg. High dose 15 µl essential oil/kg	Triggered de novo production of tumour necrosis factor mRNA in primary human monocytes/ macrophages. Induce specific (adaptive) immunity in the spleen, as well as NK cells and monocytes.	Anti-inflammatory (AI)	Yu *et al*., 2013
Panax ginseng	Ginsenoside	Impact of ginsenoside Rg2 on cerebral ischemia reperfusion induced impairments in neurological responses, memory, and caudate putamen neuronal death.	Ginsenoside Rg2 (2.5, 5 and 10 mg/kg) nimodipine (50 g/kg)	Ginsenoside Rg2 inhibits human neuronal nicotinic acetylcholine receptors in *Xenopus oocytes via* a noncompetitive manner. Ginsenoside Rg2 boosted protein expression BCL 2 and HSP-70 while inhibiting BAX and P53.	Apoptosis	Smith *et al*., 2019
Matricaria chamomilla	Terpenes	Effects of chamomile alcoholic extract on biochemical and clinical markers in a PCOS rat model in thirty virgin adults cycling wistar rats.	25, 50, 75 mg/kg	Stimulate leukocytes (macrophages and B lymphocytes). Adhere central type benzodiazepine (BZD) receptor. Suppress estradiol (E2) induced DNA synthesis. Induced PCO state is facilitated by the GABA system in conjunction with chamomile's effects on the control of LH surge secretion.	Anti-inflammatory (AI) and antioxidant (AO)	Farideh *et al*., 2010
Cinnamomum zeylanicum	Cinnamaldehyde	Mice was treated to assess cardio protection.	Low dose 10 µmg/kg/day. High dose 20 µmg/kg/day	Translocation of AKT to cell membrane can be promoted by activation of PI3K, promotion of cell survival, apoptosis can be inhibited by AKT by multiple targets regulating, for example, Bax and Bcl-2.	Antioxidant (AO), Apoptosis	Zheng *et al*., 2022

3. Global market of herbal products

One of the global sectors with the quickest rate of growth is the herbal medicine sector. This market includes a wide range of articles, such as cosmetics, personal care items, dietary supplements, and herbal medications. As per the recent reports, herbal medications market is anticipated for increase in 2022 of $165.66 billion to $347.50 billion in 2029 (Nirmal *et al*., 2014). The herbal medicines of US market are the largest, pursued by Europe, Australia, and Canada. As per WHO, these medicines are used to satisfy the basic health necessities of world's population of 75-80 per cent (Warrier, 2021). Another WHO reports says, around 75-80 per cent people worldwide rely on herbal remedies regularly in some form or to treat their primary health issues (Varghese *et al*., 2016). This is partially due to factors including population increase, the preference for herbal supplements health benefits, and the perception that these products are safer and more affordable than pharmaceutical treatments. If, we talk about herbal plants, the WHO estimates that roughly 250 medications, or 11 per cent, are derived from plants and are therefore vital for providing basic healthcare. Antimalarials such as quinine and artemisin, antihypertensive such as reserpine, paclitaxel and anticancer drugs (etoposide) and muscle relaxant (turbocurarine) are a few examples of medications that are utilised in their natural condition (Ndhlala *et al*., 2011). These plant-derived products are frequently utilized for their nutritional, therapeutic, or cosmetic characteristics. Here is a brief description of some of the most effective herbal products around globe summarized in Figure 1.

