Vol. 5 No. 2 (2026)

Pakistan Journal of Medical & Cardiological Review

https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387

Print ISSN 3007-2379

Ghaffari et al., 2026

Phytochemical Profiling and Novel Drug Delivery Approaches Enhancing Therapeutic Potential of Traditional Medicinal Plants Globally

Muhammad Abuzar Ghaffari
Faculty of Pharmaceutical Sciences, Lahore University of Biological and Applied Sciences, Lahore, Pakistan
Muhammad Shoaib Khan
Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Bahauddin Zakariya University, Multan, Pakistan
Ijaz Ali
Department of Pharmacognosy, Faculty of Pharmaceutical Sciences, Government College University Faisalabad (GCUF), Faisalabad, Pakistan
Umbreen Anwar
Sialkot College of Physical Therapy, Sialkot, Pakistan
Khuram Ashfaq
Faculty of Pharmaceutical Sciences, Lahore University of Biological and Applied Sciences, Lahore, Pakistan
Asad Ali
Department of Pharmaceutical Chemistry, Faculty of Pharmaceutical Sciences, Government College University Faisalabad (GCUF), Faisalabad, Pakistan
Muhammad Sohaib
Madina College of Pharmacy, The University of Faisalabad, Faisalabad, Pakistan
Mehreen Jabeen
Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Bahauddin Zakariya University, Multan, Pakistan
Muhammad Hafeez
Department of Pharmaceutical Chemistry, Government College University Faisalabad (GCUF), Faisalabad, Pakistan
Amir Abbas
Department of Pharmaceutical Chemistry, Faculty of Pharmacy, The Islamia University of Bahawalpur, Bahawalpur, Pakistan
Muhammad Kamran Khan
Oxford College of Medical Sciences, Mandi Bahauddin 50400, Pakistan
Muhammad Asad
Oxford College of Medical Sciences, Mandi Bahauddin 50400, Pakistan
Humaira Majeed

Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about
Online ISSN 3007-2387
Print ISSN 3007-2379

Department of Pharmaceutical Chemistry, Faculty of Pharmaceutical Sciences, Government College University Faisalabad (GCUF), Faisalabad, Pakistan
Muhammad Yousaf Quddoos
Institute of Food Science and Nutrition, University of Sargodha, Sargodha, Pakistan
Arshia
Department of Zoology, Faculty of Biological Sciences, Superior University Lahore, Pakistan
Muhammad Hamza
Pharm D, Mphil Pharmaceutics, Riphah Institute of Pharmaceutical Sciences Islamabad, Pakistan
Syed Muhammad Muneeb Zahid
MPhil Clinical Pharmacy Practice, Pharm-D, Department of Basic Medical Sciences, Shifa College of Pharmaceutical Sciences, Shifa Tameer-e-Millat University, Islamabad, Pakistans
Ghulam Abbas
MPhil Biochemistry, Hazara University, BEMS, Department of Eastern Medicine and Surgery, University of Poonch Rawalakot

Author Details
Received on 20 April, 2026
Accepted on 15 May, 2026
Published on 16 May, 2026

Corresponding E-mails & Authors*:

Abstract

Medicinal Plants remain a major source of bioactive compounds used in the prevention and treatment of many diseases around the world. Advances in phytochemical profiling techniques such as chromatography, spectroscopy, metabolomics, and mass spectrometry have greatly improved our ability to identify and characterize plant-derived constituents, including alkaloids, flavonoids, phenolics, terpenoids, and glycosides. Many of these phytochemicals exhibit multiple pharmacological properties, including antioxidant, antimicrobial, anti-inflammatory, anticancer, antidiabetic, and neuroprotective activities. However, despite their therapeutic importance, many herbal compounds have limitations including limited solubility, low bioavailability, instability, and rapid metabolism which impede their ability to be clinically used effectively. To overcome these limitations, novel drug delivery systems, including nanoparticles, liposomes, phytosomes, nanoemulsions, hydrogels, and solid lipid nanoparticles have been developed with the goal of improving targeted delivery, controlled release and

therapeutic activity. These sophisticated technologies enhance the pharmacokinetic and pharmacodynamic properties of phytoconstituents while reducing toxicity and adverse effects. The combination of traditional herbal medicine with nanotechnology and contemporary pharmaceutical science represents exciting new avenues for creating effective plant-based therapeutic agents. This literature review aims to provide an overview of the latest developments in phytochemical profiling and innovative drug delivery strategies to maximize the worldwide therapeutic potential of medicinal plants.

Keywords: Traditional medicinal plants, phytochemical profiling, phytochemicals, herbal medicine, nanotechnology, drug delivery systems, nanoparticles, phytosomes, liposomes, nanoemulsions, therapeutic potential, bioavailability, targeted delivery, ethnopharmacology, plant-based therapeutics.

