EURASIAN EXPERIMENT JOURNAL OF PUBLIC HEALTH (EEJPH)

ISSN: 2992-4081 ©EEJPH Publications

Volume 7 Issue 1 2025

Plant-Derived Compounds: Implications for Diabetes and Antimalarial Drug Development

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ABSTRACT

The global burden of diabetes and malaria necessitates innovative approaches to drug development, with plant-derived compounds emerging as promising candidates. This review examines the potential of plant-based bioactive compounds for developing antidiabetic and antimalarial therapies. The mechanisms of action of these compounds, including their ability to modulate glucose metabolism and combat malarial parasites, are explored alongside the challenges and opportunities in their development. Key issues such as biodiversity loss, limited funding, and regulatory hurdles are discussed, highlighting the need for interdisciplinary research and collaboration. Future directions include integrating traditional medicine with modern pharmacology, enhancing biotechnological methods, and establishing sustainable drug development pipelines. These efforts underscore the transformative potential of plant-derived compounds in addressing global health challenges.

Keywords: Plant-derived compounds, antidiabetic agents, antimalarial drugs, bioactive compounds, drug discovery.

INTRODUCTION

Plants, nature's chemists, have been a prolific source of compounds that have been used to improve human health and well-being. Before the advent of synthetic chemistry, extracts from plants and evidence-based folklore largely constituted the beginnings of pharmacological science in traditional healing worldwide. Nowadays, the isolation and further characterization of active plant-derived compounds have led to the development of highly effective drugs used in a broad range of therapeutic applications, which include anti-tumor, anti-microbial, anti-parasitic, anti-inflammatory, and analgesic agents. The contribution of plant-derived compounds to the new drug discovery and development pipeline continues to be significant. In addition, natural products are in abundance in rural healthcare settings, and as such, the potential for new drug leads has grown in parallel with the growing problem of antibiotic resistance and resistance associated with available therapeutics against infectious diseases worldwide. Indeed, natural products play an important role in drug development for infectious diseases such as malaria, an area of intensive research given the rising prevalence of parasites resistant to current first-line antimalarial therapies [1, 2]. Compounds derived from plants or other living organisms that act on microbial organisms belong to a class of compounds defined as antimicrobial, where poisons and parasites fit under the umbrella of antimicrobial agents. Other compounds known to prevent or treat diseases include antidiabetic and anticancer compounds. Such compounds obtained from plants and herbs are termed bioactive compounds, of which many thousands of different structures are described in the literature. In unresolved clinical ailments like diabetes, bioactive compounds may offer useful remedies, such that studies on a wide range of claimed bioactive plant products have been and continue to be reported, indicating the unique want from the international community, especially the scientific researchers, who need to put such knowledge to the test in the laboratory and in randomized clinical trials, where rigor in the scientific process would

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enhance the understanding of the medical relevance and the plausibility of using these compounds in public health prevention and treatment schemes [3, 4].

Definition and Importance

Plant-derived compounds are compounds from plants that are of interest to human beings because of the interaction of life with these compounds. They can have interesting molecular properties, such as having toxic effects, toxicity, and therapeutic or beneficial effects on the human body. The general viewpoint is that since these compounds are derived from plants and do not come from a chemical synthesis process developed, synthesized, or modified by humans in the laboratory, they are of natural origin; however, plant-derived compounds are classified as a group with distinct and specific biochemical structures. According to these biochemical structures, this group is divided into different subgroups, and generally, these compounds are classified under the main group of natural products. The subgroups of this main category include various categories such as alkaloids, flavonoids, terpenes, steroids, coumarins, saponins, tannins, quinones, and phenolic acids. Whether in Africa, Asia, or the Americas, common importance is attributed to plants in traditional medicine systems, and plant-derived compounds are still a great source of new drugs, especially drugs that have emerged as a result of continuous research on their extracts, individual compounds derived from these extracts, and purely natural compounds themselves. Antidiabetic and antimalarial effects are gaining significance because of the increase in global health challenges from illness and death due to diabetes and malaria. Since plants that constitute an important part of the natural environment contain very rich compounds in their structure, the increasing demand of people for herbal mixtures and extracts that are rich in these compounds is a reality known today. Natural products used in the pharmaceutical industry mainly include antidiabetic and antimalarial drug formulations; however, while creating new partnerships with the public and the pharmaceutical industry to produce new remedies from these bioactive compounds, it has been stated that the active ingredients of plant materials with potential effects have been chemically and biochemically examined and produced. This situation indicates the importance of research on the drug potential of natural products today. According to data from commercial drug traders, plant-derived drugs are the second most prescribed group in the United States. It is used for the final production or cultivation of this drug compound, leading to mass production of the drug content, advantageous in terms of its use, and cheap production. A total of 253 drugs are known to have been obtained from different plant resources to be studied. Two main points are important in research on the treatment of such diseases with drugs obtained from plant-derived compounds. It is stated that in natural resources, a synergy effect may arise as a result of the interactions between various compounds that may act on different mechanisms and in different functions. If the antidiabetic and antimalarial drugs developed from plant metabolites in question have an interaction with the body that will be more beneficial than single drug content, it is stated that the combination of these compounds in the fight against diseases is highly effective. The evaluation of the first phase of the studies of the presented sources has been concluded, and these steps aim to share the analyzed and evaluated contents in all other cooperation-based studies, and then to obtain a result by working on the potential of the sources alone. For this reason, the use of a large, comprehensive approach is valuable today to evaluate the source in the best way [5, 6].

