

REVIEW ARTICLE

The Role of Herbal Medicine in Combating Chronic Diseases: Mechanisms and Therapeutic Potential

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ABSTRACT

Chronic illnesses like cardiovascular disease, diabetes, cancer, and neurodegenerative diseases have emerged as major global health concerns, responsible for high rates of morbidity and mortality. With an increase in the healthcare burden, interest has developed in complementary and alternative therapies, one of which has been herbal medicine. Herbal medicines, derived from a vast array of plants, contain bioactive molecules that have shown promise in the prevention and treatment of chronic diseases. The review explains how herbal medicines perform their therapeutic roles via antioxidant, anti-inflammatory, and immunomodulatory activities. It also explains the molecular mechanisms behind the efficacy of herbal medicines, including gene expression and enzyme modulation. The therapeutic potential of various herbs in the management of chronic diseases such as hypertension, diabetes, cancer, and arthritis is discussed, with clinical evidence supporting their use. Despite the promising findings, concerns regarding lack of standardization, toxicity, and herb-drug interactions remain paramount. The future direction must be to resolve these concerns through definitive clinical trials, improving quality control, and the integration of herbal medicine into conventional health systems. Herbal medicines, in general, are a valuable resource for the therapy of chronic diseases, and their therapeutic usefulness is far from being depleted.

Keywords: Herbal Medicine, Chronic Diseases, Bioactive Compounds, Therapeutic Potential, Molecular Mechanisms

International Journal of Human and Health Sciences Vol. 09 No. 02 April'25

DOI: <http://dx.doi.org/10.31344/ijhhs.v9i2.816>

INTRODUCTION

Chronic diseases, including diabetes, hypertension, cancer, and cardiovascular disease, have become the leading causes of morbidity and mortality worldwide, placing an enormous burden on health systems globally. According to the World Health Organization (WHO), chronic diseases account for approximately 71% of all deaths worldwide, with cardiovascular diseases leading in the list of deaths¹. The increasing prevalence of these disorders is closely linked with lifestyle changes such as unhealthy diet, physical inactivity, and environmental factors. Since chronic diseases entail significant economic, social, and psychological expenses for individuals and society, the need for effective and sustainable treatment options has never been more urgent². Conventional treatments are generally symptomatic, yet these diseases are

frequently chronic and result in complications, emphasizing the necessity for complementary or alternative treatment strategies.

Herbal medicine, with a foundation in centuries of tradition, is increasingly recognized as playing a part in chronic disease management and prevention. Herbal drugs are derived from plants and contain bioactive molecules, which have been shown to possess anti-inflammatory, antioxidant, anticancer, and antidiabetic activities, making them perfect candidates for the therapy of a vast array of chronic diseases³. Herbal medicine has been utilized in many cultures to promote general health and happiness, and modern research continues to validate the therapeutic potential of many plant molecules. The resurgence of interest in herbal medicine is due partly to its natural nature and to increasing concern over the side effects and limitations of synthetic drugs, which

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at best bring temporary relief and carry with them dangers of dependency or side effects⁴. Herbal medicines exert their medicinal effects by modulating molecular mechanisms in various ways. These include the modulation of key signaling pathways involved in inflammation, oxidative stress, apoptosis, and immune response. For instance, phytochemicals like flavonoids and alkaloids were shown to possess potent antioxidant and anti-inflammatory properties that can improve the underlying pathophysiology of diseases such as diabetes and cardiovascular diseases⁵. Other phytochemicals can also bind to certain enzymes or transcription factors, thus influencing gene expression pertinent to disease⁶. Explaining such mechanisms can help to identify the most effective herbal remedies for specific disorders and to create new treatments that blend herbal and orthodox medicines.