Introduction

The use of traditional medicinal plants for healthcare has been vital to the health of humans throughout history and remains a significant contributor to the development of modern-day therapeutics. Many cultures around the world use herbal medicine for the treatment of infectious, inflammatory, metabolic, and chronic diseases. The rich diversity of medicinal plants is an abundant source of bioactive phytochemicals, which include alkaloids, flavonoids, terpenoids, glycosides, tannins, and phenolic compounds with remarkable pharmacological properties. These bioactive phytochemicals have the ability to act as antioxidants, antimicrobials, anticancer agents, antidiabetic agents, anti-inflammatory agents, and neuroprotectants. Because of their pharmacological properties, they can be utilized as pharmaceutical or nutraceutical products. Recently, researchers have been showing a growing interest in confirming the therapeutic efficacy of traditional herbal medicine through advanced analytical and pharmacological methods of study. With the recent increase in the demand for natural and plant-based therapies, there has been an impressive amount of research in this area throughout the world related to medicinal plant resources. Furthermore, the lower cost associated with herbal medicine, higher cultural acceptance, and minimal side effects associated with herbal medicine are contributing factors to the continued popularity of herbal medicine globally. There has been a renewed focus within the research and pharmaceutical community to identify and isolate new phytochemicals and develop standardized herbal

formulations to improve the therapeutic value of herbal medicines. These developments illustrate the need to integrate the traditional knowledge of herbal medicine with modern science to help maintain sustainable healthcare systems and drug discovery programs in the future (WHO, 2023)

Recently, new technologies have changed the way people study medicinal plants and their active ingredients. One of the most common ways to analyze and characterize phytochemicals is through analytical methods such as high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC/MS), nuclear magnetic resonance (NMR), Fourier-transform infrared spectroscopy (FTIR), and metabolomics. All these techniques provide researchers with detailed information about the chemical composition, molecular structure, biological activity, and pharmacological potential of plant-based substances. In addition to helping researchers locate the active ingredients that produce therapeutic effects in herbal plants, phytochemical profiling also provides researchers with a means by which to standardize and control the quality of herbal medicines. Researchers utilize bioinformatics and metabolomics to provide a better understanding of how complex plant metabolites interact with each other in biological systems. These advancements also facilitate the discovery of new and effective bioactive compounds for treating a variety of diseases. Additionally, phytochemical analysis provides great help in authenticating medicinal plants and preventing the adulteration of herbal products. The ability to validate traditional herbal medicines by using the latest technologies used in analytical chemistry will improve the credibility and acceptance of traditional herbal medicine as part of the global health care marketplace. Thus, phytochemical profiling will play an important role in connecting traditional medicinal knowledge to evidence-based pharmaceutical research for future therapeutic innovation (Pandey&Tripathi, 2014)

Despite many medicinal plants having amazing potential for therapeutic use, there are many limitations of the phytochemicals derived from plants that prevent their use clinically or pharmaceutically. Most of the compounds derivable from plants have poor solubility in water, low permeability, are unstable in the body, are rapidly metabolized, have limited bioavailability, and make absorption and therapeutic concentrations in targeted tissues lower, which ultimately affects their pharmacological

efficacy (the degree to which a medicine or therapy can produce the effect for which it was intended). In addition, certain bioactive phytochemicals become unstable very quickly while in storage or after administration, which reduces their medicinal value even further. There is a great deal of variation in the composition of plants due to seasonal, environmental, and geographical influences, which causes difficulties in ensuring the consistent quality and outcomes of herbal formulations. Phytochemicals are also delivered to patients poorly via conventional dosage forms because they are not delivered in a targeted manner or the drug release is not controlled. Because of these challenges, researchers are increasingly looking for new and innovative pharmaceutical approaches to addressing these issues in the development of herbal medicines for commercial use. In order to design effective formulations that provide the best therapeutic effects, the physicochemical limitations and pharmacokinetic limitations of phytochemicals must first be understood. Scientists are working towards increasing the stability, absorption level, solubility and ability of the plant-derived compounds to be delivered in a targeted manner to maximize the medicinal benefits of phytochemicals. By overcoming the above challenges through research, scientists will be able to support the transition of traditional herbal medicines into standardized and clinically effective therapies for patients' use (Gupta et al., 2021)

Innovative types of drug delivery systems have developed as unique ways of improving therapeutic efficiencies and clinical purposes associated with natural plant materials. Examples include advanced pharmaceutical delivery systems or carriers, such as nanocarrier systems, liposomes, phytosomes, nanoemulsions, dendrimers, hydrogels, and solid lipid carriers or nanoparticles to deliver these traditional herbal phytochemicals more effectively. Byutilizing these innovative approaches, botanicals can have increased solubility/stability/bioavailability and improved controlled release while decreasing their potential adverse/toxic side effects. Furthermore, nanotechnology-based delivery systems allow targeted delivery of phytopharmaceuticals to specific tissue/organ sites, improving the therapeutic value of the drug, and decreasing its degradation. In addition, phytosomes and liposomes improve the adsorption of poorly soluble botanicals by increasing the permeability of the cell membrane and also protect the active ingredient from metabolic degradation. Lastly, hydrogels and nanoemulsions

provide for sustained release and improved pharmacokinetic characteristics when applied to produce medicinal plants. All of these systems help to maintain adequate therapeutic concentrations of phytochemicals for an extended period and help develop strategies to reduce dosages by using these systems. Nanotechnology integration in herbal medicine has provided greater opportunities for developing phytopharmaceutical based treatments for common diseases such as diabetes, cancer, cardiovascular disease, neurological disorders, and infectious diseases. Researchers will continue to explore how to use safe and cost-effective biocompatible systems for large-scale production use in the pharmaceutical industry; therefore this next generation of systems will be important new tools for maximizing the medicinal value and therapeutic potential of traditional botanical products (Patra et al., 2018)

