World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(REVIEW ARTICLE)

Check for updates

Recent updates on antimicrobial, antifungal, and anti-cancerous agents from natural herbs of Indian Himalaya

Arun Singha [1], Bharti Minhas [1,*], Naveen Minhas [2] and Nitesh Kumar [3]

[1] *Department of Microbiology, Himachal Pradesh University, Summer Hill, Shimla (H.P.), India -171005.*
[2] *Culture & Drug Susceptibility Testing Laboratory for Tuberculosis, Department of Microbiology, Indira Gandhi Medical College, Shimla (Himachal Pradesh), India.*
[3] *Department of Botany, Himachal Pradesh University, Summer Hill, Shimla (H.P.), India -171005*

World Journal of Biology Pharmacy and Health Sciences, 2025, 21(03), 397-411

Publication history: Received on 01 February 2025; revised on 13 March 2025; accepted on 15 March 2025

Article DOI: https://doi.org/10.30574/wjbphs.2025.21.3.0279

Abstract

Indian Himalayas harbor a rich biodiversity of natural herbs that have been integral to traditional healing practices, cultural customs, and ecological balance for millennia. This chapter emphasizes the antimicrobial, antifungal, and anticancerous properties of herbs native to the Indian Himalayas, highlighting their significance in healthcare, scientific research, and cultural heritage. Traditional knowledge systems such as Ayurveda have long recognized the therapeutic benefits of herbs like Tulsi, Brahmi, and Ashwagandha, which play crucial roles in treating various ailments and enhancing overall well-being. Moreover, the cultivation and trade of Himalayan herbs contribute significantly to local economies while promoting sustainable harvesting practices guided by indigenous wisdom. Herbs offer promising alternatives or complements to conventional antimicrobial agents, addressing challenges such as antimicrobial resistance. Garlic, tea tree oil, neem, and oregano are among the herbs renowned for their antimicrobial and antifungal properties, supported by scientific research. Additionally, herbs like turmeric and green tea exhibit potent anticancerous properties, providing avenues for novel cancer treatments. The exploration of antimicrobial agents, including antibiotics, antivirals, antifungals, and antiparasitics underscores the ongoing quest to combat infectious diseases and emerging antimicrobial resistance. Herbs offer a diverse array of bioactive compounds that target microorganisms through multiple mechanisms of action, minimizing the risk of resistance development. Synergistic herbal combinations further enhance antimicrobial efficacy, reflecting the holistic approach of traditional medicine systems. The study of natural herbs for medicinal purposes transcends disciplinary boundaries, encompassing botany, pharmacology, chemistry, ethnobotany and traditional medicine systems. Interdisciplinary collaboration is essential for unlocking the full potential of medicinal plants, promoting evidence-based healthcare practices, and fostering sustainability. By embracing traditional wisdom and scientific innovation, we can harness the healing gifts of nature to promote health, preserve biodiversity and nurture the connection between humanity and the natural world.

Keywords: Natural Herbs; Antimicrobial Agents; Antifungal Agents; Anticancerous Agents and Antimicrobial Resistance

1. Introduction

The Indian Himalayas stand as a majestic epitome of natural beauty and ecological richness, harboring a diverse array of flora and fauna, among which natural herbs hold a particularly significant place. These herbs, deeply rooted in the region's cultural heritage and traditional healing practices, have long been revered for their medicinal properties, ecological importance, and economic value. First and foremost, the ancient Indian medical system known as Ayurveda has long recognised and used the therapeutic benefits of Himalayan plants. This has been the case for millennia. Herbs

* Corresponding author: Bharti Minhas.

such as Tulsi, Brahmi and Ashwagandha are among the many that the area has to offer; these can be used for the treatment of diverse range of conditions from respiratory problems to digestive disorders and more. The customary wisdom that has been passed down through the ages emphasises how deeply understood the medicinal potential of these priceless plants is (Inglis, 2012). Furthermore, the natural herb population plays a major role in the Indian Himalayas' designation as a global hotspot for biodiversity. A wide variety of animal species are supported by the complex web of plant species, creating a delicate ecological balance that is essential to the survival of the ecosystems in the area. The livelihoods of the inhabitants that depend on these natural resources must be protected, in addition to the health of the Himalayan environment, which depends on the preservation of this biodiversity. Himalayan herbs are closely associated with regional customs, religious beliefs, and culinary arts on a cultural level. Herbs like Holy Basil (Tulsi), which represent both spiritual purity and bodily well-being, are used in many facets of daily life, from ceremonial offerings to regular wellness regimens. Furthermore, the unique tastes and fragrances of these herbs enhance local cuisines, enhancing the culinary legacy of the Himalayan foothills and beyond (Anand, 2024).

Economically, the cultivation and trade of Himalayan herbs play a crucial role in the livelihoods of countless individuals residing in the region. Sustainable harvesting practices, often guided by indigenous knowledge, ensure the long-term viability of herbal resources while providing economic opportunities for rural communities. Furthermore, the global demand for herbal products continues to drive growth in this sector contributing to both local and national economies. The Himalayan herbs provide a plethora of opportunities for scientific investigation and learning. The effectiveness of conventional treatments is being verified more and more by using contemporary scientific techniques which are also helping to discover novel therapeutic uses and reveal the mysteries of these age-old healing substances. In addition to improving human health this type of study helps guide conservation initiatives and sustainable resource management plans. Himalayan herbs serve as magnets for tourism and recreation, drawing visitors from around the world eager to explore the region's natural wonders and cultural heritage. Ecotourism initiatives centered around herbal trails, wellness retreats and educational programs provide immersive experiences that foster an appreciation for the intricate relationship between humans and the natural world (Jacob *et al*., 2023). In essence, the significance of natural herbs from the Indian Himalayas transcends mere medicinal value, encompassing ecological, cultural, economic and scientific dimensions. As stewards of this invaluable heritage, it is incumbent upon us to recognize and uphold the importance of these botanical treasures, ensuring their conservation and sustainable utilization for generations to come.

1.1. Antimicrobial, antifungal and anticancerous properties of herbs

Natural herbs have been used for centuries as remedies for various health conditions, and their therapeutic properties have been the subject of extensive scientific research. Among the most intriguing are their antimicrobial, antifungal and anticancerous properties. These qualities make herbs invaluable in traditional medicine systems like Ayurveda, Traditional Chinese Medicine (TCM) and others, and they remain as a focus of modern scientific inquiry. Understanding the mechanisms behind these properties offers promising avenues for developing new treatments and improving human health.

1.1.1. Antimicrobial Properties

One of the most well-known properties of herbs is their antimicrobial activity, which refers to their potential to inhibit the growth of microbes such as bacteria, fungi, parasites, and viruses. Many herbs contain bioactive compounds like phenols, flavonoids, alkaloids and essential oils that exhibit antimicrobial effects. Garlic (*Allium sativum*) is renowned for its potent antimicrobial properties, attributed to the presence of allicin, a sulfur-containing compound. Cutler and Wilson (2004) in their study reported that garlic extract have potential to inhibit the growth of a wide range of bacteria including antibiotic-resistant strains like Methicillin-resistant *Staphylococcus aureus* (MRSA). Similarly, tea tree oil (*Melaleuca alternifolia*) possesses strong antimicrobial activity due to its high concentration of terpenes, particularly terpinen-4-ol (Badr *et al*., 2023). It has been used traditionally by Indigenous Australians to treat infections, and modern research confirms its effectiveness against bacteria, fungi and viruses.

1.1.2. Antifungal Properties

Herbs also exhibit antifungal properties, making them valuable in treatment of fungal infections e.g. candidiasis, athlete's foot, and ringworm. Fungal infections can be challenging to treat, especially with the increasing prevalence of drug-resistant strains, making natural alternatives particularly appealing. One notable herb with antifungal properties is neem (*Azadirachta indica*), a tree native to the Indian subcontinent. Neem extracts have compounds like nimbin and azadirachtin, which have been shown to inhibit the growth of various fungi, including Candida species (Alzohairy, 2016). Another herb renowned for its antifungal activity is oregano (*Origanum vulgare*), particularly its essential oil. Carvacrol and thymol two major components of oregano oil, possess potent antifungal properties and have demonstrated efficacy against fungal pathogens such as *Candida albicans* and *Aspergillus* species (Baj, 2020).