Despite the therapeutic potential of herbal medicine, its integration into mainstream medicine is faced with many challenges. A major hindrance is the lack of consistency in the quality and composition of herbal preparations, which can vary depending on plant species, geographic location, and extraction methods⁷. Furthermore, the possibility of herb-drug interactions and toxicity of certain herbal constituents must be considered, especially when used in conjunction with conventional medications⁸. To get around these challenges, rigorous clinical trials and standardization of herbal preparations are required. Future research must also focus on elucidating the pharmacokinetics and pharmacodynamics of herbal compounds so that they can be used safely and effectively in the clinic. The aim of this review is to explain the mechanisms through which herbal remedies exert their therapeutic effects in the treatment of chronic diseases. By revealing the bioactive molecules in plants and their precise molecular mechanisms, this review will clarify how herbal medicine can complement or enhance standard treatments. Furthermore, the review will reveal how herbal medicine may regulate the origins of chronic diseases, i.e., inflammation, oxidative stress, and metabolic imbalances. By providing an in-depth examination of current research, this paper will provide a comprehensive review of the effectiveness of herbal medicine in the management of chronic disease, and how it serves to improve patients' quality of life and reduce the burden on healthcare systems.

BURDEN OF CHRONIC DISEASES

Chronic diseases are the conditions with a duration of a year or longer and either requiring repeated medical treatment or limiting activity of daily living. These diseases primarily include cardiovascular diseases (CVD), diabetes, hypertension, cancer, chronic respiratory diseases, and neurological disorders. Chronic diseases are the primary source of morbidity and mortality worldwide, and the prevalence has risen exponentially due to lifestyle modification, aging population, and the environment. In Bangladesh, for instance, the prevalence of NCDs such as diabetes, hypertension, and CVD is increasingly on the rise due to urbanization, nutrition transition, and physical inactivity⁹. The global rise in chronic diseases has opened the demand for prevention strategies, novel therapies, and public health interventions.

HEALTH AND SOCIOECONOMIC INFLUENCE

The influence of chronic diseases on health is serious, involving significant loss of quality of life, increased mortality, and enormous expense. Chronic diseases, besides causing misery, also lead to disability that is persistent, restricting individuals' workforce and activities of daily living. NCDs are responsible for nearly 60% of all deaths in Bangladesh and place disproportionate burdens on poorly funded health systems there¹⁰. To add to this, high utilization of the attendant medical interventions, medicines, and prolonged treatment complicate the attendant expenditure burden further to be borne by individuals and by the public purse. The socio-economic impact is also felt in the form of decreased productivity, as individuals with chronic diseases lose their ability to work. Additionally, indirect costs of chronic diseases, such as loss of income, caregiver expenses, and family expenses, can create a poverty cycle that is difficult to escape. Low-income groups are also disproportionately affected by chronic diseases, generating massive country-level health inequities. Low socioeconomic status of the majority of individuals in Bangladesh prevents them from accessing proper care, preventive care, and necessary drugs. It leads to higher morbidity and mortality among those categories of individuals, perpetuating health inequalities in society¹¹.

The urbanization of Bangladesh has been extremely rapid, and it leads to unhealthy lifestyles on the basis of unbalanced diets, physical inactivity, and higher stress, all of which are determinants of risk for the development of chronic diseases. As a result, chronic diseases pose a public health and socioeconomic development issue for the nation.

The economic impact of chronic diseases is not only restricted to health costs but also comprises lost productivity due to premature mortality and disability. In Bangladesh, a large proportion of the nation's GDP goes into the treatment of chronic diseases, with most of the cost of healthcare being paid through out-of-pocket expenditures¹². The financial burden is particularly worst among poor households that may not be in a position to meet medical interventions and extensive care, which in turn generates disparities in health outcomes. Chronic diseases also lead to a greater demand for healthcare facilities and trained medical staff, requiring significant investments from the government and private sector to address the growing public health concern (Table 1).