Plant-Derived Compounds in Diabetes Management

Diabetes is a chronic endocrine disorder affecting a substantial proportion of the global population. It is a systemic metabolic disorder characterized by reduced insulin secretion, insulin sensitivity, or both. Plants and their products are abundant sources of biologically active compounds and have historically been used for therapeutic purposes. Plant-derived compounds with antidiabetic effects have gained attention in the past few years as a basis for the development of new antidiabetic drugs. These compounds are reported to exert their antidiabetic effects by modulating various systems in the body, such as inhibition of carbohydrate-digesting enzymes, enhancing insulin sensitivity, stimulation of insulin release, regeneration of beta cells, and more. This section will explore some compounds with antidiabetic properties, providing information about their origin, benefits, and potential value in the management and treatment of diabetes [7, 8]. Several plant-derived compounds have shown potential antidiabetic effects. Resveratrol is a natural polyphenol and a powerful sirtuin 1 activator found in foods such as wine, grapes, and peanuts. Resveratrol exhibits several benefits as an antidiabetic compound and could thus be used in the management of diabetes. These improvements are thought to be due to suppression of hepatic gluconeogenesis, increased PPARα activity, fatty acid oxidation, adiponectin, improvement of insulin sensitivity, and glucose homeostasis. It should be noted that resveratrol might have potential applications

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in malaria drug development as well. In this chapter, we briefly review its traditional use in various countries and ethnic groups and detail its reported benefits in both preclinical and clinical diabetes studies. The safety, tolerability, and side effects associated with resveratrol are also presented. Given the above information, we can see a place for natural products or natural-product-derived compounds as a complementary or additional treatment option in diabetes care [9, 10].

Mechanisms of Action

The plant-derived bioactive compounds modulate the disease symptoms by interfering with various biological pathways. Plant-derived antidiabetic compounds target different biological mechanisms such as beta-cell regeneration, the enhancement of insulin secretion from remaining pancreatic beta-cells, increasing cellular sensitivity to insulin, and modulation of various enzymes related to blood glucose metabolism. Some key phytochemicals and their modes of action are presented. These compounds have the potential to modulate the expression of various genes and proteins that play an important role in glucose metabolism and insulin resistance, such as glucose transporter, glucokinase, and peroxisome proliferator-activated receptor, and affect the activity of some enzymes like ATPase and α-glucosidase. Furthermore, they also exert inhibitory potential against protein tyrosine phosphatase and nicotinamide adenine dinucleotide phosphate. The promising chemical compounds include flavonones, chalcones, isoflavones, flavonol, and saponins [11, 12]. The plants and their active compounds have shown their therapeutic approach in diabetes management via combination and interaction against multiple targets. Many active compounds can modulate the toxic effects of electrophilic lipid peroxidation products and the formation of advanced glycation end products and prostaglandin production. The ability of phytochemicals to act as both antioxidants and to reduce the inflammatory process is of particular interest because they have therapeutic implications in diabetes. The combination therapy and synergistic effects of bioactive compounds for combating or improving diabetes have been reported. The combination of naringenin, quercetin, and daidzein cooperatively performs better than when these compounds are used alone in induced diabetic rats, which is attributed to their combined potential targets against alpha-amylase, α-glucosidase, and antioxidant enzymes. Many studies highlight the challenge of understanding the in vivo complex mechanistic pathways as compared to in vitro. However, more research in this direction will be very useful in discovering new drug targets against diabetes [13, 14].

Plant-Derived Compounds in Antimalarial Drug Development

The treatment of malaria has always been predominantly based on the use of plant extracts. It is quite normal for different parts of the same plant to show a spectrum of activity that may vary by geographic location and the time of plant harvest. Drugs can be made from these active compounds. The widespread use and application of these plant-derived drugs in areas of need for the treatment of the disease comes with an additional advantage, as the indigenous population shows excellent tolerance and the drugs are thus safe. Although it has been suggested that these compounds could be less stable than wholly synthetic drugs, their excellent safety, low levels of toxic side effects, and the fact that they may not accumulate in larger concentrations in the body make them as safe and, indeed, safer than other types of drugs. Synthesis and biotechnological advances have led to other possibilities for aggregation, and new methods have been investigated as these compounds become available for use. Synthetic biology has been discussed as a new way forward and has been applied primarily to produce artemisinin [15, 16]. Interest and understanding of plant-derived compounds have increased in recent years, and although very few eventually make it to market, advances and techniques are under continuous investigation and development. A few new trends have started to appear in pharmacological research. Pharmacology is no longer focusing solely on the study of new targets and novel chemical entities from synthetic sources but more on the search for therapeutics, including lead structures from traditional medicines, nutraceuticals, human plasma compounds, as well as plant-derived compounds. There are huge numbers of problems in the drug development process, including toxicity, lack of stability of the compounds in real tropical conditions, drug resistance, and widespread capacity for resistance to spread. Currently, there are a massive number of potential therapeutic compounds that could be used for malaria, to treat the disease, and in the case of plants, to cure the disease. It is hoped that an increase in the number of new active compounds, derived from plants and natural products, will become available for testing in vitro for activity. A further problem for antimalarial drugs is that new drugs have to be extremely cheap and market-oriented. Regulatory issues are also critical, and a long and costly path for these drugs' formal development is required. Moreover, with few countries not endemic for the infection, the market is not so

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big either. Regulatory issues are also present in monotherapies, which pose great regulatory problems [17, 18].