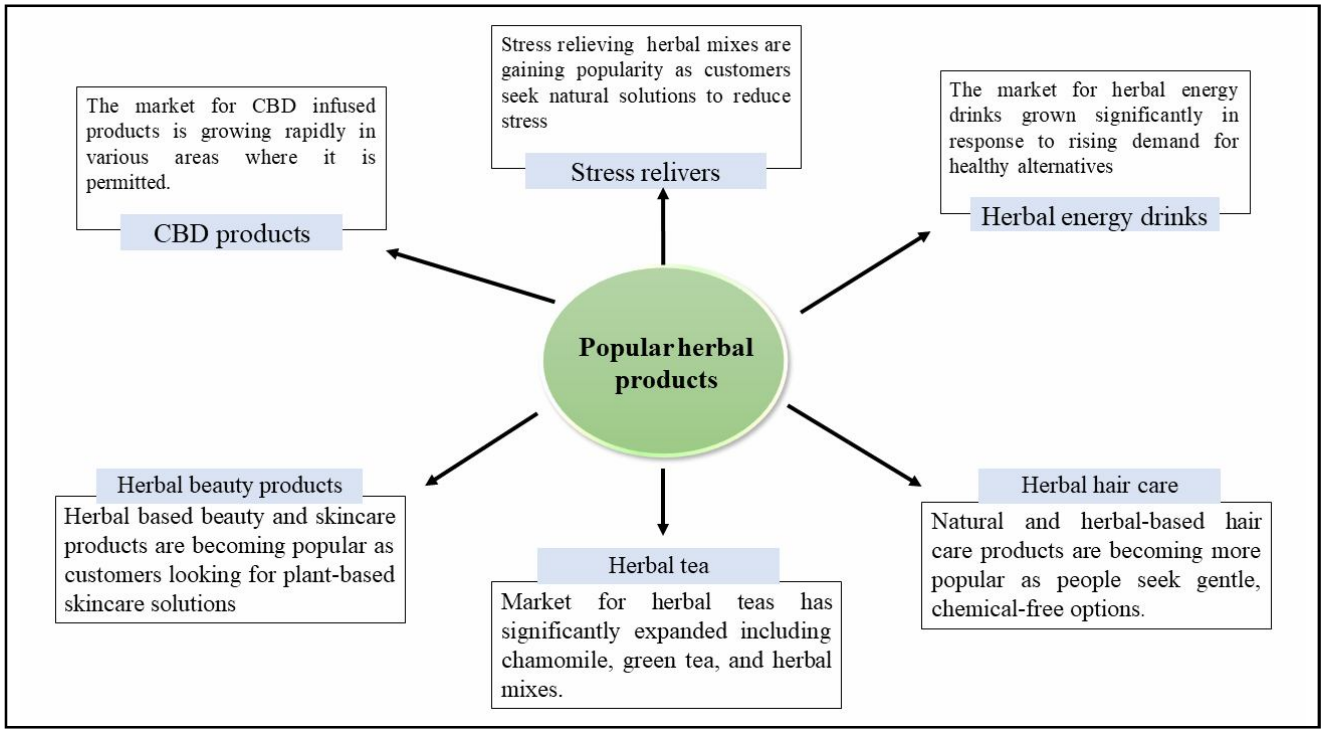

Figure 1: Global market of most effective herbal products.

3.1 Global expansion in herbal beauty and skincare products

The need for herbal ingredients is rising, fueling the market's expansion in the cosmetics industry. There is an increase demand of herbal ingredients in the cosmetic industry. Several reasons contribute to this trend, including increased consumer knowledge of natural products and their perceived low or no adverse effects. Consumers are becoming more aware of the substances in the skin care products they use, and they are actively searching out natural alternatives. One of the key causes for this is that customer desire is growing understanding about the potentially negative consequences of synthetic substances typically present in cosmetic products. Synthetic substances can occasionally cause skin irritation, allergies, or other negative effects (Pidigam *et al*., 2022). Herbal compounds, on the other hand, are frequently viewed as safer and softer on the skin are more environmentally friendly than their synthetic counterparts. Another significant element is the problem of ageing, which many people are struggling with as a result of pollution, climate change, and other factors. The ageing of the world's population has increased the focus on preventative healthcare and the use of herbal products to treat age-related health problems (Thanisorn, 2013).

3.2 Global market of herbal products in pharmaceutical and nutraceutical sector

Herbal medicine market is dominated by nutraceutical and pharmaceutical category which is due to herbal raw materials high need from the dietary supplement and industries alternative medicine. Because of herbal products benefits over time, customers emphasis is turning towards herbal products. Herbal protein powders and anti-ageing remedies are popular categories of product in the nutraceutical industry (Nemane *et al*., 2020). It is anticipated that these industries would continue to increase their need for herbal products. Throughout the projected period, this factor will support the pharmaceutical and nutraceutical segment's leadership in the global market. The second-largest market share belongs to products

for personal care and cosmetics. The main driver of the rise in demand for herbal raw ingredients in the beauty industry is the benefits they have for hair, face, and skin over the long term. The sale of herbal cosmetic products is rising as people become more aware of the product's long-term advantages (Vijayadharani *et al*., 2022). The food and beverage business are very new and yet adjusting to the product. To provide customers with alternatives to traditional beverages, herbal-flavored drinks, milk products, juices are entered in market by food producers. With the introduction of new products incoming era, this category is predicted to rise at fastest rate over the projection timeframe (Nirmal *et al*., 2014; BCC Research reports, 2018). Therefore, the pharmaceutical and nutraceutical industry held the biggest market share in 2022, as summarized in the Figure 1. This is understood to be the result of the increased demand for herbal raw materials from the manufacture of nutritional supplements and the alternative medicine sector.

