

Harnessing the power of phytopharmaceuticals in chronic disease management: Prevention and treatment



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Abstract

Globally, chronic illnesses like cancer, diabetes, and cardiovascular disease are becoming the biggest health burdens. Despite their effectiveness, conventional therapy approaches frequently have serious side effects and are not always suitable for long-term care. Because of their promise to offer safer and more efficient chronic illness care, natural alternatives specifically, phytopharmaceuticals have gained attention. Bioactive substances derived from plants, known as phytopharmaceuticals, provide a variety of pharmacological advantages, such as immunomodulatory, antioxidant, and anti-inflammatory qualities. The mechanisms of action, instances of particular phytochemicals, and difficulties in bringing these compounds to clinical usage are the main topics of this review, which looks at the function of phytopharmaceuticals in the prevention and treatment of chronic diseases.

Keywords: Phytopharmaceuticals, Chronic Disease, Alkaloids, Flavonoids, Polyphenols, Diabetes, Cardiovascular Disease

1. Introduction

Chronic diseases such as cardiovascular disease, diabetes, cancer, and neurodegenerative disorders pose a substantial health burden worldwide. The World Health Organization (WHO) reports that non-communicable diseases (NCDs) are the cause of more than 70% of deaths worldwide. Among these, cardiovascular diseases stand out, making up almost 31% of all deaths (1). While Pharmaceutical drugs have greatly improved the treatment of these illnesses, limitations like side effects, drug resistance, and limited effectiveness in halting disease progression have prompted scientists to explore natural alternatives. Phytopharmaceuticals, which are bioactive compounds obtained from plants, are increasingly being recognized as promising tools for preventing and treating chronic diseases. They provide a wide range of therapeutic advantages while causing fewer side effects (2). Phytopharmaceuticals focus on various pathways and biological processes such as oxidative stress, inflammation, and immune modulation. These are crucial factors in the development of chronic diseases. By impacting these pathways, phytopharmaceuticals both prevent the onset of disease and enhance disease management, leading to an improved quality of life for those affected.

2. Mechanism of action of phytopharmaceuticals

Phytopharmaceuticals work by engaging in a range of mechanisms crucial for preventing and managing chronic diseases. These mechanisms consist of antioxidant activity, anti-inflammatory effects, immunomodulation, and regulation of lipid and glucose metabolism.

2.1. Antioxidant activity

Oxidative stress, caused by an imbalance between free radicals and antioxidants, plays a crucial role in the onset and advancement of chronic conditions such as cardiovascular disease, diabetes, and cancer. Phytochemicals such as flavonoids, polyphenols, and carotenoids have powerful antioxidant properties. They work by scavenging free radicals and reducing oxidative stress. For instance, curcumin, extracted from turmeric, exhibits strong antioxidant properties, safeguarding against cellular harm linked to neurodegenerative conditions and specific types of cancer (3,4). Antioxidants work to neutralize reactive oxygen species (ROS) and reactive nitrogen species (RNS), two culprits involved in cell damage and the onset of chronic inflammation. By bolstering cellular antioxidant defenses, phytopharmaceuticals have the potential to postpone the development of chronic illnesses or decelerate their advancement. This can lessen the strain on healthcare systems and enhance patient results.

2.2. Anti-inflammatory effect

Chronic inflammation is widely recognized as a major contributor to various chronic conditions such as cardiovascular disease, diabetes, and arthritis. Inflammation is controlled by a variety of pro-inflammatory cytokines and enzymes, such as cyclooxygenase-2 (COX-2) and inducible nitric oxide synthase (iNOS). Phytochemicals such as resveratrol, found in grapes, and quercetin, a flavonoid found in apples and onions, regulate these inflammatory pathways by inhibiting pro-inflammatory mediators. The anti-inflammatory effects can be especially advantageous in the prevention and management of diseases characterized by inflammation, such as cardiovascular disease and arthritis (5). Curcumin, a phytochemical known for its anti-inflammatory properties, has displayed promise in reducing the activity of nuclear factor kappa B (NF- κ B), a transcription factor that controls the production of different inflammatory cytokines. Engaging in such activity renders curcumin an appealing therapeutic option for inflammatory conditions; nonetheless, bioavailability hurdles persist.

