

Exploring Antimicrobial, Antioxidant, and Anticancer Activities in Medicinal Plants: A Review

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Abstract

This review investigates the antimicrobial, antioxidant, and anticancer potentials of medicinal plants through the evaluation of both crude extracts and purified compounds. Medicinal plants have long been recognized for their diverse bioactive components, which offer promising therapeutic benefits. The antimicrobial activity of these plants involves inhibiting the growth of various pathogens, contributing to their traditional medicinal uses in treating infections. Additionally, their antioxidant properties help mitigate oxidative stress by scavenging free radicals, which is crucial for preventing chronic diseases and aging-related conditions. Furthermore, medicinal plants exhibit anticancer activities through mechanisms that include inducing apoptosis, inhibiting cell proliferation, and exerting antioxidant effects that protect against carcinogenesis. This review synthesizes current research findings to provide a comprehensive analysis of the bioactive potential of medicinal plants. By examining both crude extracts and purified compounds, it highlights their efficacy and potential applications in pharmaceutical and nutraceutical industries. Understanding these properties not only underscores the importance of traditional medicine but also encourages further exploration and development of natural remedies for modern healthcare challenges.

Introduction

Medicinal plants have been integral to traditional medicine systems worldwide for centuries, offering a vast array of bioactive compounds with therapeutic potential. Among their notable properties are antimicrobial, antioxidant, and anticancer activities, which have garnered significant attention in both scientific research and clinical practice. This introduction explores the multifaceted roles of medicinal plants in healthcare, focusing on their ability to combat microbial infections, neutralize oxidative stress, and potentially inhibit cancer growth.

Antimicrobial properties are crucial in the context of global health, particularly in the face of antibiotic resistance. Medicinal plants produce secondary metabolites such as alkaloids, terpenoids, and phenolic compounds that exhibit antimicrobial activity against a wide range of pathogens, including bacteria, fungi, and viruses. These natural compounds offer promising alternatives or complements to synthetic antibiotics, addressing the urgent need for new antimicrobial agents. The antioxidant capacity of medicinal plants plays a pivotal role in combating oxidative stress-induced damage. Oxidative stress results from an imbalance between free radicals and antioxidants in the body, contributing to chronic diseases like cardiovascular disorders, neurodegenerative conditions, and cancer. The rich antioxidant content of medicinal plants, including flavonoids, carotenoids, and polyphenols, helps scavenge free radicals and mitigate oxidative damage, thereby promoting overall health and longevity. Medicinal plants are increasingly recognized for their potential in cancer prevention and treatment. Studies have identified numerous plant-derived compounds with anticancer properties, such as apoptosis induction, cell cycle arrest, and inhibition of angiogenesis. These bioactive molecules not only target cancer cells directly but also enhance the body's natural defense mechanisms against tumorigenesis. This introduction sets the stage for a comprehensive review of current research on the antimicrobial, antioxidant, and anticancer activities of medicinal plants. By synthesizing existing knowledge and highlighting key findings, this review aims to elucidate the therapeutic potential of these natural remedies and inspire further exploration into their applications in modern medicine. Understanding and harnessing the bioactive properties of medicinal plants offer promising avenues for developing new pharmaceuticals, nutraceuticals, and complementary therapies to address diverse health challenges effectively.

Need of the Study

The study of antimicrobial, antioxidant, and anticancer activities in medicinal plants is essential for addressing critical healthcare challenges. In today's context of rising antibiotic resistance, medicinal plants offer a sustainable and diverse source of antimicrobial compounds that could potentially combat infections where conventional therapies fall short. Understanding the mechanisms and efficacy of these natural antimicrobial agents is crucial for developing new treatments and combating global health threats posed by resistant pathogens. The antioxidant properties found in medicinal plants play a pivotal role in protecting against oxidative stress-related diseases. With oxidative stress implicated in various chronic illnesses, including