Table 1: Prevalence, Health Impact, and Socioeconomic Burden of Chronic Diseases

Chronic Disease	Prevalence	Health Impact	Socioeconomic Impact
Cardiovascular Diseases (CVD) ⁹	Increasing globally, particularly in low- and middle-income countries (LMICs)	Leads to premature mortality, long-term disability	High healthcare costs, productivity loss, high treatment costs
Diabetes ¹⁰	Rising in Bangladesh and other developing countries	Impacts blood sugar regulation, leading to complications like blindness, kidney failure	Increased out-of-pocket expenditure, economic loss from disability
Hypertension ¹¹	Prevalence rising due to lifestyle factors	Causes stroke, heart attack, and renal failure	Direct healthcare costs, long-term care needs, productivity loss
Cancer ¹²	Higher incidence in urbanized populations	Decreased life expectancy, high morbidity	High treatment costs, financial burden on families
Chronic Respiratory Diseases ¹³	Increased incidence linked to air pollution and smoking	Impaired lung function, breathing difficulties	Increased hospital visits, cost of long-term medication

HERBAL MEDICINE AND ITS HISTORY

Herbal medicine has a long and diverse history, dating back thousands of years in the majority of societies across the globe. The Egyptians, Chinese, Indians, Greeks, and Native Americans are some of the ancient civilizations that used plants and herbs for their medicinal properties. For instance, the use of opium poppy for analgesic effects is recognized to have been employed as far back as 3400 BC in Mesopotamia¹⁴. Traditional Chinese Medicine has employed herbs like ginseng and ginger to cure diseases for centuries, while Ayurvedic medicine in India has utilized herbs like turmeric and ashwagandha for their anti-inflammatory and rejuvenating qualities¹⁵. These traditional systems were passed down from generation to generation and are still utilized extensively in most parts of the world today. Traditional South American and African healing systems also share an ancient legacy of herbal applications to cure diseases like malaria, fever, and gastrointestinal disorders¹⁶.

In the last several decades, there has been a resurgence of interest in herbal medicine, particularly in the treatment of chronic disease. As worries about the side effects and effectiveness in the long term of conventional medications increase, more individuals have turned to herbal remedies as less harmful alternatives or complementary treatments¹⁷. This growing trend has led to the integration of herbal medicine in modern healthcare practice, supported by scientific research that validates the therapeutic potential of many plant substances. For example, curcumin (from turmeric) is now well established for its anti-inflammatory and anticancer properties, and ginkgo biloba is used routinely for cognitive enhancement¹⁸. The World Health Organization (WHO) has even included herbal medicine in its list of essential medicines, acknowledging the role of plants in health care. As such, herbal medicines are now part of an integrative approach to chronic disease management, with promises of benefit in both preventive and therapeutic intervention.

ACTION MECHANISMS OF HERBAL MEDICINES

Phytochemicals and their action: Herbal medicines owe their curative effects to the wealth of bioactive phytoconstituents these contain, such as alkaloids, flavonoids, terpenoids, phenolic acids, and glycosides. These phytochemicals

take on important functions in the regulation of chronic conditions on the basis of a broad range of biochemical mechanisms. Alkaloids, e.g., morphine in Opium poppy and quinine in Cinchona bark, have long been renowned for their potent analgesic and antimalarial actions, respectively¹⁹. Flavonoids, which are often present in herbs like Ginkgo biloba and green tea, have antioxidant, anti-inflammatory, and anticancer activities through free radical scavenging and modulation of cellular oxidative stress pathways²⁰. Terpenoids, such as those found in ginger and turmeric, have been reported to have anti-inflammatory and anticancer activities, as well as antimicrobial activity, through their ability to inhibit pro-inflammatory enzymes like cyclooxygenase-2 (COX-2)²¹. These bioactive compounds may be a great alternative to synthetic drugs, especially in chronic illness where long-term medication is necessary.

Molecular mechanisms: The therapeutic properties of herbal drugs are largely due to their ability to interact with various cellular and molecular mechanisms and thus influence crucial mechanisms of chronic diseases. For instance, the majority of phytochemicals are antioxidant in character, neutralizing free radicals and reducing oxidative stress that can damage cells and tissues, a key driver of disease onset such as diabetes, cancer, and cardiovascular diseases²². Additionally, plant bioactive compounds like curcumin (from turmeric) and resveratrol (from grapes) have been reported to be anti-inflammatory in character by suppressing inflammatory pathway activation, e.g., the nuclear factor-kappa B (NF- κ B) pathway²³. Besides, certain herbal compounds also influence gene expression and control cellular signaling, such as the activation of peroxisome proliferator-activated receptors (PPARs) involved in glucose and lipid metabolism during diabetes²⁴. These molecular interactions are accountable for the therapeutic efficacy of herbal drugs in managing chronic diseases.