Combining traditional medicinal knowledge with modern pharmaceutical and nanotechnology advances has changed the worldwide healthcare system enormously. The recognition of medicinal plants as a valuable source of new therapeutic agents and as a basis for developing evidence-based herbal medicines is increasing. Phytochemical profiling in conjunction with advanced drug delivery technologies has led to improvements in the safety, efficacy, and acceptance of plant-based therapeutics. Researchers around the world are working to develop standardized herbal formulations with enhanced pharmacokinetic and pharmacodynamic properties to improve disease management. These new developments are critical for addressing chronic diseases, antimicrobial resistance, and new health challenges that require better and safer methods of treatment. In addition, the growing demand from consumers for natural products has created a global market for herbal medicines and nutraceuticals. Scientific validation and quality control of traditional medicinal products are also encouraged by governments and healthcare organizations to ensure they are safe and effective. The collaborative research performed between ethnobotany, pharmacology, biotechnology and nanotechnology is creating new opportunities to develop drugs and therapies. Continued advances in phytochemical research and novel drug delivery systems could result in the creation of highly effective plant-based pharmaceuticals that have therapeutic relevance globally. Therefore, medicinal plants will continue to be important

contributors to the sustainability of healthcare systems and will contribute to improving health outcomes for people worldwide (Kumar et al., 2022)

Medicinal Plants Contain Valuable Bioactive Phytochemicals

Medicinal plants are an important source of bioactive phytochemicals that have significant effects on human health, can be used to prevent diseases and are being utilized to discover new drugs. As a result of this high level of interest in natural products, there has been a large amount of research focused on validating their medicinal properties through scientific studies. Researchers have found that the bioactive components of medicinal plants possess strong pharmacological properties and confer a variety of biological activities that are useful in both traditional and contemporary medicine. In addition to being beneficial for the treatment of many illnesses, medicinal plants have also been utilized for centuries throughout various healing systems worldwide because they are effective in treating diseases and have few to no side effects. Researchers will continue to explore the therapeutic applications of plant derived products as interest continues to grow in this area. Therefore, it is clear that medicinal plants form an essential component of pharmaceuticals and will continue to serve as a critical source of identifiable and diverse examples chemical compounds with potentially novel therapeutic uses (Harborne, 1998)

Many medicinal plants possess phytochemicals that have a range of biological and pharmacological effects, making them a valuable resource in modern healthcare. For example, flavonoids and phenolics are well-known for their antioxidant properties; they can neutralize free radicals and reduce oxidative stress. Alkaloids are also well known for their analgesic, antimicrobial, and anticancer properties. Many terpenes provide anti-inflammatory and antiviral properties. Tannins are good for wound healing and prevent infections, and glycosides help regulate the cardiovascular system, as well as the metabolism of the body. These compounds will work independently and in combination with each other to produce beneficial effects on chronic diseases. Multiple studies have found that the use of phytochemicals from plants can be beneficial in treating chronic diseases such as diabetes, high blood pressure, cancer, and infectious diseases. Phytochemicals are also often considered safer alternatives to synthetic drugs, since they are derived from natural sources and may exert their effects across a wide

range of pathways. The medicinal value of phytochemicals continues to stimulate research into plant-based therapies and drug discovery approaches (Cowan, 1999)

Through modern methods of analysis and phytochemical profiling, the identification of bioactive compounds in plant medicine has greatly improved. The commonly used analytical techniques include high-performance liquid chromatography (HPLC), gas chromatography mass spectrometry (GC-MS), nuclear magnetic resonance (NMR), and Fourier-transform infrared (FTIR)—these methods have allowed for a more accurate determination of the chemical structure, concentration, and biological activity of phytochemicals than ever before. Advances in metabolomics and bioinformatics have also aided researcher's ability to simultaneously analyze multiple compounds and study complex plants. A standardized, validated, and authenticated phytochemical profile is necessary for quality control as well as developing new lead compounds for drug discovery in the pharmaceutical industry. Through increased accuracy and efficiency in compound identification, these more recent techniques have further supported the empirical literature surrounding medicinal plants and thus improved the reliability with which phytochemicals can be studied under evidence-based medicine (Sasidharan et al., 2011)