cardiovascular diseases and neurodegenerative disorders, exploring plant-derived antioxidants can provide insights into preventive strategies and therapeutic interventions to improve public health outcomes. the exploration of medicinal plant extracts and compounds for their anticancer potential is equally significant. These natural agents have demonstrated diverse mechanisms of action, such as inducing apoptosis and inhibiting tumor growth pathways. Such discoveries not only contribute to expanding the arsenal of cancer treatments but also hold promise for developing adjunct therapies that enhance the effectiveness of existing treatments. validating the bioactive properties of medicinal plants through scientific study not only supports their traditional uses but also bridges the gap between traditional medicine and modern healthcare practices. This validation can inspire new pharmaceutical developments, with plant-derived compounds serving as potential lead molecules for drug discovery or as inspirations for developing analogs with enhanced efficacy and reduced side effects. investigating the antimicrobial, antioxidant, and anticancer activities of medicinal plants addresses urgent healthcare needs and offers opportunities for advancing therapeutic strategies, promoting health, and validating traditional medicinal knowledge within a scientific framework.

Significance of the Study

This study holds significant implications for both the scientific community and public health. The systematic evaluation of antimicrobial, antioxidant, and anticancer activities of crude extracts and purified compounds from medicinal plants addresses critical gaps in current medical treatments and offers several key benefits. Firstly, the discovery of new antimicrobial agents from medicinal plants can provide effective alternatives to conventional antibiotics, which are increasingly losing their efficacy due to the rapid rise of resistant microbial strains. This has profound implications for the treatment of infectious diseases and the containment of antibiotic resistance, a major global health threat. Secondly, the identification of potent antioxidants from plant sources can play a vital role in preventing and managing oxidative stress-related diseases. By neutralizing free radicals, these natural antioxidants can mitigate the damage caused by oxidative stress, thereby reducing the incidence and severity of chronic diseases such as cardiovascular and neurodegenerative disorders. Thirdly, the exploration of anticancer properties in medicinal plants can lead to the development of novel, less toxic cancer therapies. Many plant-derived compounds have shown promise in inhibiting cancer cell growth and inducing apoptosis, offering potential breakthroughs in cancer treatment. this study contributes to the growing body of knowledge on natural therapeutics and highlights the

untapped potential of medicinal plants. By providing scientific validation for traditional medicinal practices, it paves the way for the development of new, effective, and safe therapeutic agents, thereby enhancing global health outcomes and offering hope for better disease management and prevention.

Literature Review

Tagne, R. S., Telefo, B. P., et al . (2014). Methanol extracts and fractions from various Cameroonian medicinal plants have been studied for their potential anticancer and antioxidant activities, highlighting the region's rich biodiversity and traditional knowledge in herbal medicine. These plants include *Allium sativum*, *Erythrina senegalensis*, and *Piptadeniastrum africanum*, among others. The extracts were prepared using methanol due to its efficiency in extracting bioactive compounds. The antioxidant activities were assessed using standard assays such as DPPH radical scavenging and ferric reducing antioxidant power (FRAP). Results showed that these extracts exhibited significant antioxidant properties, which are crucial in protecting cells from oxidative stress-induced damage. In addition to their antioxidant potential, the anticancer activities of these extracts were evaluated against various cancer cell lines, including breast, prostate, and colon cancers. The findings revealed that the methanol extracts and fractions induced apoptosis and inhibited the proliferation of cancer cells, indicating their potential as sources of natural anticancer agents. These activities are attributed to the presence of phytochemicals such as flavonoids, alkaloids, and saponins, which are known for their therapeutic properties. the study underscores the importance of Cameroonian medicinal plants as promising candidates for developing new antioxidant and anticancer therapies, reinforcing the need for further research and conservation of these valuable plant resources.

Mothana, R. A., Lindequist, U. et al. (2009). Selected medicinal plants from the island of Soqotra, Yemen, have been studied for their in vitro anticancer, antimicrobial, and antioxidant potentials. The unique flora of Soqotra, renowned for its biodiversity and traditional medicinal use, includes plants like *Boswellia socotrana*, *Dracaena cinnabari*, and *Aloe perryi*. These plants were chosen due to their historical usage in local medicine and their potential to contain bioactive compounds. Methanol extracts of these plants were tested for their antioxidant activities using assays such as DPPH radical scavenging and ABTS assay. The results demonstrated substantial antioxidant properties, suggesting these plants can neutralize free radicals and reduce oxidative stress. Such antioxidant properties are essential for preventing cellular damage and aging. The anticancer potential of the extracts was evaluated against

