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Bioactive Compounds in Medicinal Plants as a Source of Anti-Parasitic: Review Article

Abdullah Zaidan Khalaf Al-Quraghuli[1], Jassim Mohammed Ali[2]
[1]Dhul-Presidency of Sunni Endowment Diwan / Department of Religious Education and Islamic Studies, Dhul-Nurayn Islamic Secondary School
[2]Department of Chemistry, College of Education for Pure Sciences, University of Kirkuk, Kirkuk, Iraq

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ABSTRACT
Objective: *Despite the considerable worldwide health and economic burden imposed by gastrointestinal parasites in humans and cattle, treatment alternatives are increasingly hindered by multidrug resistance and the detrimental effects of synthetic medications.* ***Method:*** *This review encapsulates the antiparasitic potential of medicinal plants and their phytochemicals, elucidates their modes of action and pharmacological relevance, and examines their position as a possible source for next-generation antiparasitic therapeutics.* ***Results:*** *Medicinal plants, abundant in structurally varied bioactive chemicals including flavonoids, alkaloids, terpenoids, tannins, and essential oils, have historically served as significant sources of medicinal medicines.* ***Novelty:*** *This review encapsulates the antiparasitic potential of medicinal plants and their phytochemicals, elucidates their modes of action and pharmacological relevance, and examines their position as a possible source for next-generation antiparasitic therapeutics.*

INTRODUCTION

Because of their accessibility, affordability, universal acceptability, and safety, medicinal plants have attracted a lot of attention in modern medicine in current years, making herbal medicines extremely significant on a global scale. Thus, guaranteeing the quality, effectiveness, and safety of medicinal plants has emerged as a significant problem for both industrialized and developing nations [1].

Protozoal diseases can result in deadly situations and have long been a worldwide burden, especially in low- and middle-income nations [2]. Numerous of these ailments are classified as neglected tropical diseases (NTDs). Diseases include trichomoniasis (*Trichomonas vaginalis*), primary amoebic meningoencephalitis (*Naegleria fowleri*), leishmaniasis (*Leishmania spp*.), malaria (*Plasmodium spp.),* and Chagas disease (*T. cruzi*) continue to cause significant morbidity and mortality [3]. Examining the present level of medication resistance in these protozoal diseases as well as recent developments in therapies and drug discovery is therefore essential [4].

Notwithstanding progress in specific areas, for example aim identification and molecular docking, significant obstacles remain. Challenges encompass restricted healthcare access in endemic regions, insufficient financing for neglected tropical diseases, adaptive evolution of pathogens, and a nascent antiprotozoal medication pipeline. This combination of in silico design and medicinal chemistry might serve as a valuable model for multidisciplinary cooperation. In the post-resistance age, addressing these shortcomings is essential to developing long-lasting, potent treatments for protozoal diseases [4].

Gastrointestinal (GI) parasite illnesses pose a substantial health issue impacting billions of humans and cattle globally, especially in underdeveloped nations. Approximately 3.5 billion individuals are impacted worldwide, with 450 million exhibiting symptoms, and over 200,000 fatalities recorded annually [5]. Gastrointestinal parasites in animals induce substantial illness loads and considerable economic losses related to food production in several places worldwide [6;7]. Helminths and protozoa are the two main gastrointestinal parasites that affect humans. Soil-transmitted helminths, also known as geohelminths, are the main helminth infections that are spread via contaminated soil. The organisms comprise *Necator americanus, Ancylostoma duodenale, Trichuris trichiura* (whipworm), and *Ascaris lumbricoides* (roundworm) [8]. These helminths are between the greatest prevalent infectious disease agents affecting humans, with about 1.5 billion individuals (24% of the global population) acquiring at least one during their lifetime [9]. Despite the development of several pharmaceuticals for parasite diseases, many are antiquated, and resistant strains have subsequently arisen. The pharmaceutical sector has deprioritized the development of new antiparasitic medications, as most affected communities are impoverished and unable to pay costly treatments. This renders investment in therapeutic research for parasitic illnesses precarious [10]. The use of plant extracts and their secondary metabolites provide a viable alternative to manufactured pharmaceuticals. From 1981 to 2006, 1,184 new medications were registered, with 28% originating from natural sources or their derivatives, and 24% including pharmacological combinations obtained from nature. Conventional medicinal flora, especially in Asia, Africa, and the Americas, constitute a promising reservoir for the identification of antiparasitic agents [11]. Notwithstanding several encouraging in vitro outcomes, their clinical use remains constrained. This research examines medicinal plants historically utilised for the treatment of parasitic disorders, omitting tropical diseases induced by viruses, bacteria, or fungus.