In-the-midst of recognizing how phytochemicals may have beneficial clinical use, many phytochemicals encounter severe limitations that limit their use in human health care. Some examples of the limitations experienced by many phytochemicals are due to their poor water solubility characteristics and their consequently poor absorption and low bioavailability (the amount of drug that reaches the systemic circulation) in human beings. Another limitation that affects many phytochemicals is the fact that they are frequently viewed as being unstable, or having low stability, when present in physiological conditions and frequently have diminished effectiveness due to their rapid rate of metabolism. Yet another limitation of many phytochemicals is that their overall composition can vary depending on a number of environmental, seasonal and geographical factors and therefore some patients treated with herbal medicines may not be receiving the same quantity or quality of phytochemical. Conventional dosage forms often do not afford

Comparative studies-in-preclinical-trials-and-the-early-stages-of-clinical-trials-again (e.g., a drug-similar/similar-to-im- at-book (book) may not provide a controlled/targeted-release of phytochemical. The therapeutic effectiveness of a given phytochemical depends on the administration method and dosage of phytochemical given to a patient. For many phytochemicals, these limitations will make it difficult to utilize phytochemical for their effective pharmaceutical potential. For this reason, there is continued emphasis on developing advanced formulation strategies to make phytochemicals more compatible with the physicochemical and the pharmacokinetics of producing a medicinal product. Addressing the above limitations is essential for optimizing the medicinal benefits from a plant-based substance and will facilitate the integration of phytochemicals into modern day health care systems (Yadav et al., 2011)

The development of novel drug delivery systems represents a new way to address limitations associated with phyto-therapeutics and enhance their clinical effectiveness. To improve the solubility, stability, and bioavailability of botanic extracts, these innovative technologies include nanoparticle formulations, liposome formulations, phytosome formulations, nanoemulsion, hydrogels, and solid lipid nanoparticles which provide controlled and/or targeted drug delivery to specific anatomical sites for the purpose of maximizing pharmacological effects while minimizing side effects. Nanotechnology-based formulations of phytotherapeutics protect phyto-chemicals from degradation as well as improve the pharmacokinetics of phyto-therapeutics. The integration of traditional herbal medicine with innovative drug delivery systems has created new avenues for development of advanced plant-based therapies. These combined technologies increase the clinical potential of phyto-medicine and facilitate the development of safer and/or more effective therapies for numerous illnesses or diseases. As research advances, plant-based medicines and new drug delivery systems will have a high impact on the future of pharmaceutical innovation and global health second only in importance to biotechnology (Mukherjee et al., 2009)

Phytochemicals Show Important Therapeutic Activities

Phytochemicals are known to have various beneficial therapeutic effects, and bioactive compounds that occur naturally in plants can significantly improve human health and help prevent disease. Some examples of phytochemicals are alkaloids, flavonoids,

tannins, terpenes, saponins, and phenolic acids, all of which possess unique chemical structural properties and biological functions. Phytochemicals can be found throughout the plant in different parts: roots, leaves, bark, flowers, and seeds. Historically, phytochemicals have been the basis of many traditional herbal medicines and have been used extensively in every medical system in the world for centuries. Recent scientific investigations have shown that phytochemicals interact at the molecular level with biological systems via enzymes, receptors, and pathways. This interaction leads to many different therapeutic effects and demonstrates the potential of phytochemicals as valuable resources for pharmaceutical research. Phytochemicals will continue to gain importance as researchers explore the potential of plant biodiversity to provide safe and effective treatments for many different diseases(Tiwari&Rana, 2015)

Phytochemicals possess antioxidant properties, which is one of their most notable therapeutic effects, and these properties can protect the body from oxidative damage. Oxidative damage can be caused by free radicals, which are unbalanced with antioxidants in the body and associated with a wide variety of chronic disease (e.g., cancer, diabetes) as well as aging (e.g., cardiovascular disease). Flavonoids and polyphenols are examples of phytochemicals that can neutralize free radicals and maintain physiological equilibrium through cellular protection. In addition, a large number of phytochemicals have potent anti-inflammatory properties due to their ability to inhibit the actions of inflammatory mediators (e.g., cytokines and enzymes). Therefore, phytochemicals can be used as effective treatments for many chronic inflammatory diseases (e.g., arthritis; asthma; neurodegenerative disorders). Some phytochemicals also modulate the immune response, thereby enhancing the body's ability to defend itself against infections and environmental stressors (e.g., toxins). Phytochemicals exhibit numerous biological functions and have significant value to both preventative and therapeutic medicine. Ongoing research continues to explore the ways that phytochemicals work biologically, as well as their potential therapeutic applications within the modern healthcare system(Middleton et al., 2000)

Phytochemicals are effective at controlling a variety of pathogenic microorganisms including bacteria, viruses, fungi, and parasites due to their ability to disrupt microbial cell membranes, inhibit enzymes, and block the movement of DNA.