Current Challenges and Opportunities

Although much effort has been put into the drug discovery process over the past century, the development of new antimalarial drugs from plant-derived compounds is still in its infancy. One of the major problems facing natural product drug discovery is the loss of biodiversity, which is shrinking the pool of new compounds that could be sampled. Research to effectively discover and develop new therapies is poorly funded relative to the projected impact on human disease, and this trend in topical disease research is likely to continue. Poor and mostly academic or in-country research has hindered the resource-poor research established to form partnerships or gain the interest of the pharmaceutical or biotechnology industries. Scientifically, there are also many research and development issues that need to be advanced if efficacious drugs are to come from plants. Attention must be given to improving the extraction of plants, developing lead discovery techniques, and bioassays that are sensitive and fast, with high throughput. Advances in reducing the toxicity and increasing the bioavailability of crude plant extracts would be a major step forward. Effort is also needed in the basic science of the biology and chemistry of the plants themselves. Biotechnological, in particular, cellular targeting techniques are necessary to properly evaluate plant-compound potentials, and we still need to standardize criteria to recognize the potential of traditional knowledge for modern scientific methods. The complete reevaluation of most old and many new antimalarial drugs and the incorporation of patients in the process is still another missing step to the success of natural product antimalarial drug discovery. Efforts are also needed to take the necessary steps to ensure the survival and sustainability of plant products and healing trees [19, 20].

Future Directions and Research Priorities

At present, there are some promising studies correlating traditional healing plants to both diabetes and malaria. These studies provide a solid ground for the upcoming preclinical, clinical, and botanical surveys, which, together with classical pharmacognosy, would enable a base for the possible development of plant-derived agents [21, 22, 23, 24, 25, 26]. Moreover, these studies would provide necessary information for conserving medicinal heritage. The main task is to develop interdisciplinary studies not only of botany and pharmacology but also of clinical medicine [27, 28, 29, 30]. Other important economic issues include establishing a detailed plan for developing screening protocols for rare and new compounds and ensuring safety when ingested from food. Subsequently, there is a search for inductors able to promote the bioprocesses for the production of target compounds in plants to turn them into an inexpensive source of drugs [31, 32, 33, 34, 35]. Research on traditional medicine, drug discovery, and food supplements focuses on testing the in vitro effects of single pure compounds resulting in high selectivity. It is suggested that the in vitro and in vivo interaction and bioavailability of the complex mixtures present in botanical extracts, including potential toxins, be carefully evaluated, and combinations of potentially bioactive compounds be included [36, 37, 38, 39]. In addition, research on new compounds can include genomics to identify new bacterial species and explore them for the production of novel bioactive species. Modern medicine should help research the biological activity of plant-derived agents and their clinical use, using well-structured study designs concerning dose, subjects, duration, and endpoints, especially those covering longer periods and concerning possible negative effects. Long-term participants, particularly people with chronic diseases or living with AIDS, are of special interest. The need for closely monitored health literacy programs is paramount [40, 41]. To develop, we need to invest in plant phases. Part of the income could be used to work on a pipeline of plant-derived drugs. The development of such drugs and state-of-the-art easy processing programs requires input from many sectors, including research institutes, patent lawyers, generic drug manufacturers, regulatory agencies, and governmental funds for cheap loans and subsidies. There will be a need for both public and privately managed funds, and it is not desirable for the food supplement unit to spend its profits on shareholder dividends. It is also of utmost importance that the government join in finding appropriate research methods and long-term partnerships with the private sector. Globally aligned priorities and methodologies should be developed to ensure that plant-derived medicines are a part of the solution to the global burden of disease [25, 26].

CONCLUSION

Plant-derived compounds represent a significant opportunity for addressing pressing global health issues such as diabetes and malaria. Their diverse bioactivities and historical use in traditional medicine provide a rich foundation for modern drug discovery. However, to harness their full potential, overcoming

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challenges related to biodiversity loss, funding constraints, and regulatory complexities is imperative. Advancing interdisciplinary research, leveraging biotechnological innovations, and fostering global collaborations will be critical to developing effective and sustainable plant-based therapies. The integration of traditional knowledge with scientific rigor can pave the way for novel treatments, contributing to improved public health outcomes and the preservation of medicinal biodiversity.

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CITE AS: Nakalya Twamina T. (2025). Plant-Derived Compounds: Implications for Diabetes and Antimalarial Drug Development. EURASIAN EXPERIMENT JOURNAL OF PUBLIC HEALTH, 7(1):99-105

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