2.3. Immunomodulation

Immunomodulatory properties of phytopharmaceuticals assist in boosting the immune system's capacity to combat infections, cancer, and various chronic ailments. Ginsenosides from ginseng are known to enhance immune responses, thus aiding the body's defense against abnormal cell growth linked to cancer (6). Phytochemicals, such as echinacea, have a long history of traditional use due to their immune-boosting properties. Studies suggest that they could improve both humoral and cellular immunity. These compounds can be especially helpful in preventing infections that worsen chronic disease symptoms or advance disease progression.

2.4. Regulation of lipid and glucose metabolism

Several phytochemicals, like berberine and epigallocatechin gallate (EGCG) found in green tea, possess beneficial effects on lipid and glucose metabolism. These properties make them valuable tools in the management of metabolic disorders, including diabetes and obesity. Berberine, for example, triggers AMP-activated protein kinase (AMPK) which is a vital controller of glucose and lipid metabolism. This action enhances insulin sensitivity and decreases blood lipid levels (7). Aside from berberine, green tea catechins have also been proven to reduce LDL cholesterol and body weight, enhancing metabolic well-being. Phytopharmaceuticals possess qualities that make them an appealing choice for addressing metabolic syndrome, a group of conditions that elevate the chances of developing cardiovascular disease and diabetes.

3. Phytopharmaceuticals in managing specific chronic diseases

3.1. Cardiovascular disease

Cardiovascular diseases (CVDs) are the primary cause of death worldwide, resulting in millions of fatalities each year. Phytopharmaceuticals such as omega-3 fatty acids, resveratrol, and garlic extract have proven to have beneficial effects on the heart, such as lowering blood pressure, enhancing endothelial function, and reducing cholesterol levels. Omega-3 fatty acids, which are abundant in flaxseed and fish oil, have been shown to effectively lower triglyceride levels and enhance cardiovascular well-being (8).

Resveratrol, a polyphenol present in grapes, is linked to enhanced vascular function and lower cardiovascular disease (CVD) risk due to its anti-inflammatory and antioxidant qualities. Garlic extract, which contains sulfur compounds such as allicin, has demonstrated promise in lowering blood pressure and enhancing cholesterol levels, providing a supplementary option to traditional cardiovascular disease therapies (9).

3.2. Diabetes and metabolic syndrome

The prevalence of diabetes and metabolic syndrome has increased significantly in recent decades, influenced by lifestyle changes and dietary habits. Phytopharmaceuticals like curcumin, berberine, and green tea catechins have been researched for their ability to control glucose metabolism and enhance insulin sensitivity. Curcumin, specifically, boosts insulin signaling pathways, assisting in the regulation of blood glucose levels (10). Berberine has demonstrated its ability to enhance lipid profiles and lower fasting blood glucose levels, establishing it as a beneficial phytochemical for managing diabetes. In addition to that, green tea catechins help diminish oxidative stress and inflammation. This plays a vital role in improving the handling of metabolic syndrome and its related risks (11).

3.3. Cancer prevention and management

Cancer is a major global threat, characterized by intricate mechanisms that encompass various molecular and cellular processes. Phytopharmaceuticals are showing great promise for both cancer prevention and treatment, thanks to their ability to target multiple mechanisms. For instance, EGCG, a polyphenol present in green tea, has demonstrated the ability to hinder tumor growth through triggering apoptosis and obstructing angiogenesis (12). Sulforaphane, a compound discovered in broccoli, demonstrates anti-carcinogenic characteristics as it affects phase II detoxification enzymes and triggers cell cycle arrest in cancer cells. These compounds, when used alongside traditional chemotherapy, can have synergistic effects, possibly enhancing treatment results with reduced side effects (13).