Specific phytochemical classes such as alkaloids, tannins, and essential oils provide excellent antimicrobial action against pathogens. As the number of infections caused by antibiotic-resistant strains of bacteria continues to rise, there is a growing interest in exploring the use of plant-based antimicrobial agents as alternative treatment options. The use of medicinal plants to treat infections, including respiratory tract infections, skin diseases, and gastrointestinal diseases, has shown great potential for success. In addition, many phytochemicals have demonstrated antiviral activity, which can be beneficial for managing viral diseases by blocking viral entry into host cells and preventing the replication of viruses within host cells. As a result, there is an increasing emphasis on developing a new class of antimicrobial agents from plant sources as an area for future drug development and research. As part of this effort, researchers are using the vast amounts of historical knowledge regarding the use of plants in traditional medicine combined with current scientific technology to combine and test the effects of these antimicrobial agents on a variety of infectious diseases (Cowan, 2019)

Phytochemicals play an important role in cancer treatment around the world. Researchers have found many naturally occurring substances from plants that are effective against cancer by either reducing the way cancer cells reproduce, stimulating the process by which unwanted cells die (otherwise known as apoptosis), or inhibiting the formation of tumours. Flavonoids, terpenoids and alkaloids, among other plant-derived compounds, have demonstrated potential effectiveness against various stages of cancer. By influencing cell signalling pathways, inhibiting angiogenesis (the creation of new blood vessels) and affecting DNA mutation, phytochemicals can impede the development of cancers. In many instances, these naturally occurring compounds also work together with other compounds to provide added anticancer benefits. Furthermore, when compared to synthetic chemotherapeutic agents, the majority of phytochemicals are associated with fewer side effects, making them safer alternatives, or in some cases, complementary treatments. In an effort to identify potential new anticancer agents for development as pharmaceutical drugs, a substantial amount of research is currently underway to investigate new ways to utilize medicinal plants. As the incidence of cancer continues to increase worldwide, the desire for alternative natural therapeutic agents is growing and will lead to an ongoing commitment to furthering the study of

phytochemicals in oncology (cancer-related) research. In the future, there is a significant opportunity to utilize phytochemicals as a source of new drugs and treatment options for cancer (Cragg& Newman, 2013)

In summary, phytochemicals have a broad scope of therapeutic properties, thus making them important parts of all herbal medicine and Traditional Medicine systems. Through their various antioxidant, anti-inflammatory, antimicrobial, and anticancer mechanisms, these compounds play an important part in preventing disease and improving health. These compounds are also mercurial given the many biological mechanisms through which they act; thus they offer many options for pharmaceutical development. The pharmacological potential of phytochemicals is being increasingly established and validated through ongoing advances in science and technology. The integration of traditional herbal knowledge with high-tech drug discovery approaches has created new avenues to develop safe, efficacious herbal medicines. Phytochemicals continue to serve as an important source of new therapeutic agents to treat complex diseases. As more evidence is gathered to support their mechanisms and uses in evidence-based medicine, phytochemicals will increasingly find roles in modern healthcare (Dias et al., 2012)

Advanced Profiling Techniques Help Identify Active Compounds

Pharmaceuticals derived from positive phytochemical profiling due to the use of advanced profiling methodologies to assess bioactive elements in plant sources through chemical analysis. The importance of advanced phytochemical analysis is related to the recognition that phytochemicals exist in large numbers within botanical systems, necessitating the use of advanced methodologies in order to separate, detect, and characterize the biological activity of individual phytochemical compounds. Researchers can utilize advanced analytical techniques like chromatography, mass spectrometry, and spectroscopy to separate, analyze, and identify phytochemicals in medicinal plants. By having high accuracy of compound analysis, researchers can determine the phytochemical composition, structure, and biological function of phytochemicals. This information is essential in determining the specific phytochemical compounds responsible for producing beneficial pharmacological effects (i.e. therapeutic action) from traditional herbal formulations. As a result, the drug discovery process and the

development of plant medicinal products have been enhanced greatly due to advanced profiling methodologies. Advanced profiling methodologies also facilitate understanding how plants metabolize and how phytochemical compounds interact within living systems. In addition to supporting the advancement of phytochemistry, advanced profiling methodologies provide the foundation for linking traditional herbal knowledge with scientific validation. For these reasons, phytochemical profiling has become an important component of pharmaceutical and biomedical research at an international level, leading to the development of natural products with enhanced safety and effectiveness (Dai &Mumper, 2010)

High-performance liquid chromatography (HPLC) is one of the most commonly used advanced profiling techniques for separating and quantifying plant compounds. HPLC can be used to analyze complex mixtures and accurately identify the active components of those mixtures. Gas chromatography-mass spectrometry (GC-MS) is another advanced profiling technique for identifying volatile and semi-volatile compounds present in medicinal plants. GC-MS provides detailed information about the molecular mass and chemical structure of the phytochemicals detected. Nuclear magnetic resonance (NMR) spectroscopy is another important analytical technique used to establish the structural configuration of bioactive molecules. The combination of these analytical techniques provides a comprehensive chemical profile of medicinal plants. The use of multiple methods for the identification of therapeutic agents increases the accuracy and reliability of identifying therapeutic agents. These technologies have transformed the field of natural products research by increasing the speed and efficiency of the research process. They also provide new opportunities to identify new drug candidates from plant sources for the development of new pharmaceuticals and herbal medicines (Wolfender et al., 2015)

