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A Global Perspective on Medicinal Plants in Combatting Malaria and HIV

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ABSTRACT

Malaria and HIV/AIDS remain two of the most devastating infectious diseases globally, disproportionately affecting populations in low- and middle-income countries, especially across Africa. As resistance to current pharmaceutical therapies rises, the exploration of traditional medicinal plants offers a promising, cost-effective, and culturally relevant alternative for disease management. This paper examines the historical significance, phytochemical potential, and therapeutic contributions of medicinal plants in combatting malaria and HIV. It highlights key plant species such as *Artemisia annua*, *Cinchona* spp., and a range of traditional African flora used in rural health settings. Drawing upon global case studies from Zambia, Namibia, and beyond, the paper also addresses the socio-economic, regulatory, and research challenges impeding the full integration of ethnomedicine into modern healthcare systems. Future directions are discussed, including the need for sustainable harvesting, bioactive compound isolation, pharmacological validation, and improved collaboration between traditional knowledge holders and the scientific community. The review ultimately underscores the critical role of medicinal plant research in global health strategies to combat these persistent diseases.

Keywords: Medicinal plants, Malaria, HIV/AIDS, Artemisinin, Traditional medicine, Ethnobotany, Antiretroviral therapy.

INTRODUCTION

Malaria, caused by Plasmodium parasites, is transmitted by Anopheles mosquitoes and is endemic in tropical regions, threatening over half the global population, especially in less-developed countries. There are 300 to 500 million malaria cases annually, with over 1.5 million deaths, notably affecting children in Africa. The Human Immunodeficiency Virus (HIV), linked with high morbidity, presents a major global health challenge. Since the first case in 1981, approximately 42 million people have been infected, predominantly in developing countries, with predictions of over 100 million infections by 2010. The infection often remains asymptomatic, slowly compromising the immune system and leading to opportunistic infections and potential progression to AIDS. Estimates project 25 to 35 million AIDS cases by 2020, particularly prevalent in Africa, known for its diverse flora. There is hope that scientists can derive effective treatments for malaria and HIV from traditional medicinal plants. Such plants have historically been crucial for treatment in malaria and HIV/AIDS endemic regions. The last two decades have seen increased evaluation of traditional medicines, showcasing a vital resource for modern medicine amid rising global antibiotic resistance and a renewed interest in folk remedies and microbial metabolites [1, 2].

Historical Context of Medicinal Plants

Man has long utilized plants for medicinal purposes, leading to the extraction of compounds like morphine, quinine, and codeine even before modern science. This progress has resulted in a more cautious

approach to plant consumption, alongside an extensive cataloging of plant species and their pharmacological effects. By 1910, significant advancements occurred in identifying active compounds, yet many isolated substances presented serious side effects. There was substantial evolution in patent medicines, with numerous drugs derived from single plants. Traditional practices such as Ayurveda and Traditional Chinese Medicine are experiencing renewed scientific and commercial interest. The World Health Organization has recognized over 60 plant-derived products, including well-known medications like artemisinin and Taxol. The exploration of new medicines from nature is expanding, recognizing nature as a biogenetic reservoir, and new products are being evaluated from multiple perspectives. Medicinal plants are rich in secondary metabolites, which offer protection against herbivores and pathogens, as well as provide potent compounds for traditional medicine or drug discovery [3, 4].

Overview of Malaria

Malaria is a parasitic infection caused by protozoans of the genus Plasmodium, which infects red blood cells; it is transmitted to humans mainly via the bites of infected female Anopheles mosquitoes. It is considered to be one of the greatest challenges to global public health in the 3rd millennium, afflicting over 300 million individuals and killing approximately 3 million people annually. Due to human immunization, geographic isolation and use of antimalarial agents, the number of malaria infections in the USA, Western Europe and other first-world countries has decreased sharply during the past 30 years. On the other hand, with the emergence of drug resistance in malaria parasites and mosquito vectors, the recurrence of malaria has remained a public health concern in developing countries, where over 50% of the population is under risk of malaria. Plasmodium falciparum is the most virulent malaria species, causing >95% of all malaria-related mortality, and considerable effort is being made to discover and develop new agents against this organism group. Historically, alkaloids from several plant families have yielded antimalarial agents including, quinine from Cinchona, cinchonine from Cinchona and 8-aminoquinoline from a late derivative of cinchona as well as other compounds. The most important plant-derived antimalarial, artemisinin, was first discovered in the 1970s from Artemisia annua in China. Plant screening that began in China in the early 1950s has actively been pursued since then. As survivorship of drug-resistant malaria continues to mean increasing mortality for millions of people worldwide, renewed efforts are being made to search for new drug leads from nature. By category, literature reports are discussed in this review on structures of 175 plant-derived antiplasmodial compounds by major classes or groups according to their structural skeletons, for which detailed information is provided to initiate development of antimalarial drugs based on their chemical scaffolds [5, 6].