various human cancer cell lines, including breast, liver, and colon cancers. The studies indicated that several extracts inhibited cancer cell proliferation and induced apoptosis, pointing to their potential as natural anticancer agents. Additionally, antimicrobial tests against a range of pathogenic bacteria and fungi showed that these extracts possessed significant antimicrobial activity, supporting their use in traditional medicine for treating infections. The findings from these studies highlight the therapeutic potential of Soqotran medicinal plants, emphasizing their importance in the development of natural antioxidant, anticancer, and antimicrobial agents. This research also underscores the need for further studies to isolate and characterize the specific bioactive compounds responsible for these activities.

Abdel-Hameed, E. S. et al. (2012). Phytochemical studies of *Conocarpus erectus* L., commonly known as buttonwood, have revealed a rich composition of bioactive compounds that contribute to its medicinal properties. This plant, widely found in tropical and subtropical regions, has been traditionally used for its therapeutic benefits. The phytochemical analysis of *Conocarpus erectus* has identified the presence of flavonoids, tannins, saponins, phenolic compounds, and alkaloids, which are known for their health-promoting properties. The antioxidant potential of *Conocarpus erectus* extracts was evaluated using assays such as DPPH radical scavenging and ferric reducing antioxidant power (FRAP). The results demonstrated strong antioxidant activity, indicating the plant's ability to neutralize free radicals and protect against oxidative stress, which is implicated in various chronic diseases and aging processes. In vitro studies on the anticancer properties of *Conocarpus erectus* extracts have shown promising results. The extracts exhibited significant cytotoxic effects against several human cancer cell lines, including breast, liver, and colon cancers. The anticancer activity is attributed to the induction of apoptosis and inhibition of cancer cell proliferation, suggesting the potential of *Conocarpus erectus* as a source of natural anticancer agents. Furthermore, the antimicrobial properties of *Conocarpus erectus* were assessed against a spectrum of pathogenic bacteria and fungi. The extracts displayed potent antimicrobial activity, effectively inhibiting the growth of various pathogens, thereby supporting its traditional use in treating infections. The phytochemical studies and bioactivity evaluations of *Conocarpus erectus* highlight its significant antioxidant, anticancer, and antimicrobial properties. These findings emphasize the therapeutic potential of this plant and the need for further research to isolate and characterize the specific compounds responsible for these activities, paving the way for the development of natural health products.

Jarial, R., Shard, A., et al . (2018). The characterization of flavonoids from the fern *Cheilanthes tenuifolia* has revealed a diverse range of bioactive compounds contributing to its significant medicinal properties. This fern, known for its traditional medicinal use, has been subjected to detailed phytochemical analysis, which identified a variety of flavonoids, including quercetin, kaempferol, and their glycosides. The antioxidant activity of flavonoid-rich extracts from *Cheilanthes tenuifolia* was evaluated using assays such as DPPH radical scavenging and ferric reducing antioxidant power (FRAP). The results demonstrated robust antioxidant capabilities, indicating that these flavonoids can effectively neutralize free radicals and mitigate oxidative stress. This antioxidant property is crucial for protecting cells from damage associated with chronic diseases and aging. The antimicrobial potential of *Cheilanthes tenuifolia* flavonoids was assessed against a broad spectrum of pathogenic bacteria and fungi. The extracts exhibited significant antimicrobial activity, inhibiting the growth of several Gram-positive and Gram-negative bacteria as well as fungi. This supports the traditional use of this fern in treating infections and highlights its potential as a source of natural antimicrobial agents. In vitro anticancer studies revealed that the flavonoid extracts from *Cheilanthes tenuifolia* possess notable cytotoxic effects against various human cancer cell lines, including breast, colon, and liver cancers. The extracts were found to induce apoptosis and inhibit cell proliferation, suggesting their potential as natural anticancer agents. The characterization of flavonoids from *Cheilanthes tenuifolia* and the evaluation of their antioxidant, antimicrobial, and anticancer activities underscore the therapeutic potential of this fern. These findings advocate for further research to isolate and identify specific flavonoid compounds responsible for these bioactivities, paving the way for their development into natural health products and pharmaceuticals.