RESEARCH METHOD

Medicinal plants as alternative antibiotics

Near competition infections and the complex mechanisms underlying antibiotic resistance, a wide range of medications are available [12]. These antimicrobial medications' mode of action is based on selective toxicity. Several bioactive compounds, as well as coumarins, flavonoids, phenolics, alkaloids, terpenoids, tannins, essential oils, lectins, polypeptides, and polyacetylenes, have been identified in medicinal plants. [13]. For the production of antibiotics, these substances serve as essential building blocks [14]. Although synthetic antimicrobial agents are widely used, natural chemicals from a variability of sources, counting endophytes, plants, fungi, lichens, and marine creatures including seaweeds, corals, and other microbes, remain a major area of scientific study. In the battle against antibiotic-resistant bacterial illnesses, these chemical compounds have significant potential [15]. The potential of chemicals obtained from plants to treat bacterial diseases makes them noteworthy. Among the many advantageous qualities of these naturally occurring phytochemicals are their antifungal, antibacterial, and antioxidant capabilities [15]. Additionally, they could significantly improve the effectiveness of already available antibiotics, halting the spread of resistance [16]. Medicinal plant extracts include bioactive compounds that can work in a variety of ways, such as by coming into touch with certain components of bacterial membranes, such lipopolysaccharides and anionic phospholipids, which causes bacterial lysis by membrane rupture. Hydrophobicity can influence the outcome of the reaction by relating by the hydrophobic groups in the membrane. Additionally, ionic/electrostatic interactions bring the plant extract to the bilayer surface, rupturing and destabilizing the cellular membrane. [17]. Furthermore, when active ingredients contain both hydrophilic and hydrophobic residues, the aforementioned pathways could be activated [18].

RESULT AND DISCUSSION

Drug resistance in parasites

Treatment and management of parasitic diseases are hampered by drug resistance, which results from genetic changes in a parasite population brought on by selection pressure from antiparasitic drugs [19]. Different human gastrointestinal parasites, treatment resistance is already a recognised reality in animal parasites. The frequent and excessive application of same medication compounds for parasite control in cattle has resulted in elevated resistance levels, jeopardising the viability of animal businesses [20]. Anthelmintic resistance is a growing issue in sheep, goats, and horses within global industrial livestock systems [21,22]. Haemonchus contortus has demonstrated a notable capacity to acquire resistance to the principal types of anthelmintic drugs globally [23]. Resistance has emerged in most instances within less than a decade following the launch of each medication class. Resistance of *H. concortus* to benzimidazole was documented as early as 1964 in the US. Small ruminants in Europe have been shown to be resistant to the broad-spectrum antiparasitic drug moxidectin [24;25]. Sheep herds in Ontario, Canada, were shown to have Haemonchus species that are resistant to benzimidazole and ivermectin [26]. H. contortus populations resistant to moxidectin were found on sheep farms in Queensland, Australia [27]. It has been shown that H. contortus is resistant to the recently developed amino-acetonitrile derivatives (monepantel) [28]. An in vivo investigation in Lithuania demonstrated ivermectin resistance in equine nematodes [29,30].

The Import of Medicinal Plants in Pharmacological Reviews

Compounds for medication development have been obtained by many approaches, including extraction from plants and other natural sources. Despite the increasing interest from pharmaceutical firms and funding organisations in molecular modelling, combinatorial chemistry, and other synthetic chemistry techniques, medicinal plants continue to be an essential source of novel medications, drug leads, and new chemical entities (NCEs) [31]. Approximately 25% of the foremost pharmaceutical goods worldwide in 2001 and 2002 were derived from plants [32]. Plants have been crucial, since around 28% of novel chemical entities (NCEs) originated from them between 1981 and 2002. In this timeframe, 20% more NCEs were classified as natural product mimics, indicating that the synthetic molecules were developed through the analysis of natural compounds [33]. Nearly 48% of the novel chemical entities (NCEs) documented from 1981 to 2002 pertain to natural product research. Due to their diverse structures and often several stereocenters that may pose synthesis challenges, natural products serve as a foundation for novel synthetic compounds [34;35;36]. Therapeutic development depends on a variety of structural features found in natural products, including chiral centres, aromatic rings, complex ring systems, molecular saturation levels, and the quantity and ratio of heteroatoms [37, 38]. In order to create natural products and libraries that mimic them, a number of synthetic and medicinal chemists also wish to include combinatorial chemistry's ability to create molecules with the structural characteristics of natural products. As combinatorial chemistry has grown in popularity, it has been clear that these chemical libraries may be rather diverse [39, 40, 41]. Medicinal plant-based pharmaceuticals can be used as new treatments and as drug candidates for synthetic and medicinal chemists to optimise. If novel chemical structures from medicinal plants are not identified during drug development, substantial drug leads can be obtained from established molecules exhibiting distinctive biological activity. Numerous illnesses have been associated with a number of novel molecular targets since the human genome was sequenced [42].