3.4. Neurodegenerative disease

The increase in neurodegenerative conditions such as Alzheimer's and Parkinson's has led researchers to investigate the neuroprotective benefits of phytopharmaceuticals. Curcumin, resveratrol, and ginkgo biloba extracts demonstrate potential in reducing oxidative stress, by inhibiting beta-amyloid plaque formation, and improving cognitive function (14). Resveratrol, in particular, has been examined for its potential to activate sirtuins, which are proteins responsible for cellular stress response and aging. These mechanisms hint at the possibility of phytopharmaceuticals contributing to the delay of onset and progression of neurodegenerative diseases, providing a natural method for maintaining cognitive health (15).

3.5. Respiratory disease

The management of diseases related to the respiratory system has recently developed much interest in the use of phytopharmaceuticals with their diverse bioactive constituents, having both anti-inflammatory and bronchodilatory effects. Anti-bacterial properties do also help in improving lung functions with respiratory symptoms by using plants like *Glycyrrhiza glabra*, liquorice; *Adhatoda vasica*, vasaaka; *Zingiber officinale*, ginger; and *Curcuma longa*, turmeric. *Glycyrrhiza glabra* has anti-inflammatory actions that inhibit pro-inflammatory cytokines, useful in treating chronic obstructive pulmonary disease and asthma (16). *Adhatoda vasica* contains vasicine, a bronchodilator and expectorant that reduces mucus formation, being beneficial in the treatment of chronic bronchitis (17). In addition, *Zingiber officinale* possesses very potent anti-inflammatory and antioxidant activities, and it reduces airway hyper reactivity and symptoms of asthma (18). *Curcuma longa* contains curcumin, which has been widely known for its broad spectrum of anti-inflammatory activity against allergy and inflammatory responses in respiratory diseases (19). A number of phytopharmaceuticals possess fewer side effects than drugs and can be used as adjunct treatments to improve the effectiveness of therapy and adherence in patients.

4. Challenges in the development of phytopharmaceuticals

Although their potential is promising, various obstacles must be overcome for them to establish as

conventional therapeutic

4.1. Bioavailability and absorption

One significant drawback of phytopharmaceuticals is their limited bioavailability, potentially impeding their therapeutic effectiveness. One example would be curcumin, which has limited absorption and quick metabolism, leading to minimal overall effectiveness. Various strategies, including nanoencapsulation and combining with bioenhancers such as piperine, have been researched to enhance the bioavailability of phytochemicals, thereby boosting their efficacy in clinical applications (20).

4.2. Standardization and quality control

Phytopharmaceuticals tend to exhibit variations in their chemical composition because of distinctions in plant species, geographical sources, and extraction techniques. The variability involved makes standardization more complex, thereby posing a challenge in guaranteeing consistent effectiveness and safety. Advances in extraction and quality control techniques are essential to address these challenges, facilitating the development of dependable phytopharmaceutical formulations (21).

4.3. Clinical evidence and regulatory challenges

Despite promising results in preclinical studies on phytopharmaceuticals, there exists a notable gap in robust clinical evidence. Large-scale, randomized clinical trials are crucial for determining the effectiveness and safety of phytopharmaceuticals in the management of chronic diseases. Moreover, the regulatory frameworks for phytopharmaceuticals differ greatly between countries, posing a challenge in obtaining approval for clinical applications. In contrast to traditional medications that undergo thorough testing via established regulatory procedures, phytopharmaceuticals frequently encounter varying levels of regulation. In numerous regions, they are classified as supplements instead of drugs. This implies that they might not have to undergo rigorous efficacy and safety testing requirements. The absence of consistent regulatory oversight impacts both consumer confidence and the capacity of healthcare providers to confidently endorse phytopharmaceuticals (22).