Phytochemical profiling through metabolomics is an advanced technique that examines all metabolites within an organism. Metabolomics offers a complete understanding of the chemistry of plants and how they carry out their biochemical functions. By utilizing advanced analytical equipment and bioinformatics, metabolomics can generate and analyze massive amounts of chemical data to identify biomarkers that demonstrate how environmental variables alter a plant's metabolism. The validity of

herbal medicine is enhanced by the utilization of metabolomics for studying medicinal plants and examining the interactions amongst individual chemical compounds and their contributions to the plant's therapeutic effects. The metabolomics approach to quality control and standardization of herbal products provides a consistent analysis of the chemical composition. Metabolomics has greatly enhanced the validity of phytochemical research by allowing for the concurrent analysis of numerous substances, making it an invaluable technology in drug development and the investigation of natural products today. Metabolomics use to evaluate the chemistry of medicinal plants will further link traditional medicine with modern science by providing a much deeper understanding of the chemistry of medicinal plants (Sumner et al., 2003)

The analysis of complex biological and chemical data pertains to the area of bioinformatics. This application of information technology and computational analysis requires the management of large amounts of information generated by various experimental techniques, including HPLC, GC-MS, and NMR. By interpreting these data, bioinformatics is able to identify chemical structure-activity relationships for many phytochemicals. Furthermore bioinformatics allows researchers to make predictions regarding the pharmacological potential of plant compounds prior to conducting laboratory experiments, thereby reducing the time and cost for drug discovery processes. Additionally, bioinformatics has enabled the development and maintenance of databases containing information on medicinal plants and their respective active compounds, providing both researchers in pharmacology as well as natural product chemistry with useful tools. By integrating data analysis with empirical evidence, researchers are able to gain insight into the therapeutic mechanisms of phytochemical constituents. The application of bioinformatics to phytochemical research has increased the ability to quickly identify active compounds from medicinal plants, making it an essential component of both phytochemical and drug discovery efforts (Gautam et al., 2016)

The field of medicinal plant research has seen a new day in how to identify and characterize plant medicinal properties as a result of advances in profiling techniques; these new advances are more reliable, faster, and less expensive than older methods of profiling. The use of chromatography, spectroscopy, metabolomics, and bioinformatics

has allowed for the identification of new bioactive compounds and has enhanced the knowledge regarding the chemistry of the plant. In addition, these advances enable researchers to develop and manufacture quality products through the use of bioassay techniques to ensure the safety of herbal medicine products for patient use. As the field of research continues to develop and grow, modern profiling methods will have an even larger impact on the development of new drugs and support the integration of traditional herbal practice with modern pharmacology, ultimately providing new plant-derived therapies to the world (Atanasov et al., 2015)

Poor Bioavailability Limits Herbal Medicine Effectiveness

The lack of bioavailability affects the usefulness of herbal medicine and is one of the main problems to overcome when using plant-based compounds in the clinic. Bioavailability means the percentage of drug available systemically and at the site where the drug will exert its therapeutic effect. While some of the bioactive chemical constituents (like flavonoids, alkaloids, and terpenoids) found in many herbs demonstrate significant activity in vivo (in animal research), the effects of these chemicals on humans may be very different, mainly due to poor absorption, rapid metabolism, and low solubility in body fluids. Therefore, the potential for therapeutic use of many plants with well-documented medicinal properties is greatly reduced or lost because of low bioavailability. Researchers have identified improving bioavailability as a necessary step toward converting herbal extracts into viable pharmaceutical agents; without improving bioavailability, the many therapeutic benefits of the plants will not be achieved within modern health systems. Therefore, improving bioavailability is still seen as an essential issue in developing and standardizing herbal medicines (Anand et al., 2007)

Low bioavailability of herbal medicines is primarily due to low solubility in water of the phytochemicals. Many of the compounds from plants are classified as lipophilic, which means they do not dissolve well in body fluids that are largely associated with water. This reduces their ability to be absorbed from the intestinal tract when administered orally. Some phytochemicals also undergo first pass hepatic metabolism which greatly decreases the amount of active phytochemical in the general circulation. In addition to first pass metabolism, the serum concentration of the phytochemical is

further reduced due to enzymatic degradation of the phytochemicals within the gastrointestinal tract prior to entering the bloodstream. These factors combined limit the amount of phytochemicals to reach the target tissue at therapeutic levels. As a result, when high doses of the active phytochemical are given, only a very small portion of the active phytochemical will be available for use by the body. Thus, achieving consistent and reliable therapeutic results with traditional herbal products is very difficult. Therefore, it is essential to improve the solubility and stability of phytochemicals in order to improve clinical outcomes (Williamson, 2001)

Another factor of bioavailability is the permeability of phytochemicals through biological membranes. Most plant-derived compounds are either polar or large molecules that are not able to easily move through intestinal epithelial cells and therefore their absorption into the systemic circulation will be reduced. As a result of this there will be instances where efflux transporters within the intestines will actively transport these compounds back into the intestinal lumen again, leading to less efficient absorption. Furthermore, many phytochemicals will degrade in the highly acidic conditions of the stomach prior to absorption. Other variables such as the variability of digestive enzymes among people also play an important role in the absorption of phytochemicals. All of these factors will lead to differences in the therapeutic response of patients using herbal medicines. In response to these factors, researchers are trying to increase the membrane permeability and stability of active ingredients, as an enhancement to these characteristics would improve the effectiveness of plant-based medicines (Patel et al., 2012)