1.1.3. Anticancerous Properties

The search for novel and efficient cancer treatments has led to an increase in interest in anticancer capabilities of herbs in recent years. According to research, a variety of herbs may contain substances that can stop the growth of cancer cells, cause apoptosis or programmed cell death and prevent tumors from growing and spreading. Turmeric (*Curcuma longa*) is perhaps one of the most widely studied herbs for its anticancer properties, attributed to its active compound, curcumin (Verma *et al*., 2018). Curcumin has the capacity to modulate multiple signaling pathways involved in cancer development and progression, making it a potential candidate in cancer treatment and prevention. Another herb with potent anticancerous properties is green tea (*Camellia sinensis*), particularly its polyphenol epigallocatechin gallate (EGCG). Numerous studies have demonstrated that EGCG can stop the growth of cancerous cells, induce apoptosis, and inhibit angiogenesis (Almatroodi *et al*., 2020).

2. Rich tradition of herbal medicine in the region

The tradition of herbal medicine is deeply rooted in indigenous knowledge systems, cultural practices and the diverse flora of the region. The tradition of herbal medicine in the Himalayas finds its roots in ancient texts such as the Veda and the Atharva Veda, which contain references to medicinal plants and their therapeutic uses. Ayurveda, the ancient Indian system of medicine further codified this knowledge, categorizing herbs based on their properties and applications. The Himalayan region has been a cradle of Ayurvedic practice, with numerous medicinal plants like Ashwagandha, Triphala and Guggul being integral to Ayurvedic formulations (Gowans, 2004). Indigenous communities inhabiting the Himalayan region have developed their own systems of herbal medicine, passed down through oral traditions and experiential learning. Traditional healers often referred to as Vaidyas or Baidyas possess deep knowledge of local flora and their medicinal properties. This indigenous knowledge encompasses not only the identification and harvesting of medicinal plants but also the preparation and administration of herbal remedies tailored to individual needs (Pan *et al*., 2014). Herbal medicine is deeply intertwined with the cultural fabric of Himalayan communities. Many herbs hold spiritual significance and are used in religious rituals, ceremonies, and festivals (Gupta *et al*., 2014). Tulsi (*Holy Basil*) is revered as a holy plant and is worshipped as a manifestation of the goddess Lakshmi. Similarly, herbs like Neem and Amla are associated with purification rituals and protective charms, reflecting the holistic worldview that permeates traditional healing practices.

Himalayan communities have developed sustainable harvesting practices to ensure the conservation of medicinal plants and their ecosystems. Traditional knowledge systems emphasize the importance of ethical harvesting, seasonal timing and ecosystem stewardship to prevent overexploitation and promote the regeneration of wild populations. These practices are rooted in a deep respect for nature and recognition of the interconnectedness of all living beings. While traditional herbal medicine remains prevalent in the Himalayan region, there is also a growing interest in integrating traditional knowledge with modern medical practices. Many Ayurvedic herbs have gained scientific interest for their potential therapeutic applications, leading to research studies exploring their pharmacological effects and clinical efficacy (Anand *et al*., 2019).

3. Exploration of antimicrobial agents

Exploration of antimicrobial agents is a critical aspect of modern medicine, driven by the ongoing threat of infectious diseases and the emergence of antimicrobial resistance. Antimicrobial agents can inhibit the growth or kill microorganisms such as bacteria, fungi, parasites, and viruses. Antibiotics are perhaps the most well-known class of antimicrobial agents, commonly used for the treatment of bacterial infections. They act by targeting specific components of bacterial cells, such as cell walls, nucleic acid synthesis processes, or protein synthesis machinery. Examples of antibiotics include penicillins, tetracyclines, cephalosporins, fluoroquinolones, and macrolides. However, the widespread use and misuse of antibiotics have led to the emergence of antibiotic-resistant bacteria, posing a significant challenge to healthcare systems worldwide. Antiviral agents are designed to target viral infections by inhibiting viral replication or disrupting viral assembly and release. They are used to treat a wide range of viral infections, including influenza, respiratory viruses, hepatitis, herpes, and HIV/AIDS. Examples of antiviral drugs include acyclovir, oseltamivir, ribavirin and tenofovir. Antiviral drugs have been helpful in managing viral outbreaks and pandemics, such as the HIV/AIDS epidemic and the COVID-19 pandemic. Antifungal agents are used to treat fungal infections, which can range from superficial skin infections to life-threatening systemic infections. These agents work by targeting fungal cell membranes, cell walls, or metabolic pathways essential for fungal growth and survival. Examples of antifungal agents include azoles (e.g., fluconazole, voriconazole), echinocandins (e.g., caspofungin), polyenes (e.g., amphotericin B) and allylamines (e.g., terbinafine).

Antiparasitic drugs are used for the treatment of infections caused by parasites, including protozoa, helminths (worms) and ectoparasites (such as lice and mites). These drugs may target various stages of the parasite's life cycle including larval forms, adult worms or the parasite's metabolic processes. Examples of antiparasitic drugs include antimalarials (e.g., artemisinin, chloroquine), antiprotozoals (e.g., metronidazole, atovaquone), and antihelminthics (e.g., albendazole, praziquantel). Antiparasitic drugs are essential for controlling parasitic infections that affect millions of people globally particularly in tropical and subtropical regions.

Herbs have long been recognized for their antimicrobial properties, making them valuable components of traditional medicine systems worldwide. These natural antimicrobial agents offer potential alternatives or complements to conventional antibiotics, predominantly in the context of rising antimicrobial resistance. Many herbs exhibit broad-spectrum antimicrobial activity, meaning they can inhibit the growth of a wide range of microorganisms, including bacteria, fungi, parasites, and viruses (Tariq *et al*., 2019). This broad activity is due to the diverse array of bioactive compounds present in herbs such as phenols, terpenes, flavonoids, alkaloids, and essential oils.

Numerous herbs possess antibacterial properties that can help combat bacterial infections. For example, garlic (*Allium sativum*) contains allicin with potent antibacterial activity against various bacteria including antibiotic-resistant strains like Methicillin-resistant *Staphylococcus aureus* (MRSA) (Cutler and Wilson, 2004). Other herbs with notable antibacterial effects include thyme, oregano, cinnamon, and ginger. Certain herbs have demonstrated antiviral activity, inhibited the replication of viruses and reduced viral load. Elderberry (*Sambucus nigra*) contains flavonoids and anthocyanins that have been shown to inhibit the entry and replication of influenza viruses (Torabian *et al*., 2019). Similarly, licorice root (*Glycyrrhiza glabra*) contains glycyrrhizin which exhibits antiviral effects against respiratory viruses including respiratory syncytial virus (RSV) and SARS-CoV-2 (Abraham and Florentine, 2021).

Herbs are also effective against fungal infections due to their antifungal properties. For example, tea tree oil (*Melaleuca alternifolia*) comprised terpinen-4-ol which has potent antifungal activity against various fungi, including Candida species responsible for yeast infections (Alzohairy, 2016). Additionally, neem (*Azadirachta indica*) contains compounds like nimbin and azadirachtin, which exhibit antifungal effects against dermatophytes and other pathogenic fungi (Salazar *et al*., 2020). Some herbs possess antiparasitic properties which can help combat parasitic infections caused by protozoa, helminths and ectoparasites. Artemisinin derived from *Artemisia annua* (sweet wormwood) is a well-known antiparasitic compound used in the treatment of malaria (Soni *et al*., 2022). Additionally, black walnut (*Juglans nigra*) contains juglone, a compound with antiparasitic effects against intestinal worms and other parasites (Nicolescu *et al*., 2020). The potential of herbs as antimicrobial agent is often attributed to multiple mechanisms of action, including membrane disruption, inhibition of protein synthesis, interference with nucleic acid replication and modulation of host immune responses. These complex interactions allow herbs to exert their antimicrobial effects while minimizing the risk of resistance development. Herbal combinations or formulations may possess synergistic effects where the combined action of multiple herbs intensify their overall antimicrobial activity. Traditional medicine systems often utilize herbal combinations based on synergistic principles to optimize therapeutic outcomes and minimize adverse effects. Several herbs are well-known for their antimicrobial properties and have been used to inhibit the growth of microbes (Table 1).