Overview of HIV

HIV is a reproductive disease caused by HIV1 that combines to CD4 receptors on T-cells. It causes a breakdown of the immune system leading to AIDS. The T-helper cell 4 count becomes less than 200 cells per microliter. In AIDS, due to the breakdown of the immune system person gets infections from opportunistic pathogens. Anti-retroviral therapy (cART) is a combination of HIV medicines used to treat HIV infection. HIV medicines can stop HIV from replicating by inhibiting the steps involved in viral replication. There are six classes of FDA-approved antiretroviral agents with diverse mechanisms of action to limit viral replication and HIV disease progression. General categories of anti-HIV drugs are: protease inhibitors, nucleoside reverse transcriptase inhibitors, non-nucleoside reverse transcriptase inhibitors, fusion inhibitors, entry inhibitors, integrase inhibitors. Antiretroviral therapy is significant in improving the life of people living with HIV. With a remarkable better quality of life, much success has been observed with ART as the drugs suppress HIV replication. However, ART has many disadvantages, including resistance, dosing complexity, toxicity, limited availability, and lack of curative effect. ART needs to be used for life. HIV began to develop resistance to ART shortly after it was licensed for human use. There have been increasing concerns regarding the potential of HIV to become resistant to anti-retroviral (ARV) treatment since it was first reported decades ago. HIV can produce billions of new virions and can undergo thousands of replication cycles each day in a single host in sub-Saharan Africa. As pathogens become drug resistant, the need for development of new medicines is being realized all over the world. Thus, these shortcomings of ART opened avenues for the use of natural products. Natural products from both plant and animal origin have been known and used for their medicinal properties for centuries. Plants contain a plethora of secondary metabolites which are well known for having therapeutic value. The medicinal properties of plants lie in their constituent bioactive phytochemicals [7, 8].

Role of Traditional Medicine

Concerns are global regarding the emergence of malaria parasites resistant to the current artemisinin-based antimalarial treatment. Despite the overall concern and public health threat of the global emergence of artemisinin resistance, only a few significant efforts have been made to fight this emerging public health threat at an international level. The need for effective antimalarials including those targeting resistant strains is very important. Medicinal plants have remained the most affordable treatment globally. The recent rediscovery of a few compounds from a few selected plants has paved the way for an increased effort to evaluate other plants as potential sources of new lead antimalarials. Antimalarial and acyl CoA-dependent fatty acid synthetase inhibitors, starting from artemisinin derivatives and first clinical trial of the Phytolacca dodecandra-derived anticoccidial drug, and applications of metabolomics and metabolomic analyses to understand the adverse metabolic effect of the artemisinin derivative. Efforts should be made to enhance the sustainability of the production of such resources. Care of people living with HIV infection/AIDS (PLWHA) in rural Tanzania is largely dependent on the use of traditional medicine based on medicinal plants. To develop locally relevant options for the care of this group, local knowledge, usage patterns, and conservation of medicinal plants were documented. Ethnopharmacological studies and focus group discussions in rural communities revealed an extensive knowledge of the medicinal plant resource for HIV/AIDS care. Plant parts of >85 species from 73 genera were harvested for the care of HIV/AIDS and related infections. Most plant parts were harvested unsustainably without consideration for future resource availability. An urgent need for action to ensure sustainable use was prioritized. A detailed view on plants, which is in the Phylum Angiosperms, is portrayed. The sum classification grouped plants based on whether they were herbs or shrubs, trees, and vines in ascending order [9, 10].