The Potential Therapeutic Benefits of Bioactive Compounds

Bioactive substances are phytochemicals current in meals that can influence metabolic processes and enhance health. They demonstrate advantageous effects, including antioxidant activity, modulation of enzyme activity, suppression of receptor functions, and regulation of gene expression [43]. The bioaccessibility and bioavailability of separately bioactive ingredient vary significantly, and the record prevalent chemicals in consumed fruit may non always result in the largest amounts of active metabolites in target tissues. When examining the impact of bioactive chemicals in human health, the bioavailability is often not well understood[44]

Bioactive substances are present in fruits, vegetables, and whole grains [45].This category encompasses a variety of compounds, including polyphenols, carotenoids, tocopherols, phytosterols, and organosulfur compounds, characterised by their distinct "chemical structures (hydrophilic or lipophilic), natural distribution (specific to certain plant species or ubiquitous), concentration levels in food and the human body, potential sites of action, efficacy against oxidative species, as well as specificity and biological effects" [43]. Various variables affect the bioavailability of antioxidants, including dietary sources and the "chemical interactions among phytochemicals and biomolecules present. For example, fruit antioxidants are frequently combined with other macromolecules, including carbohydrates, lipids, and proteins, to create the dietary matrix". Carbohydrates are the predominant chemicals present in plant tissue, mostly in free and conjugated forms [46].

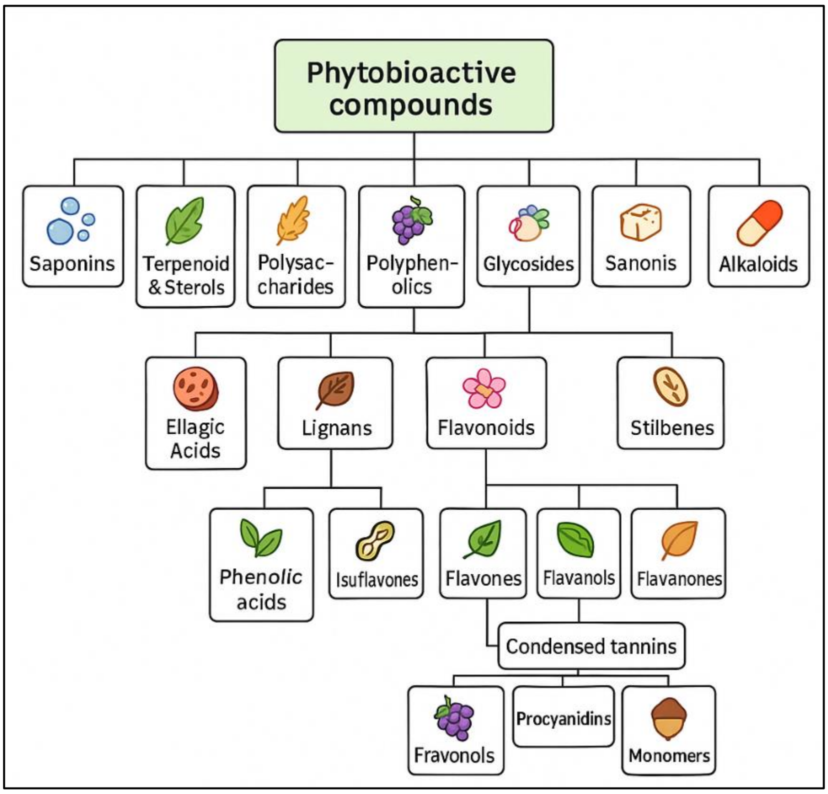

Figure 1. Phytobioactive molecule classification.