Table 1 Plant and plant products showing antimicrobial activity

Plant and Plant Product	**Compounds**	**Antimicrobial Activity**	**References**
Garlic (*Allium sativum*)	Allicin	Against antibiotic-resistant bacteria e.g. Methicillin-resistant *Staphylococcus aureus* (MRSA)	Cutler and Wilson, 2004
Haritaki (*Terminalia chebula*)	__	Against clinical isolates of bacteria	Gupta *et al*., 2010
Oregano (*Origanum vulgare*)	Carvacrol and thymol	Inhibit the growth of pathogens suggesting its capability as a natural antimicrobial agent	Karakaya *et al*., 2011
Turmeric (*Curcuma longa*)	Curcumin	Drug-resistant strains of *Mycobacterium tuberculosis*	Gupta *et al*., 2013
Brahmi (*Bacopa monnieri*)	__	Drug-resistant strains of bacteria e.g. methicillin-resistant *Staphylococcus aureus* (MRSA)	Mkk and Irfan, 2019

Honey	__	Powerful antimicrobial agent with a wide range of inhibitory effects	Almasaudi, 2021
Black sampson (*Echinacea*)	__	Reduces antibiotic usage in children having respiratory track infection	Ogal *et el*., 2021
Tulsi (*Ocimum sanctum*)	__	Multidrug-resistant strains of bacteria e.g. *Staphylococcus aureus* and *Pseudomonas aeruginosa*	Jain *et al*., 2022
Ashwagandha (*Withania somnifera*)	__	*Staphylococcus aureus* and *Klebsiella pneumoniae*	Singh *et al*., 2022
Clove (*Syzygium aromaticum*)	__	*Staphylococcus aureus*	Li *et al*., 2022
Ginger (*Zingiber officinale*)	__	*Enterococcus faecalis, Streptococcus mutans, Staphylococcus spp., and Lactobacillus spp.*	Ahmed *et al*., 2022
Tea tree oil (*Melaleuca alternifolia*)	Terpinen-4-ol	Bacterial, fungal and viral infections	Badr *et al*., 2023

3.1. Recent studies and discoveries

Recent studies and discoveries in the field of herbal medicine and antimicrobial properties have shed light on novel therapeutic agents, mechanisms of action, and potential applications. Researchers continue to discover new bioactive compounds from medicinal plants with antimicrobial properties. Recent research has explored the synergistic interactions between herbal compounds and conventional antibiotics leading to enhanced antimicrobial activity and potential strategies to combat antibiotic resistance. In 2020, a research study explored the combined effects of thymol, a compound present in thyme essential oil, with antibiotics in combating multidrug-resistant Acinetobacter baumannii (Beceiro *et al*., 2020). The combination of thymol with antibiotics significantly increased bacterial susceptibility and reduced biofilm formation. The COVID-19 pandemic has spurred research into natural compounds with potential antiviral activity against SARS-CoV-2, the virus responsible for COVID-19. A number of studies have investigated the antiviral effects of herbal formulations and bioactive compounds against SARS-CoV-2 *in vitro*. Dogan *et al*. (2022) revealed that a methanol extract of *Artemisia annua* (sweet wormwood) exhibited potent inhibitory activity against SARS-CoV-2 replication in Vero E6 cells.

Pharmacological research has elucidated the mechanisms underlying the antimicrobial properties of herbal compounds, providing insights into their mode of action and potential therapeutic targets. In 2021, a review published in the journal 'Phytotherapy Research' summarized the antimicrobial mechanisms of essential oils. It highlighted their ability to disrupt bacterial cell membranes, inhibit enzymatic activity, and modulate gene expression in bacteria (Aljaafari *et al*., 2021). Herbal compounds have shown promise in disrupting bacterial biofilms, which are complex microbial communities covered in a protective matrix and associated with chronic infections and antibiotic resistance. A recent study explored the biofilm-inhibitory activity of herbal extracts against Staphylococcus aureus and Pseudomonas aeruginosa. The findings suggest promising applications in preventing and treating biofilm-associated infections (Abdallah *et al*., 2020). Advances in drug delivery systems have facilitated the development of herbal formulations with enhanced antimicrobial activity and improved bioavailability. Nanotechnology-based approaches, such as nanoparticle formulations and nanoemulsions, have been utilized to encapsulate herbal extracts and essential oils, enhancing their stability, solubility, and targeted delivery to infection sites (Ahmed *et al*., 2021). These recent studies and discoveries underscore the diverse and dynamic nature of research in herbal medicine and antimicrobial properties, highlighting the potential of natural compounds as valuable resources in fighting infectious diseases and addressing the global challenge of resistance to antibiotics.

3.2. Potential applications in healthcare and pharmaceuticals

Herbal medicines with antimicrobial properties can be used to treat a wide range of infectious diseases caused by bacteria, fungi, parasites, and viruses. They offer alternatives or complements to conventional antibiotics, particularly in cases of antibiotic-resistant infections. Herbal formulations may target specific pathogens or exert broad-spectrum activity, making them versatile options for managing infectious diseases. Antiviral therapies derived from herbal compounds hold promise for treating viral infections including respiratory viruses (e.g., influenza, SARS-CoV-2), hepatitis viruses and retroviruses (e.g., HIV). Some herbal medicines have been explored for their anticancer potential

as adjunctive therapies in cancer treatment. Anticancer herbs may inhibit tumor growth, provoke apoptosis (programmed cell death) in cancer cells and enhance the effectiveness of conventional chemotherapy and radiation therapy. Integrative approaches that combine herbal medicine with standard cancer treatments offer opportunities to improve treatment outcomes and reduce side effects. Herbal remedies with antimicrobial and anti-inflammatory properties are commonly used in wound healing and skin care. Herbal extracts, oils, and ointments may promote tissue regeneration, reduce inflammation and prevent infection in wounds, burns, cuts and skin conditions such as eczema and acne. Herbal formulations may also have moisturizing, soothing and antioxidant effects contributing to overall skin health.

Herbal medicines are frequently employed to support gastrointestinal health and treat digestive disorders like gastritis, peptic ulcers, irritable bowel syndrome (IBS) and gastrointestinal infections. Herbs with antimicrobial, anti-inflammatory and gastroprotective properties can help alleviate symptoms restore gut flora balance and promote digestive function. Herbal teas, tinctures and capsules are commonly used for gastrointestinal support. Herbal supplements and tonics are popular choices for immune support and preventive health maintenance. Herbs with immunomodulatory, antioxidant and antimicrobial properties can enhance immune function, reduce susceptibility to infections, and support overall well-being. Herbal formulations may contain immune-boosting herbs such as echinacea, astragalus, elderberry and medicinal mushrooms. Herbal medicine plays a role in managing chronic diseases, such as diabetes, cardiovascular disease, and autoimmune conditions. Herbal remedies may help control symptoms, reduce inflammation, and improve metabolic function, contributing to disease management and quality of life. Integrative approaches that combine herbal medicine with lifestyle modifications and conventional treatments offer holistic strategies for chronic disease management. Herbal medicines with analgesic and anti-inflammatory properties are utilized for pain management and inflammatory conditions, such as arthritis, muscle pain and migraines. Herbal remedies may alleviate pain, reduce inflammation, and improve mobility without the side effects associated with conventional pain medications. Herbal formulations may include herbs like turmeric, ginger, boswellia and willow bark.