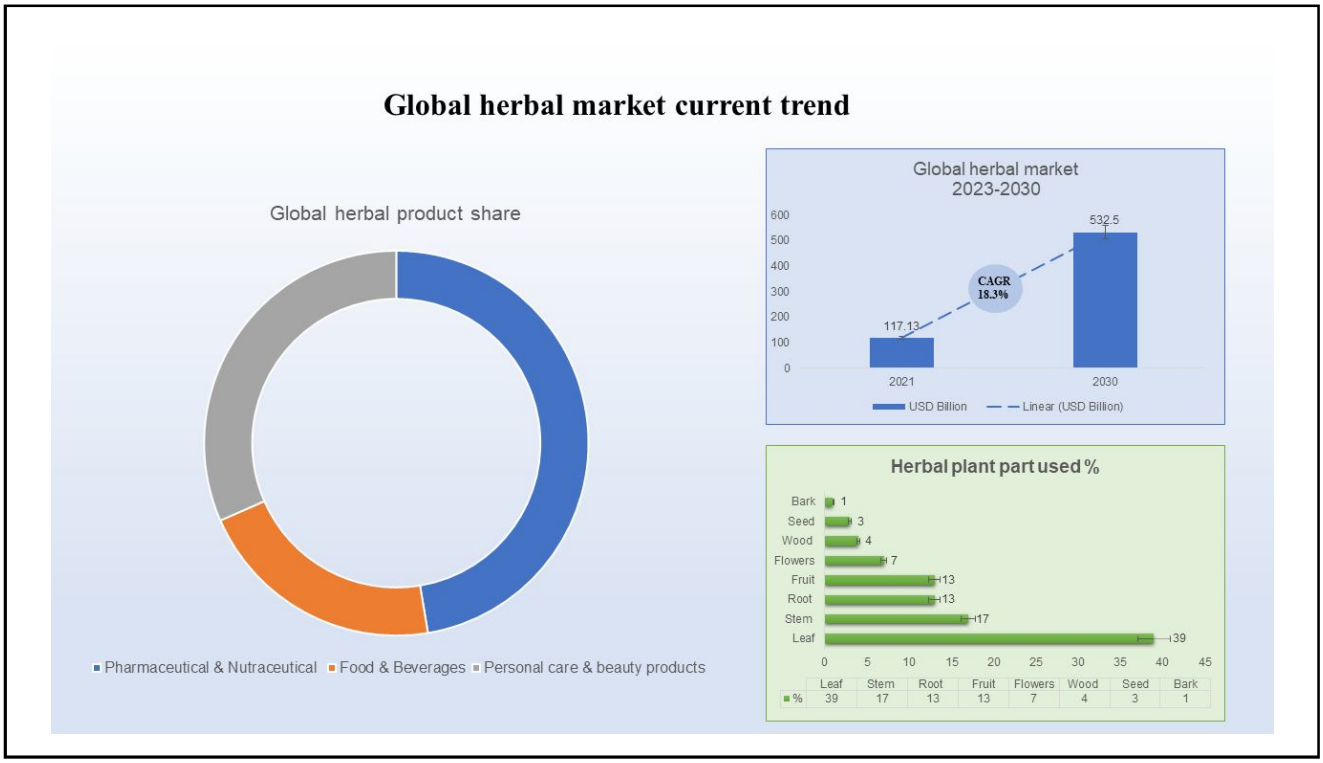

Figure 2: Pharmaceutical and nutraceutical industry market share 2022.

3.3 The current condition and trends seen in the global herbal product market

Consumer demand for herbal products is increasing, owing to factors such as a preference for natural and organic alternatives, increased health and wellness awareness, and worries about synthetic chemicals in traditional products. Customers are actively looking for herbal cures, vitamins, and personal care items. Also, herbal products are growing more popular, with big stores and pharmacies stocking a variety of herbal cures and supplements. Herbal medications have been included in the market alongside conventional drugs, making them more accessible to a wider customer base. There is a broadening of distribution networks as variety of distribution channels, including internet marketplaces, specialized shops, and direct selling networks, are used to offer herbal products. E-commerce has significantly contributed to the growth of the market for herbal products by giving customers access to a huge selection of alternatives from all over the world. It is significant to emphasise the impact of epidemic of COVID-19 on market for herbal products. Consumer interest in immune support, stress reduction, and general health and wellbeing has grown due to the pandemic, which has raised demand for herbal medicines and supplements (Rana and Chauhan, 2022). The continued consumption of herbal products is anticipated to offer the worldwide market with encouraging development potential. Hence, exploring the possible health advantages and uses of diverse herbal components is the main goal of research and development. To increase the potency and consumer appeal of herbal products, this involves discovering novel botanical extracts, herbal fusions, and formulation strategies more (Ekor, 2014; Roy *et al*., 2022).