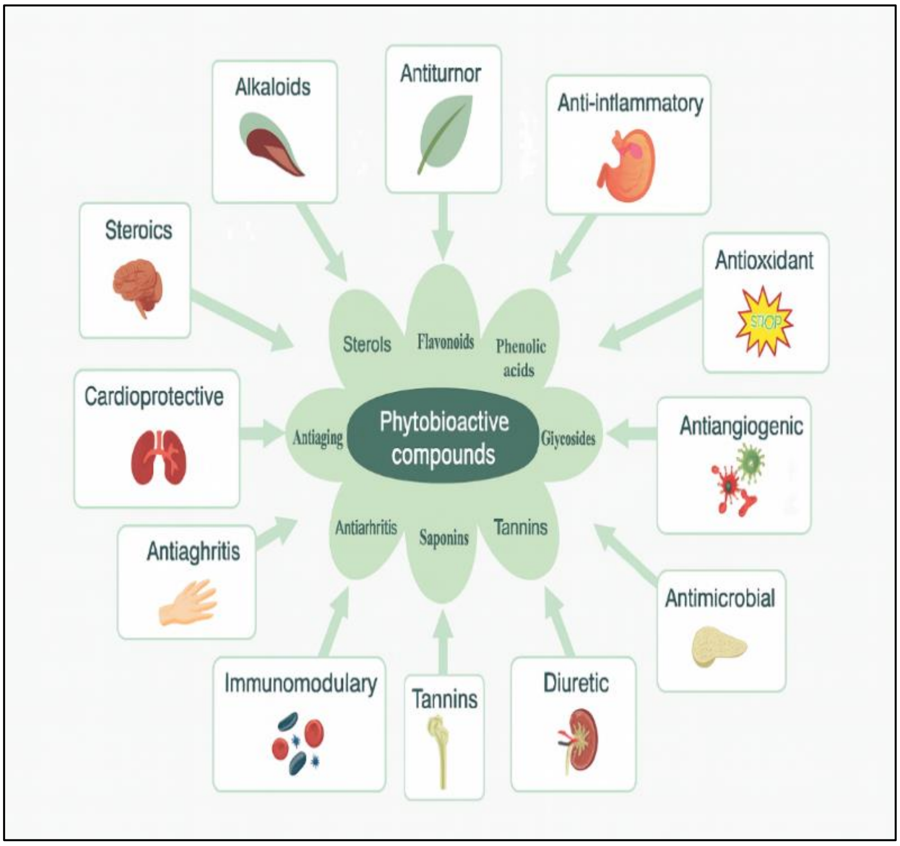

Figure 2. Summary of the therapeutic effectiveness of phytobioactive compounds [36].

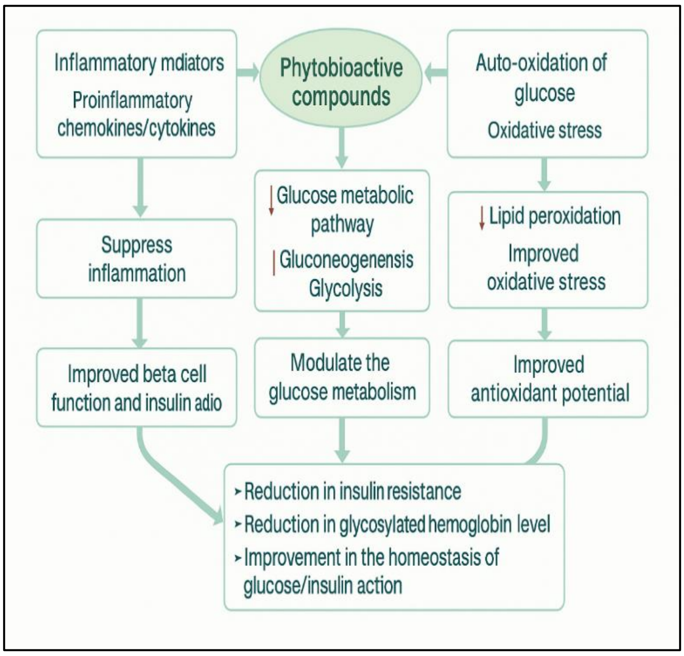

Figure 3. Illustrate the mechanism of phytoactive chemicals in the treatment of type 2 diabetes [36].

Phytochemicals

Phytochemicals are compounds produced by plants that protect plant cells against environmental threats, including pollution, stress, dehydration, UV radiation, and pathogen infiltration [47]. They play a crucial role in safeguarding human health during substantial meal consumption. Phytochemicals are categorised according to their protective roles, physical properties, and chemical features. [48]. Phytochemicals are found in numerous plant parts, counting stems, leaves, roots, flowers, fruits, and seeds. Phytochemicals are non-essential nutrients that the human body does not need for living, although they exhibit notable properties that may contribute to disease prevention. Phytochemicals contribute to the prevention and treatment of diseases due to this characteristic. Phytochemicals mitigate the risk of coronary heart disease by inhibiting the oxidation of low-density lipoprotein (LDL) cholesterol, regulating blood pressure, improving arterial flexibility, or reducing cholesterol absorption. Phytochemicals neutralise carcinogens by counteracting free radicals, inhibiting enzymes that activate carcinogens, and stimulating enzymes that detoxify them [48]. Phytochemicals have been advocated as therapies for diabetes, hypertension, and macular degeneration [49].