4. Exploration of antifungal agents

Investigation of antifungal agents is a critical area of research in healthcare and pharmaceuticals, driven by the emergence of antifungal resistance. Fungal infections ranging from superficial skin infections to life-threatening systemic diseases pose significant challenges to public health particularly in immunocompromised individuals. Antifungal agents are used for the treatment of a wide range of fungal infections including candidiasis, dermatophytosis, aspergillosis, cryptococcosis and mucormycosis. These infections can affect various organs and tissues leading to symptoms such as skin rashes, nail discoloration, oral thrush, pulmonary infiltrates and invasive tissue damage. Antifungal therapy aims to eradicate fungal pathogens, alleviate symptoms and prevent disease progression particularly in vulnerable patient populations such as organ transplant recipients, HIV/AIDS patients, and cancer patients undergoing chemotherapy. The emergence of antifungal resistance particularly in species of *Candida*, *Aspergillus* and *Cryptococcus* presents a significant challenge to antifungal therapy. Research efforts are focused on understanding the antifungal resistance mechanisms, identifying biomarkers of resistance and developing strategies to overcome resistance. This includes the development of noval antifungal agents with new mechanisms of action, combination therapy approaches and adjunctive therapies to enhance antifungal efficacy. Recent advancements in drug discovery and development have led to the identification of novel antifungal agents with enhanced efficacy, safety, and pharmacokinetic profiles. These comprised next-generation azoles, echinocandins, liposomal amphotericin B formulations and antifungal peptides. For example, isavuconazole a novel triazole antifungal agent has demonstrated efficacy against a broad spectrum of fungal pathogens including azole-resistant strains of *Aspergillus* and *Candida*.

Natural products derived from plants, fungi, microorganisms, and marine organisms represent a major source of potential antifungal agents. Traditional medicine systems worldwide have long utilized herbal remedies and botanical extracts for the treatment of fungal infections. Recent research has focused on screening natural product libraries for antifungal activity, identifying bioactive compounds and elucidating their mechanisms of action. For example, the polyene antifungal compound amphotericin B was originally isolated from the soil bacterium *Streptomyces nodosus*. Antifungal agents are also used for prophylaxis and prevention of fungal infections in high-risk patient populations. This includes preemptive antifungal therapy in patients undergoing solid organ transplantation or hematopoietic stem cell transplantation as well as antifungal prophylaxis in critically ill patients admitted to intensive care units. Prophylactic use of antifungal agents aims to reduce the occurrence of invasive fungal infections, morbidity and mortality associated with these infections. Advances in molecular diagnostics and genomics have paved the way for targeted antifungal therapy and personalized medicine approaches. Rapid identification of fungal pathogens, detection of antifungal resistance markers, and assessment of host susceptibility factors enable clinicians to tailor antifungal treatment regimens to individual patients. This precision medicine strategy optimizes therapeutic outcomes, minimizes undesirable effects and reduces the risk of treatment failure or relapse.

4.1. Antifungal properties of herbs

Herbs have been used for centuries in ancient medicine systems worldwide for their antifungal properties. These natural remedies offer an alternative or complementary approach to conventional antifungal agents, providing a source of bioactive compounds with broad-spectrum activity against fungal pathogens. Many herbs exhibit broad-spectrum antifungal activity against range of fungal pathogens including yeasts, molds and dermatophytes. These herbs can target different stages of the fungal life cycle, including spore germination, hyphal growth and biofilm formation, making them effective against various types of fungal infections. Herbs contain a diverse array of bioactive compounds that contribute to their antifungal properties. These compounds include phenolic compounds, flavonoids, alkaloids, terpenoids, essential oils and polyphenols, among others. Each of these compounds may exert antifungal effects through different mechanisms of action such as disrupting fungal cell membranes, inhibiting fungal enzyme activity, or interfering with fungal cell wall synthesis. Several herbs are well-known for their antifungal properties and have been used anciently to treat fungal infections (Table 2).

Table 2 Plant and plant products having antifungal activity

Plant and Plant Product	**Compounds**	**Antifungal Activity**	**References**
Amla (*Emblica officinalis*)	__	Dermatophyte fungi including *Trichophyton rubrum* and *Trichophyton mentagrophytes*	Ahmed and Nahor, 2012
Garlic (*Allium sativum*)	Allicin	*Candida* species and dermatophytes	Suleiman and Abdallah, 2014
Olive leaf (*Olea Europaea*)	__	*Candida albicans, Candida glabrata, Candida tropicalis and Candida krusei*	Shialy *et al*., 2015
Neem (*Azadirachta indica*)	Azadirachtin and Nimbin	Skin infections and fungal diseases	Alzohairy, 2016
Goldenseal (*Hydrastis canadansis*)	Berberine	*Candida* and *Cryptococcus neoformans* strains, as well as against biofilm producers	Silva *et al*., 2016
Black Walnut (*Juglans nigra*)	Juglone	*Alternaria alternata, Rhizoctonia solani, Botrytis cinerea, Fusarium culmorum* and *Phytophthora infestans*	Wianowska *et al*., 2016
Tea Tree Oil (*Melaleuca alternifolia*)	Terpinen-4-ol	Topically used to treat fungal skin infections such as athlete's foot and nail fungus	Mumu, 2017
Brahmi (*Bacopa monnieri*)	Oil	*Candida albicans* and reported potent fungicidal effects	Mkk and Irfan, 2019
Turmeric (*Curcuma longa*)	Curcumin	*Candida albicans* and reported potent inhibitory effects on fungal growth and biofilm producers	Murugesh *et al*., 2019
Oregano (*Origanum vulgare*)	Carvacrol and Thymol	*Candida* species and other fungal pathogens	Baj, 2020
Guduchi (*Tinospora cordifolia*)	__	*Candida albicans* and reported significant inhibition of fungal growth and biofilm producers	Hsu *et al*., 2021
Cinnamon (*Cinnamomum verum*)	Oil	*Phytophthora Cococasia*	Hong *et al*., 2021

Antifungal herbs can be used both topically and systemically to treat fungal infections. Topical application of herbal preparations such as creams, ointments or essential oil formulations can target localized infections on the skin, nails or mucous membranes. Systemic use of antifungal herbs may involve oral consumption of herbal supplements, teas or

tinctures to address systemic fungal infections or support immune function. Herbal combinations or formulations may possess synergistic effects where the combined action of multiple herbs increases their overall antifungal activity. Traditional medicine systems often utilize herbal combinations based on synergistic principles to optimize therapeutic outcomes and minimize adverse effects. For example, combining garlic with tea tree oil or oregano oil may enhance their antifungal effects against certain fungal pathogens. Herbal antifungal agents are generally well-tolerated and have less adverse effects compared to conventional antifungal drugs. Though it is essential to use herbs safely and responsibly as some individuals may experience allergic reactions or other side effects. Consulting with a healthcare professional or qualified herbalist is recommended especially for individuals with pre-existing medical conditions or those taking medications.

4.2. Recent studies and discoveries

Recent research in the field of antifungal activities has yielded valuable insights into novel therapeutic agents, mechanisms of action and strategies for combating fungal infections. Researchers have identified several novel compounds with potent antifungal activity from natural sources, synthetic libraries and microbial extracts. Peptide-based therapeutics has emerged as potential candidates for the treatment of fungal infections due to their broad-spectrum activity and low likelihood of resistance development. Recent research has emphasized on the development and optimization of antifungal peptides derived from natural sources or designed de novo. For example, a study published in "ACS Infectious Diseases" described the design and synthesis of a novel antifungal peptide, PAF104, with potent activity against *Candida* species and *Cryptococcus neoformans* (Gangia *et al*., 2019).

Synergistic interactions between antifungal agents and other compounds enhance their efficacy and overcome resistance mechanisms. In 2021, a research study explored the synergistic effects of combining fluconazole, a widely used antifungal drug with honokiol, a natural compound derived from Magnolia officinalis. This combination therapy demonstrated improved antifungal activity against fluconazole-resistant isolates of Candida albicans, indicating a potential approach for overcoming antifungal resistance (Trifan *et al*., 2021). Nanotechnology-based approaches have been utilized to enhance the delivery and efficacy of plant based antifungal agents. In recent studies, there has been a strong emphasis on creating nanoformulations including lipid nanoparticles, polymeric nanoparticles and nanosuspensions to encapsulate and precisely deliver antifungal drugs**.** These nanocarrier systems improve drug solubility, stability and bioavailability leading to enhanced antifungal activity and reduced toxicity (Saka and Chella, 2021).