3.4 Nutraceuticals

Since the beginning of time, people have used herbs as natural remedies for a wide range of physiological conditions. Their value from nature as a contribution to humanity for the illness's treatment was highlighted in ancient medical literature. Numerous herbs are incorporated in manufacturing of cheese for adding flavors and coagulants. Some of the herbs have also been used in cooking (Souyoul *et al*., 2018). Huge shifts in lifestyle, habits, habitations of rural areas have a big impact on diets in emerging nations, which increases the prevalence of many health issues. Food products demand from consumers with desired health advantages keeps rising as healthcare costs continue to rise. Additionally, rather than taking medications separately, many choose to eat foods that provide the required health benefits (Durazzo *et al*., 2020). Natural bioactive chemical substances known as "nutraceuticals," also known as "phytochemicals," have therapeutic, disease-prevention, or health-

promoting qualities. Hippocrates (father of medicine), a Greek physician suggested, let food be your medicine. The driving philosophy is to concentrate on prevention. Nutraceuticals are simply defined as nutritive + pharmaceutical: a food item that promotes health, whether as a dietary supplement or fortified food. Foods or dietary components known as nutraceuticals provide health benefits, such as the capacity to diagnose a disease (Nasri *et al*., 2014). The usage of nutritional supplements can improve health, delay the ageing process, prevent chronic illnesses, increase lifespan, or support various bodily structures and functions. Nutraceuticals are manufactured foods including cereals, soups, and drinks that have been genetically modified to be "designer" meals. They can also be diets, herbal items, dietary supplements, and isolated nutrients. Following are the three broad categories into which nutraceuticals can be divided (Dureja *et al*., 2003). (a) food components known as nutrients**,** including as vitamins, minerals, amino acids, and fatty acids, perform well-known nutritional roles, (b) dietary supplements: Substances sourced from outside sources (such as pyruvate, chondroitin sulphate, and steroid hormone precursors) that are used for a variety of purposes, including meal replacements, weight-loss aids, and sports nutrition, and (c) herbals: Extracts and concentrations of herbs or other botanical items (Raviraj *et al.,* 2023).

Herbal market and dietary supplements, the food industry, the pharmaceutical company, all produce products that are considered nutraceuticals. In addition to eliminating the cancer and coronary artery disease risk, a number of products are advertised as being able to prevent or treat headaches, high blood pressure, macular degeneration, cataracts, insomnia, menopausal symptoms, memory loss, and constipation (Dutta *et al*., 2018). Nutraceuticals can be sold as a single product or as a collection of different preparations. For generations, people have used herbs as food and medicine. Herbs have contributed significantly to preserving human health, enhancing human existence, and providing us with essential ingredients for seasoning, beverages, cosmetics, colours, and medications. Since 1960, there has been a rise in concept of "natural health" along with herbal products usage (Singh *et al*., 2021). People who seek conventional treatment frequently use herbal bioactives, a significant category of nutraceuticals. Flavonoids, lignans, sulphides, polyphenols, saponins and phthalates are just a few of the active phytochemicals found in herbs (Tungmunnithum *et al*., 2018).

Compared to medications, nutraceuticals have fewer adverse effects and contain nutritional supplements that are naturally occurring. By combating acute and chronic conditions brought on due to inadequate nutrition, herbal nutraceuticals are employed as a powerful tool to promote optimum well-being, lifespan, and standard of living (Hussain *et al*., 2015). A kind of alternative medicine called nutritional therapy uses food supplements or nutraceuticals to treat patients. The therapy is based on the notion that food may provide energy, nutrition, and medication. Nutraceuticals help to attain the mentioned goal through aiding in the body's detoxification processes, preventing vitamin and mineral shortages, and reestablishing normal digestive and dietary patterns. In essence, phytonutrients are nutrients that are present in plants and have certain biological effects that are advantageous to human health (Zhao, 2008).