Mishra, A., Sharma, A. K., et al (2013). *Bauhinia variegata*, commonly known as the orchid tree, is a plant revered for its diverse medicinal properties. Extracts from its leaves have garnered significant attention in scientific research due to their potent antibacterial, antioxidant, and anticancer activities. The antibacterial properties of *Bauhinia variegata* leaf extracts have been demonstrated against a variety of pathogenic bacteria, showcasing the plant's potential as a natural alternative to conventional antibiotics. This activity is attributed to the presence of bioactive compounds such as flavonoids and tannins, which disrupt bacterial cell walls and inhibit their growth. In addition to its antibacterial efficacy, *Bauhinia variegata* leaf extracts

exhibit strong antioxidant properties. The high levels of phenolic compounds and flavonoids contribute to the scavenging of free radicals, thereby reducing oxidative stress and protecting cells from damage. This antioxidant activity not only supports overall cellular health but also plays a crucial role in preventing the onset of chronic diseases. Furthermore, research indicates that *Bauhinia variegata* leaf extracts possess anticancer properties. These extracts have been shown to inhibit the proliferation of various cancer cell lines, including breast and lung cancers. The anticancer activity is believed to be mediated through the induction of apoptosis, modulation of cell cycle progression, and inhibition of metastasis. *Bauhinia variegata* leaves offer a promising natural source for developing therapeutic agents with antibacterial, antioxidant, and anticancer capabilities.

Mothana, R. A., Abdo, et al (2010). The study of Yemeni medicinal plants reveals a wealth of potential therapeutic benefits, particularly in the realms of antimicrobial, antioxidant, and cytotoxic activities. These plants, long utilized in traditional medicine, are now being scientifically evaluated to understand their bioactive components and therapeutic efficacy. Phytochemical screening of these plants has uncovered a variety of compounds such as alkaloids, flavonoids, tannins, and saponins, which contribute to their medicinal properties. The antimicrobial activities of these Yemeni medicinal plants have been tested against a range of pathogenic microorganisms, including bacteria and fungi. Results have shown that extracts from plants such as *Salvia officinalis* and *Ocimum basilicum* exhibit significant inhibitory effects on microbial growth. These findings suggest that these plants could serve as alternative or complementary treatments to conventional antibiotics, especially in the face of rising antibiotic resistance.

Saeed, A., Abotaleb, S., et al (2020). The in vitro assessment of marine macroalgae has unveiled significant antimicrobial, antioxidant, and anticancer properties, highlighting their potential as valuable resources for therapeutic applications. Marine macroalgae, commonly known as seaweeds, are rich in bioactive compounds that contribute to their medicinal efficacy. The antimicrobial activities of these algae have been tested against various pathogenic bacteria and fungi, with results indicating strong inhibitory effects. For instance, extracts from species like *Ulva lactuca* and *Sargassum muticum* have shown effectiveness in inhibiting the growth of harmful microorganisms, suggesting their potential as natural alternatives to synthetic antibiotics, especially in combating antibiotic-resistant strains. In addition to their

antimicrobial capabilities, marine macroalgae exhibit substantial antioxidant activities. These activities are primarily attributed to the high levels of phenolic compounds, flavonoids, and carotenoids present in the algae.

Prakash, S., Ramasubburayan, et al (2016). The in vitro scientific evaluation of traditional coastal medicinal plants has revealed significant antimicrobial, antioxidant, and cytotoxic properties, along with a rich array of phytochemical constituents. Coastal plants such as *Avicennia marina* and *Rhizophora mucronata* have demonstrated substantial antimicrobial activity, effectively inhibiting the growth of various pathogenic bacteria and fungi. This efficacy is attributed to bioactive compounds like alkaloids, flavonoids, and tannins, which disrupt microbial cell walls and inhibit enzyme activities. The antioxidant potential of plants such as *Sesuvium portulacastrum* and *Ipomoea pes-caprae* has been confirmed through their high levels of phenolic compounds and flavonoids. These antioxidants are crucial in scavenging free radicals, thereby reducing oxidative stress and protecting cells from damage, which is pivotal in preventing chronic diseases like cancer and cardiovascular disorders. The cytotoxic properties of plants like *Barringtonia asiatica* and *Calophyllum inophyllum* have shown promising anticancer potential by inducing apoptosis and inhibiting the proliferation of cancer cells. Phytochemical screening has identified a diverse range of bioactive compounds, including terpenoids and saponins, which contribute to these therapeutic effects. These findings validate the traditional use of coastal medicinal plants and underscore their potential as sources for new therapeutic agents in modern medicine.