4.3. Potential applications in fungal infections treatment

Recent scientific breakthroughs in antifungal research have revealed novel therapeutic agents, their modes of action, and their potential impact on treating fungal infections. These findings are crucial for healthcare professionals and policymakers, particularly as antifungal resistance continues to rise, necessitating alternative treatment strategies**.** Advances in drug innovation and development have led to the identification of novel antifungal compounds with potent activity against resistant fungal pathogens. For example, recent studies have highlighted the antifungal properties of natural products such as plant-derived compounds, marine-derived peptides, and fungal metabolites. These novel compounds offer promising candidates for the creation of new antifungal therapies with improved efficacy and safety profiles.

5. Exploration of anticancer agents

The exploration of anticancerous agents represents a crucial aspect of oncology research, aiming to discover novel therapeutic compounds, elucidate mechanisms of action, and develop effective treatments for cancer. Anticancer agents encompass a diverse range of drugs and therapies designed to target cancerous cells while reducing harm to healthy tissues. Oncology researchers continuously explore novel compounds and therapeutic strategies to combat cancer. This includes screening natural products, synthesizing small molecules, and repurposing existing drugs for anticancer activity. High-throughput screening methods, molecular modeling techniques, and structure-activity relationship studies play vital roles in identifying potential anticancer agents with specific molecular targets or mechanisms of action. Understanding the mechanisms of action of anticancer agents is essential for optimizing their efficacy and minimizing adverse effects. Anticancer drugs may target various hallmarks of cancer such as uncontrolled cell growth, angiogenesis, metastasis and evasion of apoptosis. Common mechanisms of action include DNA damage, inhibition of cell cycle progression, disruption of signaling pathways, induction of apoptosis, and modulation of the tumor microenvironment. Using medications that specifically target particular molecules or pathways involved in the growth of cancer is known as targeted therapy. These molecular targets may include receptor tyrosine kinases, growth factor receptors, angiogenic factors or intracellular signaling proteins. Targeted anticancer agents such as monoclonal

antibodies and small molecule inhibitors offer the potential for more precise and personalized treatment approaches, reducing off-target effects and improving therapeutic outcomes.

Immunotherapy enables the immune system to identify and eliminate cancer cells. Immune checkpoint inhibitors, adoptive cell therapies, cancer vaccines and immune modulators are among the various immunotherapeutic approaches used in cancer treatment. These agents work by enhancing immune responses against tumors, overcoming immune evasion mechanisms and inducing long-lasting antitumor immunity. Immunotherapy has completely changed the way that cancer is treated, improving survival rates and producing long-lasting effects in some cases of cancer. Chemotherapy remains a cornerstone of cancer treatment, utilizing cytotoxic drugs to kill rapidly dividing cancer cells. While traditional chemotherapy agents have significant toxicities and adverse effects, recent advancements have focused on developing more targeted and less toxic chemotherapy regimens. Combination chemotherapy, dose optimization and drug delivery technologies are among the strategies employed to enhance the efficacy and tolerability of chemotherapy while minimizing side effects.

Natural products including plant-derived compounds, marine extracts and microbial metabolites represent a valuable source of potential anticancer agents. Traditional herbal medicines and botanical extracts have been used for centuries in various cultures for their purported anticancer properties. Bioactive substances having anticancer potential found in natural sources, such as vinca alkaloids, taxanes and camptothecins have been discovered recently. These compounds can be used as lead compounds in drug development**.** Resistance to anticancer agents remains a major obstacle in cancer treatment, leading to treatment failure and disease progression. Researchers investigate the molecular mechanisms underlying drug resistance, including genetic mutations, drug efflux pumps and adaptive signaling pathways. Strategies to overcome resistance include combination therapies, targeted drug delivery systems, and the development of next-generation anticancer agents with improved efficacy against resistant tumors. Clinical trials are essential in assessing the safety and efficacy of novel anticancer agents in human subjects. Translational research bridges the gap between preclinical studies and clinical practice, translating scientific discoveries into clinically meaningful interventions. Phase I, II and III clinical trials assess the pharmacokinetics, safety and therapeutic efficacy of anticancer agents, guiding their development and regulatory approval for cancer treatment.

5.1. Anticancer properties of herbs

Since ancient times, herbs have been valued in traditional medicine systems for their potential anticancer properties. Research into the anticancer properties of herbs has gained significant attention due to their diverse bioactive compounds and potential as complementary or alternative treatments to conventional cancer therapies. Many herbs possess potent antioxidant properties due to the existence of bioactive compounds such as polyphenols, flavonoids and carotenoids. Antioxidants neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is implicated in cancer development and progression. By scavenging free radicals and protecting cells from oxidative damage, antioxidant-rich herbs may prevent DNA mutations and inhibit tumor initiation. Chronic inflammation has a crucial function in carcinogenesis by promoting tumor growth, angiogenesis and metastasis. Several herbs exhibit anti-inflammatory effects by inhibiting pro-inflammatory cytokines, enzymes (such as cyclooxygenase-2) and signaling pathways involved in inflammation-mediated cancer progression. By modulating the inflammatory response, these herbs may suppress tumor-promoting processes and enhance the body's immune surveillance against cancer cells. Apoptosis or programmed cell death, is a natural process that regulates cell proliferation and eliminates damaged or abnormal cells.

One of the characteristics of cancer is the dysregulation of apoptosis, which enables cancer cells to avoid dying and multiply uncontrollably. Certain herbs contain bioactive compounds that can induce apoptosis in cancer cells by activating apoptotic pathways, such as the intrinsic (mitochondrial) or extrinsic (death receptor) pathways. Inducing apoptosis in cancer cells can inhibit tumor growth and promote their elimination by the immune system. Angiogenesis is necessary for tumor growth and metastasis as tumors require a blood supply to receive nutrients and oxygen. Several herbs contain compounds that stop the formation of new blood vessels by going after pro-angiogenic elements like matrix metalloproteinases (MMPs) and vascular endothelial growth factor (VEGF).By inhibiting angiogenesis, these herbs can disrupt tumor blood supply, inhibit tumor growth and prevent metastasis.

Herbs can modulate the immune system to enhance antitumor immune responses and suppress tumor immune evasion mechanisms. Certain herbs contain immunomodulatory compounds that stimulate immune cells such as natural killer (NK) cells, T cells and macrophages to recognize and eliminate cancer cells. These herbs may strengthen the body's natural defenses against cancer by enhancing immune surveillance and promoting immune-mediated tumor cell death. Metastasis is the process of cancer cells spreading from the original tumor to distant organs, significantly contributes to cancer-related deaths. Some herbs exhibit antimetastatic properties by inhibiting key processes partispating in

metastasis like cell adhesion, migration, invasion and epithelial-mesenchymal transition (EMT). By interfering with these processes, these herbs can impede the spread of cancer cells and reduce the likelihood of metastatic colonization in distant organs. Uncontrolled cell proliferation is indicative of cancer, contributing to tumor growth and progression. Certain herbs contain bioactive compounds that exert anti-proliferative effects by inhibiting cell cycle progression, DNA synthesis, or growth factor signaling pathways involved in cell proliferation. These herbs can suppress tumor cell proliferation and slow down tumor progression by arresting cell growth and inducing cytostatic effects. Some herbs have demonstrated to enhance the sensitivity of cancer cells to conventional chemotherapy or radiotherapy.

These herbs may act synergistically with anticancer drugs to potentiate their cytotoxic effects, overcome drug resistance or reduce chemotherapy-induced toxicity. By enhancing drug sensitivity, these herbs can improve treatment outcomes and reduce the required dosage of conventional anticancer therapies. Several herbs are well-known for their anticancerous properties and have been used traditionally for the treatment of cancer development (Table 3).