3.5 Impact of nutraceuticals in a range of diseases

Nutraceuticals, comprising a wide array of bioactive compounds found in food and dietary supplements, have emerged as potential allies in the prevention and management of various diseases (Bradbury *et al*., 2014). These compounds, including vitamins, minerals, antioxidants, and probiotics, have been studied for their impact on a range of health conditions. From cardiovascular diseases and metabolic disorders to neurological conditions and cancer, nutraceuticals have demonstrated potential therapeutic benefits (Mahmoud and Rafieian-Kopaei, 2012). They may influence disease outcomes by affecting factors such as inflammation, oxidative stress, and metabolic processes. This burgeoning field of research highlights the promise of nutraceuticals as adjuncts to conventional medical treatments or as preventive measures (Asgary *et al*., 2014). However, it also underscores the importance of rigorous scientific investigation to establish their safety, efficacy, and optimal dosages for specific disease contexts. Understanding the impact of nutraceuticals in diverse diseases holds significant potential for improving public health and well-being (Gürbüz *et al*., 2019; Park *et al*., 2019). One of the main public health issues nowadays is cancer. Carotenoids function as antioxidants and aid in the prevention of cancer. Lycopene and related carotenoids act as a barrier against cancer (Willis and Wians, 2003). Apples contain a soluble fiber pectin, that show protection against prostate cancer by avoiding the adhesion of malignant cells to healthy cells. Naturally occurring phenolic compounds such as gallic acid, ferulic acid, caffeic acid have been claimed to have anticancer action. It has been suggested that the polyphenol curcumin, which is derived from the *Curcuma longa* plant, possesses anticarcinogenic, antioxidative, and anti-inflammatory properties. Congestive heart failure, osteoarthritis, hyperlipidemia, respiratory problems, cancer, and decreased fertility are all major medical conditions that are exacerbated by obesity. Nutraceuticals with putative antiobesity benefits include capsaicin, conjugated linoleic acid, *Momordica charantia*, *Citrus aurantium*, and psyllium fiber (de Freitas Junior; de Almeida, 2017). Herbal stimulants that help with weight loss include ephedrine, caffeine, chitosan, and green tea (Sachdeva *et al*., 2020).

4. Combination of probiotics and herbs

It may be advantageous to combine probiotics with certain herbs to enhance general health and wellbeing. Probiotic digureics are living microorganisms that, when taken in sufficient quantities, have positive effects on health. They are frequently linked to enhancing gut health and facilitating digestion. Probiotics, or beneficial microbes that enhance human health, are a growing area of study. Probiotics are a culture of living microorganisms (which can be a single or mixed culture) that, when given in the right dose, offer therapeutic advantages for the recipient (WHO, 2006).

4.1 Mechanism of action of probiotics

Probiotics primarily work by improving the epithelial barrier, increasing adhesion to the intestinal mucosa, concurrently inhibiting pathogen adhesion, actively excluding pathogenic microorganisms, producing anti-microorganism substances, and modifying the immune system summarized below in the Figure 3A. The following are some important ways that probiotics work: (a) boosting of epithelial barrier: Probiotics can help to strengthen the intestinal mucosa, which is the gut's natural barrier (Ohland; Mac Naughton, 2010). They aid in the preservation of the gut lining's integrity, lowering the chance of toxic chemicals and pathogens entering the circulation and triggering inflammation (Hooper *et al*., 2001). (b) enhance adhesion to the intestinal mucosa: Probiotics help the cell adhere tightly to the gut

wall. They aid in the preservation of the gut lining's integrity, lowering the chance of toxic chemicals and pathogens entering the circulation and causing inflammation. As a result, adhesion to intestinal mucosa is viewed as a need for colonization and is critical for the interaction between probiotic strains with the host (Beachey, 1981; Juntunen *et al*., 2001). (c) production of antimicrobial compound against pathogen: Probiotics can synthesize metabolites such as short-chain fatty acids (SCFAs), which have anti-inflammatory characteristics and support gut health. SCFAs also provide energy to colon cells and aid in the maintenance of the gut environment (Alakomi *et al*., 2000; De Keersmaecker *et al*., 2006). (d) pathogen's competitive exclusion: Greenberg coined the term "competitive exclusion" to describe the situation in which one species of bacteria competes more ferociously than another for receptor sites in the intestinal tract in a 1969 report on the complete exclusion of *Salmonella typhimurium* from blowfly maggots. A hostile microecology is produced, available bacterial receptor sites are removed, antimicrobial agents and selective metabolites are produced and secreted, and critical nutrients are depleted competitively (Roy *et al*., 2018). Hence, competition between pathogens and beneficial bacteria for resources and attachment sites in the gut is one way that probiotics might prevent the spread and colonization of pathogenic germs. (e) activates intestinal (IM) immune cells: Probiotic microorganisms have a well-known ability to modulate the immune system. These microorganisms can interact with dendritic cells (DCs), monocytes/ macrophages, lymphocytes, and (EP) epithelial cells (Yesilyurt *et al*., 2021). Probiotics also have an influence on the GBA, *i.e*., gut-brain axis. Probiotics may have an impact on how the gut and the brain communicate, or the gut-brain axis. Potential effects on mood, behavior, and mental health may result from this (Mörkl *et al*., 2020).