Medicinal Plants in Malaria Treatment

Artemisinin combination therapies (ACT) are the first line treatment for P. falciparum and chloroquine (CQ)-resistant malaria. Due to its short half-life, artemisinin must be combined with a second drug from another class to reduce the chance of resistance. ACT treatment is highly effective yet its effectiveness is reduced by barriers to its accessibility, the poor quality of drugs available, and treatment-seeking behaviour for traditional medicines [11, 12, 13, 14]. Herbal medicines are the source of most of the main groups of modern antimalarial drugs: artemisinin from the Chinese herb Artemisia annua, and quinine from Cinchona spp. bark. Efforts to increase the accessibility and quality of ACTs have had some success, yet many people in endemic areas continue to use herbal cures. Over 1000 plants around the world are being used as potential antimalarial agents, in part due to the lack of accessibility and high retail cost of ACTs. Preliminary studies reported that the secreted endophytic fungi Paraconiothyrium sp. SB-141 produced adducts related to arteannuin B. The presence of artemisinin and its endophytic fungi were confirmed both in less known plant sources usually used to treat malaria. Clinically efficacious antimalarial plants could represent a sustainable, cheaper alternative source of treatment that could be used to treat malaria and tackle resistance [15, 16, 17, 18]. Malaria is an infectious disease of great ravaging effects in the world. Recently, the World Health Organization reported that half the world's population is at risk of malaria transmission, accounting for 1 to 2 million annual deaths, predominantly affecting children in Africa. Four protozoan species of the genus Plasmodium are responsible for this infection, although the P. falciparum species is responsible for the majority of fatal cases. Malaria has been treated with quinine, chloroquine, mefloquine, and artemisinin. However, the resistant flowering plants of the Apocynaceae family have been used many years in African traditional medicine to treat malaria, febrile illnesses, and fevers. With the emergence of resistance against many current treatment regimens, the protozoans have focused attention on the hunt for new antimalarial chemotherapeutic agents from plant sources [19, 20, 21, 22].

Medicinal Plants in HIV Treatment

Human immunodeficiency virus (HIV) infection and acquired immune deficiency syndrome (AIDS) have remained one of the most challenging global health calamities since the disease was first reported over 30 years ago. While most people with HIV can now expect to live a long and healthy life if they are diagnosed early and effective anti-retroviral therapy (ART) is provided, many challenges still remain, particularly in resource-poor countries where the disease burden is highest. These challenges range from access to health care, logistics, human and infrastructure resources, high cost of therapy, to poor adherence to treatment [23, 24, 25]. HIV does not have a cure, and the antiretroviral drugs on the

market vary in their efficacy, resistance patterns, toxicity and cost. As the best-selling anti-HIV drug, tenofovir is closely watched for potential use against viral infections other than HIV because of its broad activity profile against viruses that are both orthogonal and closely related to HIV. New avenues for research are opening up as pathogens develop drug resistance. New medicines are sought after, and it is realized that natural products may provide an answer. Plants that have been traditionally used by indigenous population groups, but whose use is no longer widely known, should be investigated. Importantly, a broad-spectrum HIV-1 integrase inhibitor that is structurally related to the antiretroviral drug rilpivirine has been discovered from a plant that was traditionally used to treat HIV infection [26, 27, 28, 29, 30].