Yessoufou, K., Elansary, et al (2015). *Ficus drupacea* L., a medicinal plant renowned for its therapeutic properties, has demonstrated notable antifungal, antibacterial, and anticancer activities in scientific studies. The antifungal efficacy of *Ficus drupacea* L. has been observed against various pathogenic fungi, making it a potential natural alternative for treating fungal infections. This antifungal activity is attributed to the presence of bioactive compounds such as flavonoids and tannins, which inhibit fungal growth and disrupt fungal cell membranes. In addition to its antifungal properties, *Ficus drupacea* L. exhibits significant antibacterial activity. Studies have shown that extracts from this plant can effectively inhibit the growth of several bacterial strains, including both Gram-positive and Gram-negative bacteria. The antibacterial action is linked to the plant's rich phytochemical content, which includes alkaloids and phenolic compounds known for their ability to penetrate bacterial cell walls and inhibit critical cellular

processes. *Ficus drupacea* L. has shown promising anticancer potential. In vitro studies have revealed that its extracts can induce apoptosis and inhibit the proliferation of various cancer cell lines, including breast and colon cancer cells. The anticancer activity is primarily due to the presence of bioactive compounds such as triterpenoids and saponins, which interfere with cancer cell metabolism and signaling pathways. Overall, *Ficus drupacea* L. stands out as a potent source of natural bioactive compounds with significant antifungal, antibacterial, and anticancer properties, highlighting its potential for developing novel therapeutic agents.

Afsar, T., Razak, S., et al (2016). *Acacia hydaspica* R. Parker, a plant known for its medicinal properties, has been scientifically evaluated for its antioxidant, anti-hemolytic, and anticancer activities using various solvent extracts from its aerial parts. The antioxidant potential of *Acacia hydaspica* has been confirmed through assays that demonstrate its ability to scavenge free radicals and reduce oxidative stress. This activity is primarily attributed to the high levels of phenolic compounds and flavonoids in the extracts, which protect cells from oxidative damage and help prevent chronic diseases. In addition to its antioxidant properties, *Acacia hydaspica* exhibits significant anti-hemolytic activity. The plant's extracts have been shown to protect red blood cells from hemolysis, which is the breakdown of red blood cells that can lead to various health issues. The anti-hemolytic effect is due to the presence of bioactive compounds that stabilize cell membranes and inhibit oxidative damage to red blood cells. Furthermore, the anticancer activity of *Acacia hydaspica* has been evaluated in vitro, with promising results. The extracts have demonstrated the ability to induce apoptosis and inhibit the proliferation of cancer cell lines, including breast and liver cancer cells. This anticancer effect is linked to the presence of compounds such as saponins and terpenoids, which interfere with cancer cell growth and signaling pathways. *Acacia hydaspica* R. Parker exhibits considerable antioxidant, anti-hemolytic, and anticancer activities, making it a valuable candidate for developing new therapeutic agents.

Shahat, A. A., Hidayathulla, et al (2019). *Gastrocotyle hispida*, a plant native to Saudi Arabia, has been the subject of scientific investigation for its phytochemical profiling, antioxidant, and anticancer activities. Phytochemical analysis has revealed a rich composition of bioactive compounds, including alkaloids, flavonoids, tannins, and phenolic acids, which contribute to the plant's medicinal properties. These compounds are known for their therapeutic potential and play a crucial role in the plant's biological activities. The antioxidant properties of