Herbs, on the other hand, have a long history of being used traditionally for their medicinal effects, which range from inducing relaxation and lowering inflammation to bolstering the immune system (Jiang, 2019). Therefore, the leaves, fruits, seeds, bark, roots, oils, juices, and other parts of the plants are all employed as medicine, depending on their medicinal components (Wink, 2015). Secondary metabolites or bioactive components found in medicinal herbs, including phenolic compounds, terpenoids, and polysaccharides, are rich in antioxidants and have antibacterial capabilities, making them effective in treating a range of illnesses and disorders (Meng *et al*., 2017; Wei *et al*., 2022). There are certain herbs that may increase the effectiveness of probiotics when taken with their advantages as summarized in Figure 3B. For instance, chamomile and ginger can improve digestion and induce relaxation, while turmeric and garlic have immune-boosting and anti-inflammatory effects. Probiotics and herbs may combine to provide the many advantages such as probiotics can aid in maintaining a healthy gut flora (Fernando and Flint, 2012). While herbs like chamomile, ginger, and peppermint may reduce stomach pain and improve gut motility (Balakrishnan, 2015; Fernando and Flint, 2012). Also, when herbs and probiotics are used together it can enhance immune system as probiotics and immune stimulating plants (ISP) like echinacea and garlic may combine to improve the body's resistance to diseases and infections (Catanzaro *et al*., 2018; Percival, 2016).