There are multiple strategies developed to enhance the efficacy of herbal medicine and overcome their poor bioavailability. Some of these strategies include using advanced formulations such as: - Nanoparticles - Liposomes - Phytosomes - Solid lipid carriers These advanced formulations are utilized to increase solubility, protect active substances (compounds) from degradation, and provide enhanced absorption within the GI tract. Nanoformulation provides superior release profiles for drugs with controlled (or targeted) release that improve therapeutic efficacy. The use of absorption enhancers and enzyme inhibitors has also indicated improvement in bioavailability. Structural modifications may also be performed on phytochemicals to improve stability

and permeability of the compound. The enhancements mentioned above will have improved the clinical potential of many plant-derived compounds; however, there remains a great need to research these delivery systems to optimize for large-scale pharmaceutical applications. Addressing bioavailability is critical in bridging the gap between traditional herbal knowledge, and evidence-based medicine (Shah et al., 2014)

The limited effectiveness of herbal medicine has been affected by low bioavailability. Bioavailability can negatively affect the absorption, distribution and therefore therapeutic effects of phytochemicals in the body. Phytochemicals have demonstrated significant pharmacologic activity in laboratory settings; however, they have not demonstrated similar efficacy in the clinical setting due to low bioavailability. Thus, improving bioavailability is critical for achieving maximum therapeutic efficacy from medicinal plant use. Several innovative methods have been developed using advances in pharmaceutical science and nanotechnology to address issues related to bioavailability. Ongoing research in this area will be instrumental in converting traditional herbal remedies into more reliable and standardized therapeutic agents. Ultimately, increasing bioavailability will improve the success of plant-derived drug development and encourage the integration of herbal medicine into modern medical practice (Eid et al., 2013)

Novel Drug Delivery Systems Improve Stability And Absorption

New & innovative drug delivery systems enhance the stability & absorption of phytochemical residues, thus making these compounds function more effectively in a therapeutic manner. These innovative drug delivery systems have been designed specifically to address the limitations of conventional herbal formulations, such as low solubility, rapid degradation or metabolism, and low bioavailability. By using state-of-the-art pharmaceutical technologies, the active component of an herb can be protected from chemical and/or biological degradation prior to reaching its intended action site within the body. Thus, this dramatically increases the effectiveness of these compounds in a therapeutic capacity. Examples of innovative drug delivery systems include: nanoparticles, liposomes, phytosomes, nanoemulsions, solid-lipid nanoparticles, and polymer-based carriers. Each of these systems have been demonstrated to increase the pharmacokinetic (PK) and/or pharmacodynamic (PD) properties of herbal medicines.

Consequently, more than ever before, we can successfully utilize phytochemicals from medicinal plants to treat disease. As interest in both of these fields continues to grow, through research & development, the future of herbal medicine within the global health-care delivery system looks very promising (Singh et al., 2017)

A key benefit of novel drug delivery systems is enhancing the stability of phytochemicals. Many compounds from plants are sensitive to environmental conditions: temperature, humidity, oxygen, pH, and light. These environmental factors can lead to the breakdown of the active component and subsequently decrease its efficacy. Several encapsulation techniques, such as liposomes or nanoparticles, help protect these active components from being degraded while they are stored, and/or they aid in providing protection of the active component upon administration or delivery to the targeted area(s) of the body. Therefore, when the active component is delivered, it will remain stable until it reaches its targeted tissue. In addition, an improvement in the stability of these active components will lead to increased shelf life for each dosage form and/or provide better consistency in the percentage of the active component present in each dosage form. Novel drug delivery systems also contribute to improving the consistency of therapeutic effects on patients, thus positively affecting the reliability of plant-based medicines used in clinical practice (Pardeike et al., 2011)

Novel drug delivery systems provide many benefits, one of which is that they make it easier for phytochemicals to be absorbed into the human body. Many plant compounds have poor water solubility and poor permeability across biological membranes, which reduces their absorption in the gastrointestinal tract. The use of nano-sized carriers and lipid-based systems increases solubility of the compounds, allowing them to easily pass through the intestinal barrier. Additionally, these systems can bypass the "first pass" metabolism of compounds, allowing for more of the active compound to be available in circulation. Improved absorption results in higher bioavailability and stronger therapeutic effects with lower doses, which decreases the risk of side effects and improves patient compliance. Targeted drug delivery systems can also help direct drugs to specific areas within the body (i.e., targeted drug delivery) to improve the efficiency of treatment. These advancements have greatly enhanced the

clinical efficacy of herbal medicines and will continue to create new opportunities for the development of novel products (Date et al., 2010)