Target pathways in chronic diseases: Herbal drugs target several of the important pathways that are dysfunctional in chronic diseases. In cardiovascular disease, for example, flavonoids in garlic and hawthorn modulate the renin-angiotensin-aldosterone system (RAAS), which is crucial in controlling blood pressure and fluid balance [25]. In oncology, phytochemicals like sulforaphane in cruciferous vegetables inhibit

the growth and spread of tumors by modulating tumor suppressor genes and cell cycle control pathways [26]. In neurodegenerative disease like Alzheimer's, herbs like ginkgo biloba and ginseng may show neuroprotection against oxidative damage and improve cognition by modulating expression of neurotrophic factors and acetylcholinesterase modulation [27]. By targeting these key mechanisms, herbal molecules provide an adjuvant approach for managing chronic disease over symptom control, including modification and prevention of disease (Table 2).

Table 2: Mechanisms of Action of Herbal Medicines in Chronic Disease Management

Phytochemicals	Roles in Chronic Disease Management	Molecular Mechanisms
Alkaloids ^{14,15,16}	Possess anti-inflammatory, antioxidant, and anticancer properties	Modulate inflammatory pathways and gene expression
Flavonoids ^{17,18}	Antioxidant, anti-inflammatory, and anticancer effects	Inhibit oxidative stress, reduce inflammation
Terpenoids ^{19,20}	Antioxidant, anti-inflammatory, and anticancer properties	Interact with signaling pathways for apoptosis
Saponins ^{21,22}	Immunomodulatory, anti-inflammatory, and anticancer effects	Modulate immune responses, inhibit inflammation
Polyphenols ^{23,24}	Protect cells from oxidative damage and support cardiovascular health	Enhance antioxidant enzyme activity, reduce lipid peroxidation
Tannins ^{25,26,27}	Antioxidant, antimicrobial, and anticancer effects	Suppress growth of cancer cells, reduce inflammation

THERAPEUTIC POTENTIAL OF HERBAL MEDICINES IN SPECIFIC CHRONIC DISEASES

Cardiovascular diseases: Cardiovascular diseases (CVD), like hypertension, atherosclerosis, and heart disease, are still major causes of death worldwide. Traditional herbs have been used for centuries to treat cardiovascular diseases. For instance, Garlic (*Allium sativum*) was discovered to reduce blood pressure, lower cholesterol, and improve endothelial function and is thus a valuable herb to treat hypertension²⁸. Similarly, Hawthorn (*Crataegus* spp.) has been found to enhance cardiovascular health by improving

coronary flow and antioxidant activity²⁹. A few other herbs like Olive leaf (*Olea europaea*) have been discovered to potentially reduce oxidative stress and blood pressure³⁰.

Diabetes Mellitus: Herbal medicines have also been investigated for the management of blood glucose levels as an alternative to allopathic diabetic drugs. Bitter melon (*Momordica charantia*) has long been known to lower blood glucose levels due to its insulin-like compounds and is a significant herb in the treatment of diabetes³¹. Fenugreek (*Trigonella foenum-graecum*) contains high amounts of soluble fiber, which can control blood sugar by slowing down the absorption of carbohydrates³². Turmeric (*Curcuma longa*) which contains the active constituent curcumin has also been shown to enhance insulin sensitivity and reduce inflammation and thereby to treat type 2 diabetes³³.