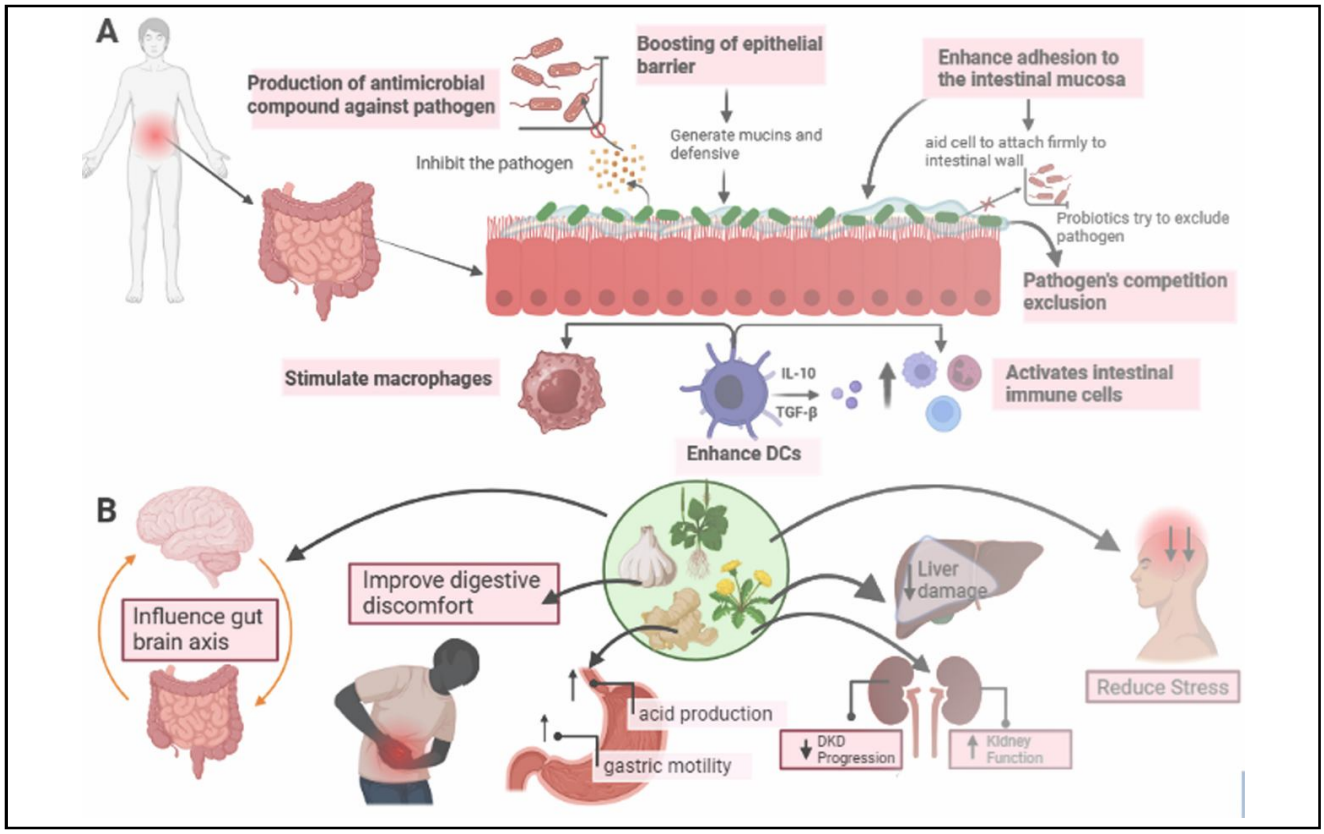

Figure 3A, 3B: The figure shows the five different mechanisms of action by which probiotics helps against the microbial pathogens; medicinal effects of herbs on human body.

An human trial study shows that herbs for stress relief are a common and time-honored method of dealing with the effects of stress on the body and mind (Pratte *et al.*, 2014). Adaptogens are herbs containing characteristics that help the body adapt to and cope with stress more efficiently. Adaptogenic herbs such as Ashwagandha, Rhodiola, and Holy basil are frequently used to enhance relaxation, decrease anxiety, and balance stress hormones (Balakrishnan, 2015; Chandrasekhar *et al.*, 2012; Singletary, 2018). These herbs may have a significant influence on promoting a healthy gut-brain axis and lowering stress when taken with probiotics. A wide range of medicinal herbs and phytochemicals have been studied as complementary and alternative therapies for chronic liver disease. Because certain herbal items have already been utilised to treat liver disorders in some nations or regions (Hong *et al.*, 2015). Another combination of herbs with probiotics is in reducing inflammation as curcumin, the main ingredient in turmeric, has potent anti-inflammatory actions. It may help reduce inflammation in the stomach and throughout the body when administered in combination with probiotics (Peng *et al.*, 2021).

However, it is essential to seek advice from a medical expert or a licensed herbalist before beginning any new supplement regimen, especially one that includes probiotics and herbs. Taking into account any current medical issues or drugs you might be taking; they can assist in choosing the best combination for your unique health requirements (Telrandhe and Gunde, 2022). Additionally, make sure you are utilizing herbal supplements and probiotics of the highest caliber from reliable suppliers.

4.2 Adulteration found in herbal products

Adulteration in herbal medications is defined as "the practice of partially or completely replacing the first illicit drug to some similar-looking drugs that are either devoid of inferior in terms of pharmacological and chemical effects" (Choudhary *et al.*, 2020). The commercial growth of natural products has been severely hampered by the adulteration and replacement of herbal medications, which is a serious concern in the herbal industry. Raw pharmaceuticals adulteration or replacement have come from the destruction and loss of numerous species, as well as inaccurate identification of many plants (Banti, 2020). A variety of foods and drinks often get contaminated in a variety of conditions due to excessive demand or seasonality in availability. Various writers, like (El loly *et al*., 2013; Asrat and Yilma 2014), claim that adulterations might be accidental, inadvertent, or intentionally made. As a result, it is critical to examine them independently. The distinctive trend and bad effects linked to contaminated herbal products are discussed in several study publications on herbal medications and dietary supplements (Ernst, 2002; Posadzki *et al*., 2013).

Traditional Chinese medicines are alluring and susceptible to adulteration since they have a strong worldwide market. On a smaller scale, in order to support therapeutic claims, allopathic drugs with established efficacy are being added to African traditional medicines (Shahrajabian *et al*., 2019; Agbor and Naidoo, 2016). Studies revealed the TCM and ATM adulteration with a variety of medications, including aphrodisiacs, antihypertensives, antidiabetics, analgesics, weight-loss aids, and contraceptives (Leung *et al*., 2020). The main concern is "Why herbal medications are specified for adulteration?" Solution is found in the regulatory frameworks in place for the manufacture, distribution, and dispensing of herbal medicines.

4.3 Factors leading to adulteration in herbal medicinal products

Adulteration causes can be divided into two categories: Intentional and Unintentional.