Table 3 Plant and plant products showing anticancer activity

Plant and Plant Product	**Compounds**	**Anticancer Activity**	**References**
Kokum (Garcinia indica)	Hydroxycitric acid (HCA) and garcinol	Show remarkable result in inhibiting cancer	Pan *et al.,* 2001 and Hong *et al.,* 2007
Sang Ji Sheng (Loranthus parasiticus)	Viscotoxin and lectins	Used for its anticancerous effect	Powell *et al.,* 2003
Lingnan Garcinia (Garcinia oblongifolia)	Garcinol, xanthochymol, isoxanthochymol and guttiferone K	Demonstrates anticancer potential	Hemshekhar *et al.,* 2011
Chinese Sheshecao (Hedyotis diffusa)	Oridonin	Exhibits anticancer properties	Wu *et al.,* 2013
Turmeric (*Curcuma longa*)	Curcumin	Modulate multiple signaling pathways participating in cancer development and progression	Verma *et al*., 2018
Dhamasa (Fagonia indica)	__	Induces apoptosis in cancer cells; used traditionally for anticancer properties	Rajput *et al.,* 2018
Sweet Wormwood (*Artemisia annua*)	Artesunate	Effective anticancer compound	Khan *et al*., 2019
Ginseng (*Panax ginseng*)	Ginseng	Ginsenosides may inhibit cancer cell proliferation induce apoptosis and modulate immune function and tumor microenvironment	Zhang *et al*., 2019
Green tea (*Camellia sinensis*)	Polyphenol epigallocatechin gallate (EGCG)	Suppress the growth of cancer cells, induce apoptosis, and inhibit angiogenesis	Almatroodi *et al*., 2020
Ginger (*Zingiber officinale*)	Gingerol and Parado	Inhibit cancer cell growth, induce apoptosis and suppress inflammation and angiogenesis	Shanmugan *et al.*, 2022
Tea plant (Camellia sinensis)	__	LC-540 Leydig Cell Testicular Tumor Cell Line (rats)	Bhardwaj and Thakur, 2022
Red sage (lantana camara)	__	LC-540 Leydig Cell Testicular Tumor Cell Line (rats)	Bhardwaj and Thakur, 2022

Himalayan cedar (Cedrus deodara)	__	LC-540 Leydig Cell Testicular Tumor Cell Line (rats)	Bhardwaj and Thakur, 2022

5.2. Potential applications as anticancer treatment

The potential of herbs as sources of innovative therapeutic agents for the treatment of cancer has been brought to light by recent advances in our understanding of their anticancer effects. The main goals of research have been to discover bioactive substances, clarify the molecular mechanisms of action and investigate potential synergies with traditional cancer treatments. Studies have elucidated the diverse mechanisms by which herbs exert their anticancer effects. These mechanisms include inducing apoptosis (programmed cell death), inhibiting cell proliferation, suppressing angiogenesis (blood vessel formation), modulating immune responses and interfering with signaling pathways involved in cancer progression and metastasis. For example, herbs such as curcumin from turmeric (Curcuma longa) have been shown to inhibit the NF-κB pathway, which plays a crucial role in inflammation and cancer development (Zoi *et al*., 2021). Advances in molecular biology and pharmacology have made it possible for researchers to determine specific molecular targets within cancer cells that can be modulated by herbal compounds. Targeted anticancer therapy aims to selectively disrupt signaling pathways or cellular processes that are aberrantly activated in cancer cells while sparing normal cells. For instance, resveratrol, a polyphenol found in grapes and berries has demonstrated to inhibit the PI3K/AKT/mTOR pathway, which is frequently dysregulated in cancer (Khan *et al*., 2020). Herbs have been found to exhibit immunomodulatory effects that enhance the body's immune response against cancer cells. Compounds derived from herbs such as *Astragalus membranaceus* and *Ganoderma lucidum* (reishi mushroom) have been shown to stimulate immune cell activity, promote cytokine production and enhance natural killer (NK) cell-mediated cytotoxicity against cancer cells. These immunomodulatory effects are being investigated as potential adjuvant therapies for cancer immunotherapy (Yue *et al*., 2021).

Angiogenesis is a critical process involved in tumor growth and metastasis, and herbs have been found to possess antiangiogenic properties that inhibit blood vessel formation within tumors. Compounds such as epigallocatechin gallate (EGCG) from green tea (*Camellia sinensis*) and quercetin from onions (*Allium cepa*) have been shown to inhibit angiogenesis by targeting endothelial cell proliferation, migration and tube formation. These antiangiogenic effects may help to suppress tumor growth and prevent metastasis (Sun *et al*., 2015). Advances in screening technologies and bioinformatics have facilitated the screening of large libraries of natural products derived from herbs for their anticancer activity. High-throughput screening assays and computational modeling techniques allow researchers to identify bioactive compounds with specific anticancer properties such as cytotoxicity against cancer cells or inhibition of oncogenic signaling pathways (Kalimuthu *et al*., 2021). These screening approaches have led to the discovery of novel anticancer agents and potential drug candidates for further development. Combination treatments involving herbs and standard anticancer drugs have been shown to enhance therapeutic efficacy, reduce drug resistance and mitigate treatment-related side effects. For example, curcumin has been found to enhance the sensitivity of cancer cells to chemotherapy drugs such as paclitaxel and cisplatin leading to improved treatment outcomes (Hussain *et al*., 2021).

6. Challenges

One of the significant challenges in herbal medicine is the lack of standardization in herbal products. Variability in the composition and potency of herbal preparations can affect their efficacy, safety and reproducibility. Standardization of herbal products is vital to ensure consistency in quality and dosage. While traditional knowledge supports the use of many herbs for various health conditions, there is often a lack of robust scientific evidence from well-designed clinical trials. Limited funding for herbal research, methodological challenges, and publication limits the high-quality evidences which support the efficacy of herbal interventions. Herbal products can act together with prescription medications, potentially leading to adverse effects or reduced efficacy of conventional treatments. However, comprehensive information on herb-drug interactions is often lacking, making it challenging for healthcare professionals to assess the safety of combining herbal and pharmaceutical therapies. Herbal products are subject to varying regulatory frameworks across different countries, leading to inconsistencies in quality standards, labeling requirements and safety monitoring. Regulatory challenges, including the lack of standardized regulations for herbal supplements and traditional herbal medicines, pose barriers to ensuring product safety and efficacy. Many medicinal herbs are harvested from wild populations, leading to concerns about overharvesting, habitat destruction, and loss of biodiversity. Unsustainable harvesting practices and environmental degradation threaten the long-term availability of medicinal plants and compromise their medicinal properties.

7. Conclusion

Herbal medicine represents a rich source of therapeutic compounds with the potential to address a wide range of health conditions. Throughout history, diverse cultures have relied on traditional knowledge and practices to harness the healing properties of medicinal plants. Today, modern scientific research is uncovering the pharmacological mechanisms of action underlying the efficacy of herbal medicines, validating their traditional uses, and identifying novel therapeutic compounds. Despite the promising potential of herbal medicine, several challenges remain, including standardization, safety concerns, regulatory issues and the need for more rigorous scientific evidence. Addressing these challenges requires collaborative efforts between traditional knowledge holders, researchers, healthcare professionals, policymakers and industry stakeholders. Future research directions in herbal medicine will focus on identifying bioactive compounds, elucidating mechanisms of action, conducting clinical trials, and optimizing formulations for improved efficacy and safety. Integrating traditional knowledge with modern science offers a holistic approach to healthcare that recognizes the interconnectedness of human health, the environment and cultural heritage. By embracing interdisciplinary collaboration, promoting evidence-based practices and fostering sustainability, we can unlock the full potential of herbal medicine to promote health and contribute to a more equitable and sustainable future for all.

Compliance with ethical standard's

Acknowledgement

The authors would like to express their gratitude to the Department of Microbiology, Himachal Pradesh University, Shimla, for their support in conducting this study. We also acknowledge the contributions of the Department of Botany, Himachal Pradesh University and Culture & Drug Susceptibility Testing Laboratory for Tuberculosis, Department of Microbiology, Indira Gandhi Medical College, Shimla (Himachal Pradesh) for providing necessary information in writing the article. Additionally, we appreciate the support of our colleagues for their valuable discussions and insights.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abraham, J., & Florentine, S. (2021). Licorice (Glycyrrhiza glabra) extracts-suitable pharmacological interventions for COVID-19. A review. Plants, 10(12), 2600.

[2] Ahmed, H. M., Nabavi, S., & Behzad, S. (2021). Herbal drugs and natural products in the light of nanotechnology and nanomedicine for developing drug formulations. Mini Reviews in Medicinal Chemistry, 21(3), 302-313.