Cancer: Cancer is one of the universal leading causes of death, and herbal medicines have shown excellent anticancer activity. Turmeric with curcumin as the active component is highly recognized for its antioxidant and anti-inflammatory properties that can be beneficial in cancer cell growth prevention and apoptosis in tumor cells³⁴. Green tea (*Camellia sinensis*) with high polyphenol content such as epigallocatechin gallate (EGCG) has been reported to inhibit cancer cell growth, particularly in breast, prostate, and lung cancers³⁵. Other plants such as Ginger (*Zingiber officinale*) have also demonstrated their capacity to inhibit cancer cell proliferation and also break through the adverse effects of chemotherapy³⁶.

Other diseases: Herbal therapy may also prove effective in other diseases that are chronic in nature. Arthritis patients have achieved satisfactory results through herbs such as Ginger, anti-inflammatory in nature, as well as Devil's Claw (*Harpagophytum procumbens*), to reduce pain and inflammation³⁷. For neurodegenerative disease such as Alzheimer's, herbs like *Ginkgo biloba* are employed to improve brain function and memory recall by improving blood flow to the brain and exhibiting antioxidant activity³⁸. Herbs like Cinnamon (*Cinnamomum verum*) are also being investigated for their potential application to manage metabolic syndrome by improving insulin sensitivity and lowering the levels of cholesterol based on Table 3³⁹.

Table 3: Therapeutic Potential of Herbal Medicines in Managing Chronic Diseases

Herbs	Disease	Therapeutic Effect
Garlic (<i>Allium sativum</i>)	Cardiovascular Diseases (CVD)	Reduces blood pressure, lowers cholesterol, improves endothelial function
Hawthorn (<i>Crataegus</i> spp.)	Cardiovascular Diseases (CVD)	Improves coronary flow, enhances antioxidant activity
Olive Leaf (<i>Olea europaea</i>)	Cardiovascular Diseases (CVD)	Reduces oxidative stress, lowers blood pressure
Bitter Melon (<i>Momordica charantia</i>)	Diabetes Mellitus	Lowers blood glucose levels due to insulin-like compounds
Fenugreek (<i>Trigonella foenum-graecum</i>)	Diabetes Mellitus	Controls blood sugar by slowing carbohydrate absorption
Turmeric (<i>Curcuma longa</i>)	Diabetes Mellitus	Enhances insulin sensitivity, reduces inflammation
Turmeric (<i>Curcuma longa</i>)	Cancer	Prevents cancer cell growth, induces apoptosis in tumor cells
Green Tea (<i>Camellia sinensis</i>)	Cancer	Inhibits cancer cell growth (breast, prostate, lung cancers)
Ginger (<i>Zingiber officinale</i>)	Cancer	Inhibits cancer cell proliferation, reduces chemotherapy side effects
Ginger (<i>Zingiber officinale</i>)	Arthritis	Reduces pain and inflammation
Devil's Claw (<i>Harpagophytum procumbens</i>)	Arthritis	Reduces pain and inflammation
<i>Ginkgo biloba</i>	Neurodegenerative Diseases	Improves brain function, memory, and blood flow
Cinnamon (<i>Cinnamomum verum</i>)	Metabolic Syndrome	Improves insulin sensitivity, lowers cholesterol

CLINICAL EVIDENCE AND STUDIES

Preclinical and Clinical Studies: Preclinical and clinical studies have a vital importance in

evaluating the safety and effectiveness of herbal medicine. Numerous studies have provided evidence for the health benefits of herbal therapy in controlling chronic diseases. For example, Bitter melon (*Momordica charantia*) study revealed it to reduce the level of blood glucose in animal models of diabetes and human clinical trials⁴⁰. Similarly, Turmeric (*Curcuma longa*), and more specifically its active compound curcumin, has been extensively studied for its anti-inflammatory, antioxidant, and anticancer properties. Curcumin was shown in clinical trials to have the potential to reduce inflammation in rheumatoid arthritis and anticancer⁴¹. In cardiovascular disease, Garlic (*Allium sativum*) has been studied in clinical settings to understand its impact on cholesterol and blood pressure levels. Several randomized controlled trials (RCTs) have determined that garlic supplement lowers systolic and diastolic blood pressure in hypertensive patients⁴². In oncology, Green tea (*Camellia sinensis*), more specifically its high-content polyphenol epigallocatechin gallate (EGCG), has been discovered to have anticancer effects by its inhibition of cancer growth and metastasis in preclinical and clinical settings⁴³. Also, *Ginkgo biloba* has been studied for its neuroprotective activity, and clinical trials have established it as effective in the improvement of memory and cognitive function in patients of neurodegenerative diseases such as Alzheimer's disease⁴⁴.