Global Case Studies

The use of traditional medicines in the management of HIV and ANC-positive individuals is well documented in Zambia. However, the knowledge on medicinal plants used to manage HIV and other diseases related to HIV/AIDS in these two districts is limited. Thus, the present study was designed to document the medicinal plants used in the management of HIV-related diseases in Livingstone and Mongu districts. An ethnobotanical survey was carried out in Livingstone and Mongu districts of Southern and Western Provinces, respectively, of Zambia. These provinces were selected based on previous ethnobotanical investigations of plants used in the management of HIV/AIDS-related diseases, after which it was revealed that traditional medicine is still widely used in these regions. For the purposes of collecting ethnobotanical data, four study sites or high-density areas (HDAs) were purposively selected. HDAs in Livingstone district included Ngwenya and Maramba and in Mongu district, Crazy Corner and Membe. During the ethnobotanical survey, focus group discussions (FGDs) were conducted with lay experts to seek their general knowledge on the use of traditional medicines in the management of HIV and other diseases related to HIV/AIDS. Fourteen traditional healers (THs) with the highest number of years of apprenticeship and practice in traditional healing participated. Ethnomedicinal plants used by traditional healers in the management of HIV/AIDS opportunistic diseases in Rundu, Kavango East Region, Namibia have been documented. Interviews were conducted with 32 respondents using a semi-structured questionnaire and the empirical use of 37 plant species in 10 families for the treatment of HIV/AIDS-associated opportunistic infections were reported [31, 32, 33, 34, 35]. The families with the highest number of species were, Asteraceae (5) followed by Fabaceae and Compositae (4). The most used plant species were contributed by: Commicarpus plumbagineus and Drimia robusta for HIV/AIDS and its associated opportunistic infections respectively. They were mostly used in decoctions and combinations of 2-3 species were frequently used [36, 37, 38, 39, 40].

Challenges In Research and Development

Many challenges significantly limit the research and development efforts related to medicinal plants for combating malaria and HIV. These challenges arise from a variety of factors, including economic restrictions, technical difficulties, and legislative hurdles that can impede progress. A lack of sufficient funding is a particularly significant barrier that hampers effective research, especially when it comes to basic research in developing countries where resources are often scarce. In this context, it is essential that stakeholders initiate and strengthen collaborative partnerships between pharmaceutical companies and local researchers, as these collaborations can lead to more innovative and effective solutions. Governmental support, as well as backing from various organizations, is crucial to encourage the formation of university-industry collaborations that can lead to significant advancements in research. Academic institutions play a vital role in this ecosystem; they need to actively share their insights concerning the safety and efficacy of lesser-known medicinal plants. To facilitate further research, institutions should utilize their existing infrastructure for thorough testing and work on forming specialized task forces that include industry support to successfully advance research into valuable clinical studies. On another note, the study of traditional knowledge often tends to lag behind, which creates a need for ethnobiological studies aimed at supporting patent applications. The process of obtaining patents can be lengthy and cumbersome, often taking years. A notable example is the patented chlamydia arrestant derived from cypress leaves, which, despite being patented, has never been utilized in practical applications. This example underscores the importance of protecting traditional knowledge from exploitation, as increased efforts in this area are essential for maintaining the integrity and value of indigenous practices. Furthermore, strict patent regulations found in developing countries complicate the existing drug development processes, rendering them lengthy and costing local companies significant resources. The commercial development of native plants hinges on adequately safeguarding local

traditions and the invaluable knowledge of practitioners regarding the beneficial properties of these plants. It is therefore imperative that policies and frameworks are established to protect these practices and promote the sustainable use of medicinal plants in the context of modern medicine and health care strategies [17, 18].

Future Directions in Research

The efforts of researchers to control malaria and HIV/AIDS using medicinal plants from Algeria offer a plethora of research avenues. Future studies in Algeria, as well as outside if appropriate, can be segmented into: Pharmacology. Few published studies encompass toxicological evaluation of the cited plant drugs. No detailed in vitro or in vivo analyses on selected drug phytocomplexes were available. Nonetheless, studies on a few isolated bioactive compounds and some selected extracts are available. Continued work in this large domain is essential so as to provide natural lead compounds. Such efforts should also focus on separation of pure products, as the plants are mostly investigated up to the level of extracts. Thus the establishment of the bioactive profiles should be useful to study the synergistic, antagonistic or additive interactions among the secondary metabolites. On account of the advanced technologies available today, investigation of natural drugs using mutagenesis in herbaceous and woody plants should expand. Discovery of new structures with noteworthy pharmacological activities could warrant the exploitation of an unexplored plant-family or -genus. The current knowledge of the medicinal plants cited here can serve as a reference for researchers interested in investigating the anti-malarial and anti-HIV characteristics of Algerian flora. As the plants are available in other parts of Africa and beyond, caution is needed in the choice of plants for testing outside Algeria. Phytochemical investigation of these plants to identify their active principles would be very useful to allow the synthesis of potentially powerful drugs derived from botanicals, while reducing pressure on endangered species. Phytochemical studies of related drug-decorated plant genera or families from different botanicals may also lead to the discovery of different compounds with the same chemical scaffolds. Bioactivity-guided isolation may permit the discovery of new active drugs from other groups of chemical compounds not shown in phytochemical studies. Biodiversity-rich African countries need to intensify their study of the medicinal flora in a manner similar to the present one [19, 20].