4.3.1 Intentional adulteration

Economic motivations are frequently used to justify adulteration. By incorporating cheaper or inferior materials into products, unethical people or corporations can boost their earnings. Another factor which leads to intentional adulteration would be market demands: when a product is in great demand, providers may turn to adulteration to match the demand and capitalize on the opportunity. Also, Scarcity of specific products or raw materials might result in adulteration as suppliers attempt to maintain production levels. Intentional adulteration happens when there is a cutthroat pressures as in competitive marketplaces, corporations may turn to adulteration in order to provide cheaper pricing than competitors and therefore attract more customers. Broad and complicated supply chains might generate chances for purposeful adulteration since it is difficult to monitor and regulate every stage of manufacturing and delivery (Momtaz *et al*., 2023).

4.3.2 Unintentional adulteration

When various products or parts are produced in the same site or machinery, it might result in unintentional adulteration. Unintentional adulteration also caused by mislabeling: when errors in labelling or packaging might lead to the accidental inclusion of an erroneous substance or allergy. Also, human error is common as in manufacturing errors, such as faulty measuring or mixing, can result in unintended adulteration. There is also a chance of contamination during storage and transportation: When improper storage conditions or insufficient transportation practices can lead to product contamination with foreign substances. Natural variation: Variations in plant or animal sources might accidentally contribute to changes in product composition in natural products.

Adulteration, whether deliberate or accidental, may have detrimental effects for both consumers health and businesses bottom lines. Strict regulatory controls, quality assurance procedures, supply chain transparency, and consumer education campaigns are necessary to counteract adulteration. Consumers should be alert and knowledgeable about the possible hazards connected with product adulteration while businesses should employ rigorous testing and verification systems to verify the authenticity and safety of their products (Manning and Soon, 2014).

4.4 How to alleviate adulteration

Improvements in the accessibility of laboratory analytical methods give responsible members of the herb sector greater possibilities to help assure proper identity and authentication of botanical ingredients, extracts, and essential oils as well as to identify the presence of potentially unwanted adulterants and contaminants. Governments should impose tight laws and quality control requirements to guarantee the integrity and safety of food items. Regular testing, certification, and inspection programs can aid in the detection and prevention of adulteration. Strict legal sanctions and fines for adulteration can serve as a deterrence. Another step can be takes as by initiating transparency in supply chain. Keeping the supply chain transparent and traceable is essential to preventing adulteration. At various phases of manufacturing, distribution, and

retail, the use of systems including track and trace technology, quality certifications, and auditing methods can assist detect and get rid of contaminated items. Additionally, there is a need for increased public awareness. Consumers can be empowered to make wise decisions if they are taught about the dangers of adulteration and given instructions on how to spot and report suspicious occurrences. Campaigns to raise awareness among the general public, workshops, and educational resources may all be very effective in reducing adulteration. Improving the traceability and authentication of food items may be done by embracing technical developments like blockchain, DNA testing, and spectroscopy. These tools can offer real time data and assist in quickly and effectively identifying items that have been contaminated. Regular monitoring and surveillance programs can aid in the identification of growing adulteration trends and the detection of novel adulterants. This proactive strategy enables early interventions and the avoidance of adulteration practices (Goyal *et al*., 2022; Zhang *et al*., 2011).

Overcoming adulteration is critical for assuring fair trade practices, building consumer trust, supporting economic stability, safeguarding cultural legacy, and minimizing environmental repercussions. To develop a safe and dependable food system that serves both individuals and society as a whole, all stakeholders must work together.

5. Conclusion

In conclusion, the extensive history of traditional usage and possible health advantages of herbs indicate that they have a promising future as a source of nutrition. Herbal products are predicted to be more in demand as customers become more health conscious and look for natural alternatives. Herbs will continue to gain popularity as health-promoting substances as a result of ongoing scientific studies confirming their effectiveness. Herbs are anticipated to gain more market share as a result of being included in functional foods, nutraceuticals, and individualized nutrition regimens. To guarantee secure and efficient herbal supplements, it is essential to give priority to quality control and sustainable sources. Additional possibilities for the use of herbs in healthcare may be opened up by incorporating them into conventional medicine and combination treatments. Integrating herbs into traditional medicine and combination medicines may increase their acceptance and use in the healthcare market. However, ongoing research and interaction with healthcare experts are required to ensure informed and safe usage. Overall, the future of herbs as a health food is bright, but prudent usage, further study, and contact with healthcare professionals are required to reap the full advantages.

Conflict of interest

The authors declare no conflict of interest relevant to this article.

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