Gastrocotyle hispida have been extensively studied, demonstrating the plant's ability to neutralize free radicals and reduce oxidative stress. This activity is primarily attributed to the high levels of phenolic compounds and flavonoids found in the plant, which help protect cells from oxidative damage and prevent the onset of various chronic diseases. The strong antioxidant activity of Gastrocotyle hispida supports its potential use in promoting overall health and preventing conditions related to oxidative stress. In addition to its antioxidant capabilities, Gastrocotyle hispida has shown promising anticancer activity. In vitro studies have indicated that the plant's extracts can induce apoptosis and inhibit the proliferation of cancer cell lines, including those of breast and liver cancers. The anticancer effects are linked to the presence of bioactive compounds such as saponins and terpenoids, which disrupt cancer cell metabolism and signaling pathways. These findings highlight Gastrocotyle hispida as a valuable source of natural compounds with significant antioxidant and anticancer properties, underscoring its potential for development into therapeutic agents.

Cai, Y., Luo, Q., Sun, et al (2004). The study of 112 traditional Chinese medicinal plants has highlighted their significant antioxidant activity and the presence of phenolic compounds, which are closely associated with anticancer properties. These plants, long utilized in traditional Chinese medicine, have been scientifically evaluated to uncover the bioactive constituents that contribute to their therapeutic effects. The high levels of phenolic compounds found in these plants, including flavonoids, tannins, and phenolic acids, are primarily responsible for their robust antioxidant activities. Antioxidants play a crucial role in neutralizing free radicals, thereby reducing oxidative stress and protecting cells from damage. This protective effect is vital in preventing the onset of various chronic diseases, including cancer. The phenolic compounds in these medicinal plants enhance the body's defense mechanisms against oxidative damage, supporting overall cellular health and reducing the risk of malignant transformations. many of these traditional Chinese medicinal plants have demonstrated potent anticancer activities in vitro and in vivo.

Research Problem

Despite the historical use of medicinal plants in traditional medicine, there is a critical need for rigorous scientific evaluation of their therapeutic potentials, particularly in combating contemporary health challenges such as antimicrobial resistance, oxidative stress, and cancer. The global rise in antibiotic-resistant pathogens has rendered many conventional antibiotics ineffective, posing a significant threat to public health. There is an urgent demand for new antimicrobial agents capable of overcoming resistance mechanisms and providing effective

treatments for infectious diseases. Simultaneously, oxidative stress is implicated in a wide array of chronic diseases, including cardiovascular, neurodegenerative disorders, and cancer. The imbalance between free radicals and antioxidants in the body leads to cellular damage and disease progression. Identifying natural sources of potent antioxidants can play a crucial role in disease prevention and health maintenance. Furthermore, cancer continues to be a leading cause of death worldwide, and current treatments often come with severe side effects. There is a pressing need for new anticancer agents that are both effective and less toxic. Medicinal plants, with their diverse array of bioactive compounds, offer a promising source for such therapeutic agents. However, the bioactivities of many plant extracts and their purified compounds remain underexplored and scientifically unvalidated. This research seeks to address these gaps by evaluating the antimicrobial, antioxidant, and anticancer activities of crude extracts and purified compounds from selected medicinal plants. By systematically investigating these properties, the study aims to identify new bioactive molecules that could lead to the development of novel therapeutics, thereby addressing critical health challenges and contributing to improved global health outcomes.

Conclusion

The review of antimicrobial, antioxidant, and anticancer activities in medicinal plants underscores their significant potential in modern healthcare. The diverse bioactive compounds found in these plants offer promising avenues for combating antibiotic-resistant infections, mitigating oxidative stress-related diseases, and advancing cancer treatment options. By synthesizing current research findings, this review highlights the importance of understanding and harnessing the therapeutic properties of medicinal plants. Continued exploration of these bioactive properties is essential for developing new pharmaceuticals and nutraceuticals that can address evolving health challenges effectively. Validating traditional medicinal practices through scientific research not only enhances the credibility of plant-based therapies but also facilitates their integration into mainstream healthcare systems. Moreover, the discovery of novel compounds from medicinal plants serves as inspiration for future drug development efforts, potentially leading to innovations that improve patient outcomes and quality of life. The exploration of antimicrobial, antioxidant, and anticancer activities in medicinal plants represents a valuable intersection of traditional knowledge and modern scientific inquiry. By advancing our understanding of these natural remedies, we pave the way for innovative healthcare solutions that are sustainable, effective, and culturally resonant.

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