Limitations of current research: Despite promising results from preclinical and clinical trials, there are robust limitations that restrict the use of herbal drugs in clinical practice. One of the most important limitations is the lack of standard formulations and dosage regimens for the majority of herbal treatments. The effectiveness of herbal drugs may be influenced by factors like plant source, preparation process, and dosing schedule. Such variability is responsible for heterogeneity of findings among different studies and populations, thereby making it impossible to derive unequivocal conclusions about the therapeutic efficacy of specific herbs⁴⁵. Another issue with herbal medicine studies is the lack of large, well-designed clinical trials. A majority of those that are available are small, poorly designed, or conducted on non-human populations, and extrapolation to more significant populations is difficult. For instance, even though

Fenugreek (*Trigonella foenum-graecum*) studies have demonstrated its efficacy in sugar level control, data from multicenter large-scale RCTs are limited⁴⁶. Besides, herbal remedies are also prone to interact with conventional drugs, leading to potential drug-herb interactions, which are not always well documented or fully understood. The drug-herb interactions have the potential to affect the safety and efficacy of both the herbal and drug therapies.

In addition, regulatory barriers and lack of financing for clinical trials of herbal medicines provide another hurdle. Unlike pharmaceutical medication, which undergoes intense regulatory processes before approval, herbal remedies are subjected to non-standardized testing and regulation, and therefore there are concerns about quality and safety⁴⁷. Larger and more comprehensive clinical studies, therefore, must be conducted to confirm the actual therapeutic potential and safety profiles of herbal preparations in chronic diseases.

SAFETY AND TOXICITY OF HERBAL DRUGS

While herbal drugs have a myriad of therapeutic uses, they are also risky. Among the key issues with the use of herbal drugs is the potential for side effects, especially when they are used improperly or in excess. Most herbal drugs consist of bioactive compounds which, although beneficial in therapeutic doses, become toxic in excess. For instance, Comfrey (*Symphytum officinale*), a plant previously regularly used in the treatment of wounds, has been reported to be responsible for inducing liver toxicity and is banned for internal use in most countries due to its hepatotoxicity⁴⁸. Similarly, Kava (*Piper methysticum*), an anxiolytic agent, triggers widespread liver damage and has been banned or illegal in most places⁴⁹. Herb-drug interaction is another crucial concern in the safety of herbal medicine. These herbs all contain substances that will impinge on the metabolism of medication that has been prescribed, cutting their effectiveness or augmenting their toxicity. Hypericum perforatum, also known as St. John's wort, is used commonly to treat minor depression. Induction of the cytochrome P450 enzyme system causes a decrease in the effectiveness of warfarin, oral contraceptives, and certain antidepressants⁵⁰. The diversity in the quality of herbal medicine,

depending on such parameters as source plant, environmental factors, and preparation, also contributes to the potential danger involved in taking these medicines.

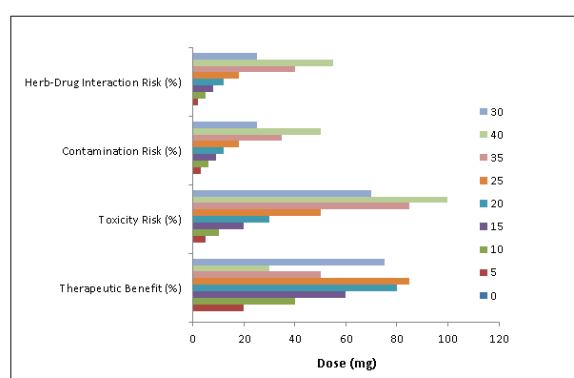
Furthermore, ingestion of untested or poorly processed herbal supplements is also capable of leading to heavy metal, pesticide, or other toxic chemical contaminations, and this increases the risk of toxicity. For instance, Chinese herbal remedies were found to consist of lead, arsenic, or mercury, which are confirmed to cause grave health complications if retained in the body⁵¹. Nonstandardization of herbal medicinal products is also equivalent to subjecting the patients to uncontrolled amounts of active ingredients and hence to potential adverse effects.