Ethical Considerations

The global trade in medicinal plants exceeded $60 billion annually and continues to rise, bringing with it a host of ethical issues, such as the alarming loss of biodiversity and the stark inequalities in access to valuable resources. Sustainable biodiversity management must not only consider profits but also prioritize the careful and responsible conservation of trade stocks. Moreover, preserving biocultural heritage is not just about protecting natural resources; it necessitates the equitable and fair use of plants and the traditional knowledge associated with them. Developing robust brands that promote and celebrate biocultural heritage through innovative financing and strategic partnerships is absolutely vital for ensuring that these practices thrive [41, 42, 43, 44]. It is essential to recognize biocultural sustainability amid the rapid growth of trade to effectively combat the ongoing issues of biodiversity loss and wealth inequality. Furthermore, traditional medicine systems must have fair and just access to intellectual property protections to safeguard their knowledge and practices. Creating model laws or an international convention could significantly help standardize transparent trade practices and ensure fair benefit-sharing mechanisms. There are various options available, such as species-level patents and promoting ownership of indigenous knowledge, but the urgency of this situation cannot be overstated, especially with the increasing presence of biotech firms in the market. Courts have begun to assert that corporations cannot claim patents on indigenous plant uses without obtaining proper consent, which marks a significant step toward justice. Despite the existence of various biopiracy cases, the level of accountability remains alarmingly insufficient. Initiatives like the Manioc Accord and the Biotrade Initiative aim to support the sustainable use of biodiversity, yet their voluntary nature often limits their overall effectiveness and ability to bring about meaningful change. In developed nations, the complex landscape of intellectual property protection can, at times, reinforce existing biocultural wealth, further complicating the intersection of trade, sustainability, and equity [21, 26].

Public Health Implications

African health ministries are taking steps to promote the use of medicinal plants for better health. Success hinges on commitment and support from all stakeholders health administrators, physicians, and the public. Advocacy and awareness through targeted campaigns in print and electronic media are essential to elevate this commitment. Phytochemical investigations, involving numerous scientists backed by financial

resources, are necessary to isolate and identify bioactive compounds in these plants. Collaborative biological evaluations should also be pursued, requiring significant funding from national and international bodies supporting traditional medicine projects globally. Regular updates to reviews are critical, incorporating new research on medicinal plants and their bioactive molecules. Plants like Bougainvillea, Jatropha, and Pongamia can thrive in dry, rocky areas unsuitable for agriculture, providing a cost-effective means to harvest high-quality raw medicinal materials. This approach not only generates local herbal drugs for health care but also offers self-employment opportunities for impoverished farmers, catering to market demands for herbal products [23, 24].

CONCLUSION

Medicinal plants have long served as an essential component in the fight against infectious diseases, offering a rich source of bioactive compounds with proven and potential efficacy against malaria and HIV. Despite the significant progress made in pharmaceutical interventions, the growing threat of drug resistance and limited healthcare access in many parts of the world renew the urgency to explore plant-based therapies. Traditional knowledge, deeply rooted in communities, continues to guide researchers toward promising plant candidates. However, the road to clinical validation and integration of these treatments into mainstream healthcare is fraught with scientific, ethical, and logistical challenges. To bridge this gap, multi-disciplinary collaborations between local healers, researchers, and policy-makers are critical. Investments in sustainable cultivation, ethical bioprospecting, and pharmacological studies must be prioritized. As the world seeks more inclusive, affordable, and effective health solutions, the strategic integration of traditional medicinal plants could transform public health outcomes in the ongoing battle against malaria and HIV.

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