5. Future directions in phytopharmaceuticals research

As interest in this field grows, various avenues in research and development show promise in improving the effectiveness of these compounds in managing chronic diseases:

5.1. Advancement in drug delivery system

One of the most promising approaches to enhance the effectiveness of phytopharmaceuticals involves the creation of innovative drug delivery systems. Nanotechnology-based delivery methods, such as liposomes, nanoparticles, and micelles, have the ability to improve the bioavailability and stability of phytochemicals. These delivery systems protect phytochemicals from deterioration in the gastrointestinal tract and enhance their absorption in specific tissues. For example, nano-encapsulated curcumin has demonstrated increased stability and bioavailability, resulting in improved effectiveness in animal models of cancer and neurodegenerative diseases (23).

Moreover, crafting specialized delivery mechanisms to precisely target phytochemicals towards affected tissues can minimize adverse reactions and enhance treatment effectiveness. These specialized methods hold particular value in the field of cancer treatment. Precise targeting minimizes harm to healthy cells while amplifying the anti-cancer properties of phytopharmaceuticals.

5.2. Exploring synergistic combinations

When phytochemicals are combined with conventional pharmaceuticals or other phytochemicals, they can create synergistic effects that improve therapeutic results. Studies have indicated that when curcumin is combined with anti-inflammatory medications such as non-steroidal

anti-inflammatory drugs (NSAIDs), it can improve pain relief and decrease the necessary dosage of the standard drug, thereby reducing unwanted side effects (24). In a similar vein, the pairing of resveratrol with chemotherapeutic drugs has been shown to enhance the effectiveness of cancer treatment and decrease toxicity (25). Researching the pharmacodynamics and pharmacokinetics of such combinations could lead to the development of more effective, multi-targeted therapies that capitalize on the advantages of both synthetic drugs and natural compounds.

5.3. Phytochemical genomics and precision medicines

Phytochemical genomics is an up-and-coming area of study that delves into the impact of genetic factors on how individuals react to phytochemicals. This has the potential to tailor phytopharmaceutical treatments to each person's unique needs. Understanding individual genetic profiles could aid in identifying patients more likely to benefit from specific phytochemicals, ultimately optimizing therapeutic outcomes. Certain genetic variations can influence the body's metabolism or response to substances like resveratrol or curcumin, which can impact their effectiveness in preventing and treating diseases (26).

Incorporating precision medicine into phytopharmaceutical research has the potential to enhance treatment approaches by making them more tailored and personalized. This can ultimately improve patient outcomes and decrease the likelihood of adverse effects.

5.4. Integrating the wealth of traditional and modern medical knowledge

Traditional medicinal practices, including Ayurveda, Traditional Chinese Medicine (TCM), and Indigenous wisdom, have a history of utilizing medicinal plants for managing chronic health conditions. Modern phytopharmaceutical research can benefit immensely by merging traditional knowledge with scientific methods. This integration helps in pinpointing plants and compounds with a proven historical efficacy. Integrative approaches can speed up the discovery of potential therapeutic compounds, all the while aligning traditional knowledge with scientific principles (27).

Moreover, partnering with traditional healers and ethnobotanists has the potential to enrich phytopharmaceutical studies by bringing to light plant species and preparation techniques that could be easily disregarded in contemporary pharmacological research. Phytopharmaceuticals present an intriguing and largely unexplored potential for the prevention and management of chronic illnesses.

6. Conclusion

Phytochemicals offer a valuable complement or alternative to conventional therapies with their multi-targeted mechanisms of action. These include antioxidant, anti-inflammatory, immunomodulatory, and metabolic-regulating effects. However, certain challenges like inadequate bioavailability, absence of standardization, and limited clinical evidence are currently impeding their extensive utilization in clinical settings. Advancements in drug delivery systems, standardization methods, and personalized approaches can overcome these obstacles, paving the path for enhanced and available phytopharmaceutical solutions. Additionally, it is crucial to blend traditional knowledge with meticulous clinical trials and implement clear regulatory frameworks. These steps are essential for advancing the safe and efficient utilization of phytopharmaceuticals in managing chronic diseases. Research is ongoing, and it is becoming more apparent that phytopharmaceuticals hold promise in enhancing the health outcomes of patients with chronic diseases.

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