[3] Ahmed, N., Karobari, M. I., Yousaf, A., Mohamed, R. N., Arshad, S., Basheer, S. N.,& Yean, C. Y. (2022). The antimicrobial efficacy against selective oral microbes, antioxidant activity and preliminary phytochemical screening of Zingiber officinale. Infection and Drug Resistance, 2773-2785.

[4] Ahmed, Z., & Nahor, U. (2012). Benificial Uses and Antimicrobial Activity of Phyllanthus Emblica, Achyranthes Aspera and Allium Sativum-A Mini Review. IOSR Journal of Pharmacy and Biological Sciences, 3(4), 28-32.

[5] Aljaafari, M. N., AlAli, A. O., Baqais, L., Alqubaisy, M., AlAli, M., Molouki, A., & Lim, S. H. E. (2021). An overview of the potential therapeutic applications of essential oils. Molecules, 26(3), 628.

[6] Almasaudi, S. (2021). The antibacterial activities of honey. Saudi journal of biological sciences, 28(4), 2188-2196.

[7] Almatroodi, S. A., Almatroudi, A., Khan, A. A., Alhumaydhi, F. A., Alsahli, M. A., & Rahmani, A. H. (2020). Potential therapeutic targets of epigallocatechin gallate (EGCG), the most abundant catechin in green tea, and its role in the therapy of various types of cancer. Molecules, 25(14), 3146.

[8] Alzohairy, M. A. (2016). Therapeutics role of Azadirachta indica (Neem) and their active constituents in diseases prevention and treatment. Evidence-Based Complementary and Alternative Medicine, 2016.

[9] Anand, A. K. (2024). CEREMONIAL AND RITUAL PLANTS OF INDIA: The Shubh-Labh Connections Between Spirituality And Science. Blue Rose Publishers.

[10] Anand, U., Jacobo-Herrera, N., Altemimi, A., & Lakhssassi, N. (2019). A comprehensive review on medicinal plants as antimicrobial therapeutics: potential avenues of biocompatible drug discovery. Metabolites, 9(11), 258.

[11] Badr, M. M., Taktak, N. E., & Badawy, M. E. (2023). Comparison of the antimicrobial and antioxidant activities of tea tree (Melaleuca alternifolia) oil and its main component terpinen-4-ol with their nanoemulsions. Egyptian Journal of Chemistry, 66(2), 111-120.

[12] Baj, T., Biernasiuk, A., Wrobel, R., & Malm, A. (2020). Chemical composition and in vitro activity of Origanum vulgare L., Satureja hortensis L., Thymus serpyllum L. and Thymus vulgaris L. essential oils towards oral isolates of Candida albicans and Candida glabrata. Open Chemistry, 18(1), 108-118.

[13] Ben Abdallah, F., Lagha, R., & Gaber, A. (2020). Biofilm inhibition and eradication properties of medicinal plant essential oils against methicillin-resistant Staphylococcus aureus clinical isolates. Pharmaceuticals, 13(11), 369.

[14] Bhardwaj, P., & Thakur, S. (2022). In vitro anticancer activity of medicinal plants of Himalayan region. Indian Journal of Traditional Knowledge, 21(2), 269-275.

[15] Cutler, R. R., & Wilson, P. (2004). Antibacterial activity of a new, stable, aqueous extract of allicin against methicillin-resistant Staphylococcus aureus. British journal of biomedical science, 61(2), 71-74.

[16] da Silva, A. R., de Andrade Neto, J. B., da Silva, C. R., Campos, R. D. S., Costa Silva, R. A., Freitas, D. D., & Nobre Junior, H. V. (2016). Berberine antifungal activity in fluconazole-resistant pathogenic yeasts: action mechanism evaluated by flow cytometry and biofilm growth inhibition in Candida spp. Antimicrobial agents and chemotherapy, 60(6), 3551-3557.

[17] Dogan, K., Erol, E., Didem Orhan, M., Degirmenci, Z., Kan, T., Gungor, A., & Guzel, M. (2022). Instant determination of the artemisinin from various Artemisia annua L. extracts by LC-ESI-MS/MS and their in-silico modelling and in vitro antiviral activity studies against SARS-CoV-2. Phytochemical Analysis, 33(2), 303-319.

[18] Gandia, M., Garrigues, S., Hernanz-Koers, M., Manzanares, P., & Marcos, J. F. (2019). Differential roles, crosstalk and response to the antifungal protein AfpB in the three mitogen-activated protein kinases (MAPK) pathways of the citrus postharvest pathogen Penicillium digitatum. Fungal genetics and biology, 124, 17-28.

[19] Gowans, S. (2004). Ayurveda for Health & Well-Being. Jaico Publishing House.

[20] Gupta, P. K., Kulkarni, S., & Rajan, R. (2013). Inhibition of intracellular survival of multi drug resistant clinical isolates of Mycobacterium tuberculosis in macrophages by curcumin. The Open Antimicrobial Agents Journal, 4(1).

[21] Gupta, P., Sharma, V. K., & Sharma, S. (2014). Healing traditions of the Northwestern Himalayas. Springer India.

[22] Hemshekhar, M., Sunitha, K., Santhosh, M. S., Devaraja, S., Kemparaju, K., Vishwanath, B. S., & Girish, K. S. (2011). An overview on genus Garcinia: phytochemical and therapeutical aspects. Phytochemistry Reviews, 10, 325-351.

[23] Hong, J., Kwon, S. J., Sang, S., Ju, J., Zhou, J. N., Ho, C. T., & Yang, C. S. (2007). Effects of garcinol and its derivatives on intestinal cell growth: Inhibitory effects and autoxidation-dependent growth-stimulatory effects. Free Radical Biology and Medicine, 42(8), 1211-1221.

[24] Hong, Z., Talib, K. M., Mujtaba, K. G., Dabin, H., Yahya, F., Congying, Z., & Fukai, W. (2021). Antifungal potential of cinnamon essential oils against Phytophthora colocasiae causing taro leaf blight. Chemical and Biological Technologies in Agriculture, 8, 1-9.

[25] Hsu, H., Sheth, C. C., & Veses, V. (2021). Herbal extracts with antifungal activity against Candida albicans: A systematic review. Mini reviews in medicinal chemistry, 21(1), 90-117.

[26] Hussain, Y., Islam, L., Khan, H., Filosa, R., Aschner, M., & Javed, S. (2021). Curcumin–cisplatin chemotherapy: A novel strategy in promoting chemotherapy efficacy and reducing side effects. Phytotherapy Research, 35(12), 6514-6529.

[27] Inglis, K. (2012). Ayurveda: Asian Secrets of Wellness, Beauty and Balance. Tuttle Publishing.

[28] Jacob, D. E., Nelson, I. U., & Izah, S. C. (2023). Healing Trails: Integrating Medicinal Plant Walks into Recreational Development. In Herbal Medicine Phytochemistry: Applications and Trends (pp. 1-53). Cham: Springer International Publishing.

[29] Jain, A., Mehta, A., Jain, S., & Saxena, G. (2022). Antimicrobial activity of Tulsi (Ocimum sanctum Linn): A systematic review. International Journal of Research in Ayurveda Pharmacy, 13, 172-5.

[30] Kalimuthu, A. K., Panneerselvam, T., Pavadai, P., Pandian, S. R. K., Sundar, K., Murugesan, S., & Kunjiappan, S. (2021). Pharmacoinformatics-based investigation of bioactive compounds of Rasam (South Indian recipe) against human cancer. Scientific reports, 11(1), 21488.

[31] Karakaya, S., El, S. N., Karagozlu, N., &Sahin, S. (2011). Antioxidant and antimicrobial activities of essential oils obtained from oregano (Origanum vulgare ssp. hirtum) by using different extraction methods. Journal of medicinal food, 14(6), 645-652.

[32] Khan, K., Quispe, C., Javed, Z., Iqbal, M. J., Sadia, H., Raza, S., & Sharifi-Rad, J. (2020). Resveratrol, curcumin, paclitaxel and miRNAs mediated regulation of PI3K/Akt/mTOR pathway: go four better to treat bladder cancer. Cancer Cell International, 20(1), 560.