Uses for Bioactive Substances

Fruits and vegetables are the dominant sources of biologically active compounds. They are biological compounds that occur naturally, which may or may not exhibit nutritional properties. It often plays a crucial role in human growth and development, and helps to prevent cardiovascular disease [51]. Biologically active compounds are utilised in various sectors, including food, pharmaceutical preparations, and cosmetics. Plant extracts can be valuable ingredients in the manufacture of various food products and are also suitable for inclusion in cosmetics and the medical sector [52]. Currently, more than 30% of biologically active compounds are used in the food and cosmetics sectors, while 80% are applied in medicines [44]. Periodically active compounds are generally extracted from the source and then re-presented. It was also obtained from blue bacteria and Marine Microalgae [50]. It is generally obtained by solvent extraction [53]. The packaging procedure is usually used in the food industry to maintain the effectiveness of biologically active ingredients. These compounds offer a range of benefits in various areas. These compounds were primarily found in the food, feed, and ambiguity sectors. Chemical material applications are explained below [54].

Bioactive Substances as Organic Pigmenting Agents

Firstly, carotenoids and flavonoids serve as coloring factors. In addition to these chemicals, many additional biologists are used for food coloring and natural dyeing purposes [55]. Anthocyanin is used in the food sector for coloring and has shown therapeutic effects after being employed for several years in treating diseases such as high blood pressure, diarrhea, and increased [56]. It is primarily used in the food industry to enhance the colour of specific food products. In addition to having unique colour enhanced properties, it has excellent capabilities to modify nutrients and functional meals for both commercial and local applications [57]. Lycopene, a prominent natural food colorant, is present in tomatoes, watermelons, and other sources. Owing to its pigment characteristics, it is frequently utilised in human food items [58].

Bioactive Compounds as Agents to Reduce Inflammation and Prevent Cancer

Flavonoids are often found within a broad category of phenolic compounds. Additionally, it is categorised into six compounds: flavonoids, anthocyanins, flavonols, flavanols, and flavones [59]. Isflavones represent the most significant category exhibiting anti-inflammatory actions [60]. Isoflavones are prevalent in soybeans and legumes. Besides its anti-inflammatory properties, it also exhibits anti-cancer and antibacterial effects, functioning as an antioxidant [61]. The primary compounds are Genistein and Daidzein. It typically functions as a phytoestrogen [59]. The primary technology is linked to the location of oestrogen receptors in animals via pseudo-hierarchical methods [63]. In addition to its anti-inflammatory properties, it has anti-cancer benefits via suppressing potent oestrogen pathways by binding. Combating hormone-dependent malignancies, such as prostate and breast cancer, is essential. Biologically active chemicals, such as lacobin, possess anti-inflammatory and anti-cancer effects [64].

Antioxidant Bioactive Compounds

The most common and often encountered biologically active compounds are phenolic molecules, such as ascorbic acid and carotenoids [65]. Citrus fruits, Brussels sprouts, tomatoes, and related foods are the primary sources of ascorbic acid [66]. Papaya, sweet potatoes, and carrots are familiar sources of carotenes. It is the most prevalent source of antioxidants [67]. These molecules' primary job is to shield cell membranes and their constituent parts from harm caused by free radicals [68]. In some materials, it can prevent microbiological activity [69]. To store food, they have a variety of options [70,71].

CONCLUSION

Fundamental Finding : Medicinal plants have several uses due to their effectiveness, minimal side effects, and plant chemical components that can effectively treat a range of disorders. Use potent medicinal herbs to treat a variety of diseases and infections. In underdeveloped countries, nearly 85% of the population relies on traditional medicine, primarily herbal remedies. **Implication :** The management of antibiotic resistance is one of the most urgent issues facing world health. As traditional antibiotics are rapidly losing their effectiveness due to growing concerns about antibiotic resistance, these plant extracts offer viable alternatives. **Limitation :** Medicinal plants have several uses due to their effectiveness, minimal side effects, and plant chemical components that can effectively treat a range of disorders, yet their role is mostly confined to traditional medicine in underdeveloped countries where nearly 85% of the population relies on herbal remedies, indicating that scientific validation and standardization remain limited. **Future Research :** As traditional antibiotics are rapidly losing their effectiveness due to growing concerns about antibiotic resistance, these plant extracts offer viable alternatives, suggesting that further studies should focus on exploring their pharmacological properties, developing standardized formulations, and integrating them into modern healthcare systems.

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Abdullah Zaidan Khalaf Al-Quraghuli
Dhul-Nurayn Islamic Secondary School, Iraq

Jassim Mohammed Ali
University of Kirkuk, Iraq