Regulatory concerns: The regulatory system for herbal medicine is complex and varies significantly from nation to nation. In the majority of regions on the planet, herbal medicines are not subject to the same stringent standards of testing and approval as pharmaceuticals. This poor regulation can contribute to unpredictable product quality, safety concerns, and inadequate consumer protection. For example, while the United States Food and Drug Administration (FDA) regulates herbal supplements as food, it neither approves them prior to marketing nor does it subject them to a process of checking for safety and effectiveness as done for prescription medication⁵². Quality assurance for herbal supplements is therefore often the prerogative of producers who do not necessarily practice good manufacture standards or ensure their product free of contamination.

On the other hand, other countries, such as Germany, are more regulated with regard to herbal medicines. The German Commission E, for instance, contains detailed monographs of accepted herbal drugs, such as indications, dosage, and potential side effects. While the system permits some regulation, there still remain problems with ensuring the consistency and safety of herbal products across the globe. Furthermore, there is a lack of global harmonization in the regulation of herbal medicine, which makes it difficult to develop globally accepted standards for product quality, safety, and efficacy. Standardization and quality control are significant concerns in the global herbal medicine market. The variations of chemical content among plant species because of the variability of cultivation, harvesting time,

and processing are challenges to offering uniform therapeutic responses. Additionally, herbal medicines are adulterated with chemical drugs or substandard active ingredients in order to enhance potency or reduce expenses, thereby presenting further safety issues⁵³. Therefore, the existence of international guidelines and harmonized standards for the regulation of herbal medicines and quality assurance is essential in order to ascertain that these medicines are safe and effective for use by consumers (see Figure 1).

Figure 1. Conceptual illustration of the safety and toxicity concerns in herbal drugs



As inferred from the Figure 1, herbal drug safety and toxicity depend on factors such as potential side effects, drug-herb interaction, risk of contamination, and regulatory matters. The figure illustrates that herbal drugs are effective in therapeutic amounts but become toxic if applied incorrectly or in excess, as exemplified by the case of Comfrey and Kava. Additionally, some herbs such as St. John's wort have interactions with drugs, reducing their efficacy or enhancing toxicity. Contamination with heavy metals or pesticides in low-quality processed herbal supplements also enhances health hazards. The data employed for this figure was derived from a systematic review of literature on herbal drug toxicity, herb-drug interactions, risk of contamination, and variations in regulatory regimes across countries.

CHALLENGES AND FUTURE DIRECTIONS

Integration with conventional medicine:

Harmonizing herbal medicine with mainstream healthcare systems is a challenge. Perhaps the most basic challenge is the disparity in the evidence base between mainstream and herbal treatments. Whereas mainstream medicine is supported by large clinical trials, evidence for

herbal medicines is generally poor, with few herbal products having large-scale, high-quality clinical trials to determine efficacy and safety. This absence of evidence warrants caution by health professionals in the use of herbal medicines as an adjunct to standard therapy⁵⁴. Standardization of herbal products is also a problem. Unlike pharmaceutical medicines, which are rigorously tested for dose, purity, and consistency, herbal remedies show much variability in their active content depending on plant species, growing conditions, and manufacturing processes. This lack of standardization makes it difficult for healthcare providers to prescribe herbal medicines confidently as part of therapeutic regimens⁵⁵. Moreover, healthcare providers might lack proper knowledge about herbal medicines and therefore underuse or harm patients if these medicines are prescribed along with conventional medicines without suitable advice.