[33] Khan, T., Ali, M., Khan, A., Nisar, P., Jan, S. A., Afridi, S., & Shinwari, Z. K. (2019). Anticancer plants: A review of the active phytochemicals, applications in animal models and regulatory aspects. Biomolecules, 10(1), 47.

[34] Khayam, A. U., Patel, H., Faiola, N. A., Figueroa Milla, A. E., Dilshad, E., Mirza, B., ... & Sheikh, M. S. (2020). Quinovic acid purified from medicinal plant Fagonia indica mediates anticancer effects via death receptor 5. Molecular and Cellular Biochemistry, 474, 159-169.

[35] Li, J., Li, C., Shi, C., Aliakbarlu, J., Cui, H., & Lin, L. (2022). Antibacterial mechanisms of clove essential oil against Staphylococcus aureus and its application in pork. International Journal of Food Microbiology, 380, 109864.

[36] Mkk, F., Sp, D., & Irfan, M. (2019). Antibacterial and antifungal activity of various extracts of Bacopa monnieri. arXiv preprint arXiv:1909.01856.

[37] Mumu, S. K. (2017). Antimicrobial activity of Tea Tree oil (Melaleuca alternifolia) against skin infection causing bacteria and comparison of its effectiveness with that of the Eucalyptus oil, Lemongrass oil and conventional antibiotics (Doctoral dissertation, BRAC University).

[38] Murugesh, J., Annigeri, R. G., Mangala, G. K., Mythily, P. H., & Chandrakala, J. (2019). Evaluation of the antifungal efficacy of different concentrations of Curcuma longa on Candida albicans: An: in vitro: study. Journal of Oral and Maxillofacial Pathology, 23(2), 305.

[39] Nicolescu, V. N., Redei, K., Vor, T., Bastien, J. C., Brus, R., Bencať, T.,& Stefancik, I. (2020). A review of black walnut (Juglans nigra L.) ecology and management in Europe. Trees, 34, 1087-1112.

[40] Ogal, M., Johnston, S. L., Klein, P., & Schoop, R. (2021). Echinacea reduces antibiotic usage in children through respiratory tract infection prevention: a randomized, blinded, controlled clinical trial. European journal of medical research, 26, 1-9.

[41] Ospina Salazar, D. I., Hoyos Sanchez, R. A., Orozco Sanchez, F., Arango Arteaga, M., & Gomez Londono, L. F. (2015). Antifungal activity of neem (Azadirachta indica: Meliaceae) extracts against dermatophytes. Acta Biologica Colombiana, 20(3), 181-192.

[42] Pan, M. H., Chang, W. L., Lin-Shiau, S. Y., Ho, C. T., & Lin, J. K. (2001). Induction of apoptosis by garcinol and curcumin through cytochrome c release and activation of caspases in human leukemia HL-60 cells. Journal of agricultural and food chemistry, 49(3), 1464-1474.

[43] Pan, S. Y., Litscher, G., Gao, S. H., Zhou, S. F., Yu, Z. L., Chen, H. Q.,& Ko, K. M. (2014). Historical perspective of traditional indigenous medical practices: the current renaissance and conservation of herbal resources. Evidence-based complementary and alternative medicine, 2014.

[44] Pasha, M. R., & Islam, S. A. (2021). Antimicrobial efficacy of Terminalia chebula (Haritaki) ethanol extracts against Escherichia coli and Salmonella isolated from commercial broiler. Bangladesh Journal of Veterinary and Animal Sciences, 9(2).

[45] Powell, C. B., Fung, P., Jackson, J., Dall'Era, J., Lewkowicz, D., Cohen, I., & Smith-McCune, K. (2003). Aqueous extract of herba Scutellaria barbatae, a Chinese herb used for ovarian cancer, induces apoptosis of ovarian cancer cell lines. Gynecologic Oncology, 91(2), 332-340.

[46] Saka, R., & Chella, N. (2021). Nanotechnology for delivery of natural therapeutic substances: a review. Environmental Chemistry Letters, 19(2), 1097-1106.

[47] Shanmugam, K. R., Shanmugam, B., Venkatasubbaiah, G., Ravi, S., & Reddy, K. S. (2022). Recent Updates on the Bioactive Compounds of Ginger (Zingiber officinale) on Cancer: A Study with Special Emphasis of Gingerol and Its Anticancer Potential: Effect of Ginger and Its Compounds in Cancer Subjects. In Handbook of Oxidative Stress in Cancer: Therapeutic Aspects (pp. 1-18). Singapore: Springer Nature Singapore.

[48] Shialy, Z., Zarrin, M., Nejad, B. S., & Naanaie, S. Y. (2015). In vitro antifungal properties of Pistacia atlantica and olive extracts on different fungal species. Current medical mycology, 1(4), 40.

[49] Soni, R., Shankar, G., Mukhopadhyay, P., & Gupta, V. (2022). A concise review on Artemisia annua L.: A major source of diverse medicinal compounds. Industrial Crops and Products, 184, 115072.

[50] Suleiman, E. A., & Abdallah, W. B. (2014). In vitro activity of garlic (Allium sativum) on some pathogenic fungi.

[51] Sun, Q., Heilmann, J., & Konig, B. (2015). Natural phenolic metabolites with anti-angiogenic properties–a review from the chemical point of view. Beilstein journal of organic chemistry, 11(1), 249-264.

[52] Tariq, S., Wani, S., Rasool, W., Shafi, K., Bhat, M. A., Prabhakar, A.,& Rather, M. A. (2019). A comprehensive review of the antibacterial, antifungal and antiviral potential of essential oils and their chemical constituents against drug-resistant microbial pathogens. Microbial pathogenesis, 134, 103580.

[53] Torabian, G., Valtchev, P., Adil, Q., & Dehghani, F. (2019). Anti-influenza activity of elderberry (Sambucus nigra). Journal of functional foods, 54, 353-360.

[54] Trifan, A., Bostanaru, A. C., Luca, S. V., Temml, V., Akram, M., Herdlinger, S., & Schuster, D. (2021). Honokiol and magnolol: Insights into their antidermatophytic effects. Plants, 10(11), 2522.

[55] Vazquez-Ucha, J. C., Martinez-Guitian, M., Lasarte-Monterrubio, C., Conde-Perez, K., Arca-Suarez, J., Alvarez-Fraga, L., & Beceiro, A. (2020). Syzygium aromaticum (clove) and Thymus zygis (thyme) essential oils increase susceptibility to colistin in the nosocomial pathogens Acinetobacter baumannii and Klebsiellapneumoniae. Biomedicine and Pharmacotherapy, 130, 110606.

[56] Verma, R. K., Kumari, P., Maurya, R. K., Kumar, V., Verma, R. B., & Singh, R. K. (2018). Medicinal properties of turmeric (Curcuma longa L.): A review. International Journal of Chemical Studies, 6(4), 1354-1357.

[57] Wianowska, D., Garbaczewska, S., Cieniecka-Roslonkiewicz, A., Dawidowicz, A. L., & Jankowska, A. (2016). Comparison of antifungal activity of extracts from different Juglans regia cultivars and juglone. Microbial Pathogenesis, 100, 263-267.

[58] WU, Z., Jin, C., LI, J., Chen, X., Yao, Q., & Zhu, Q. (2013). Inhibition of colon cancer cells by ethanol extract of Oldenlandia diffusa. Journal of Kunming Medical University, 31-34.

[59] Yue, G. G. L., Lau, C. B. S., & Leung, P. C. (2021). Medicinal plants and mushrooms with immunomodulatory and anticancer properties—a review on Hong Kong's experience. Molecules, 26(8), 2173.

[60] Zhang, Y., Qiu, Z., Qiu, Y., Su, T., Qu, P., & Jia, A. (2019). Functional regulation of ginsenosides on myeloid immunosuppressive cells in the tumor microenvironment. Integrative Cancer Therapies, 18, 1534735419886655.

[61] Zoi, V., Galani, V., Lianos, G. D., Voulgaris, S., Kyritsis, A. P., & Alexiou, G. A. (2021). The role of curcumin in cancer treatment. Biomedicines, 9(9), 1086