The regulatory climate is also a barrier to integration. Herbal remedies in most countries are not regulated as vigorously as drugs. Uncertainty of regulation could lead to poor quality, adulterated, and unsafe herbal preparations that could discourage prescribing doctors from prescribing them. To mitigate the integration of herbal medicine into mainstream healthcare, regulatory bodies should better design guidelines, offer quality control, and standardized formulations of herbal products⁵⁶.

Future research needs: Even though herbal medicine is gaining widespread popularity, huge gaps in the research need to be addressed in order to integrate these therapies into modern healthcare in a complete way. First and foremost, more rigorous clinical trials have to be carried out to determine the effectiveness and safety of herbal medicines. Although preclinical studies and traditional medicine suggest the therapeutic utility of herbs in chronic diseases, large, randomized controlled trials (RCTs) need to confirm their therapeutic efficacy and safety profiles⁵⁷. The long-term effects of herbal therapy must also be explored in studies since most available studies are confined to short-term outcomes. Another area to be explored in the future is the investigation of herb-drug interactions. Both conventional drugs and herbal remedies are taken by a great majority of the population, and their interactions have the potential to produce adverse effects or reduce the therapeutic efficacy. It is worth investigating

these interactions for the safe co-administration of herbal remedies with standard therapy. Research in this field must cover the reasons behind these interactions, as well as the formulation of guidelines for medical professionals to manage them in an appropriate manner⁵⁸.

Besides, the requirement for molecular pathways of therapeutic activities of herbal medicine is being made a reality. Although various plants have shown some therapeutic activities in chronic diseases, the particular molecular pathways through which they exert activities are unknown. The mode of action of particular herbs, such as how their activity influences the expression of gene, synthesis of protein, and cellular signaling events, must be explored in ongoing studies. This data will assist in delineating the scientific basis of herbal medicine and making it acceptable for use in personalized medicine approaches⁵⁹. Lastly, the sustainability and environmental implication of the production of herbal medicine must be explored. With increasing demand for herbal medicine across the world, there must be measures to make the cultivation and harvesting of medicinal plants sustainable. The future research must focus on sustainable agriculture practices, conservation, and ethically procured medicinal plants so that the environmental contribution of herbal medicine production could be reduced and biodiversity maintained⁶⁰.

CONCLUSION

Herbal medicine has been an optimistic therapeutic approach in the management of chronic conditions and is revealed to be of great potential for improving patient outcomes. Numerous herbs, such as turmeric, bitter melon, and garlic, contain bioactive molecules like alkaloids, flavonoids, and terpenoids that are well documented to confer therapeutic benefits by modulating key molecular pathways that play a role in inflammation, oxidative stress, and gene expression. These mechanisms are involved in the regulation of a variety of chronic conditions, including cardiovascular diseases, diabetes, and cancer. However, with greater application, difficulties have been encountered in integrating herbal medicine into conventional practice primarily because of the absence of good quality clinical evidence, safety, and consistency of herbal product formulations. Rigorous quality control measures and good quality randomized

controlled trials are of paramount significance to establish the safety, efficacy, and consistency of herbal preparations. Moreover, regulatory directives must be reinforced to meet herb-drug interaction and toxicity concerns, and healthcare providers must be educated on the proper use of herbal remedies. Traditional and conventional medicine must be unified in an integrated model, and future research on the molecular mechanism of the therapeutic actions of herbal medicine will foster an integrated and evidence-based chronic disease management system.

Acknowledgements: The author expresses sincere thanks to Islamic Azad University, Jouybar Branch, Iran, for helpful cooperation provided in

carrying out this research. Sincere appreciation is also being extended to the Academy of Sciences of the Republic of Tajikistan for its cooperation in this scientific activity and academic research.

Conflict of Interest: The authors declare no conflict of interest.

Funding Statement: None.

Ethical Approval: Not applicable.

Author's Contribution: The author is solely responsible for literature search, review, compilation and writing, editing and submission of the manuscript.

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