The second important aspect of the design of innovative drug delivery systems is the controlled release of active ingredients. Many innovative drug delivery systems promote controlled amounts of active substances to be released into the body at a specific time during treatment; thusly providing a means for maintaining a constant level of therapeutic drug concentration in the body over extended periods by preventing the need to take multiple doses within a short period. Additionally, the sustained rate at which therapeutic agents are provided by innovative drug delivery systems often produces less variation between maximum and minimum concentrations of therapeutic drugs within the body. This helps avoid experiencing toxicity as the patient receives fewer fluctuations in the concentration of therapeutic drugs within their bodies, providing safety and reducing toxicity. Frequently, innovative drug delivery systems have targeted delivery systems that deliver drugs only to specific sites in the body; such as to infected or tumor cells. Delivering drugs to specific cells provides targeted treatment with fewer side effects because healthy cells are protected as a result of drug targeting. Targeted delivery systems are particularly important for chronic diseases that require long-term therapies. Because of these advantages, innovative drug delivery systems are of great value in modern drug discovery and developing herbal remedies (Allen &Cullis, 2013)

Novel delivery systems for drugs are very important in keeping phytochemicals stable, able to be absorbed, and effective. They help solve some of the main problems faced by traditional herbal formulations multiple pharmacological uses for plant-derived medicines, enhance the usage of plant-derived drugs in the treatment of various conditions, are developed based on nanotechnology combined with pharmacological sciences, will create safer and more effective means of delivering herbal ingredients, provide platforms for converting traditional medicinal plant-based products into consistent and reliable therapeutic agents, and will enable continued technology injection improvements to reinforce the growing use of medicinal plants in the health care system today. Novel delivery systems for drugs will also provide a significant

innovation that can maximise the value of natural products in the prevention and treatment of disease (Khatri et al., 2018)

Nanotechnology Enhances Targeted Delivery And Controlled Release

Nanotechnology has improved the methodology and system for targeted delivery and controlled release of therapeutic agents by enabling the manipulation of materials on a nanometer scale (e.g., typically between 1 and 100 nm).The application of nanotechnology within pharmaceutical science and/ or herbal medicine has transformed the application of drug delivery by significantly increasing the accuracy and efficiency of drug delivery systems. Many plant-derived compounds have been exhibited to present limitations towards their use therapeutically due to their limited solubility, instability, and limited bioavailability. The development of nanotechnology has addressed these problems by producing nanosystems which can facilitate the direct transportation of active compounds to the target cell/ tissue. The advantage of using a targeted method of drug delivery facilitates a higher concentration of drug at the site of pathology and minimizes the side effects produced to normal cells. Therefore, the overall efficacy of phytochemicals as a drug is dramatically improved from the use of nanotechnology. Thus, nanotechnology has become a fundamental tool within the development of new pharmaceuticals and for the advancement of biomedical research (Emerich&Thanos, 2007)

Targeted drug delivery via nanoparticles engineered for identifying certain cells, e.g., cancer cells, or infected tissues is one of the most important aspects of nanotechnology. They obtain this ability by using ligands or antibodies as surface modifications on the nanoparticle's surface. The result of this interaction is that the drug can be specifically selected to attach to the target area and keep the drug from being distributed through the body. Targeting the area reduces toxicity and maximizes treatment success. Many phytochemicals are powerful but non-specific; therefore, nanotechnology will improve the therapeutic index of these types by specifically directing them to where they will have an effect. Overall, the targeted approach has been successfully applied to treating cancer, infectious diseases, and inflammatory disorders, making it a great contribution to modern medicine (Kohli et al., 2014)

Another key benefit of using nanotechnology for drug delivery systems is that they can provide controlled release of the active ingredients over an extended period of time (e.g., days or weeks). This helps to maintain consistent levels of the drug in the blood, as opposed to having peaks and valleys in concentration, which can affect how well the drug works and can also cause adverse side effects. There are many different types of nanocarriers used to achieve this controlled release (e.g., liposomes, polymeric nanoparticles, solid lipid nanoparticles), and these can be designed to respond to external stimuli (e.g., environmental factors such as pH, temperature, or enzymes) so that the drug can be released exactly where it is needed. Through controlled release, there is typically a decrease in the number of times a patient must take medication, thus improving compliance. In addition, because of their stability, phytochemicals can be maintained for longer periods of time when using controlled release systems as compared to non-controlled release systems; therefore, they provide long-term therapeutic benefits, which is particularly useful for chronic disease management (Malam et al., 2009)

Nanotechnology has the dual functions of being able to target a specific product and provide controlled release. In addition to these three functions, nanotechnology has also been found to increase the solubility and stability of poorly soluble phytochemicals. Many of these phytochemical compounds decompose rapidly in an in vivo condition resulting in decreased effectiveness as a therapeutic agent. Encapsulation of these compounds with nanoparticles provides a means of protecting these compounds from enzymatic and chemical decomposition. In addition, the practical effect of nanoparticles is that they increase the surface area and permeability of poorly soluble phytochemicals thereby enhancing the absorption of these compounds in the gastrointestinal tract. These two effects also enhance the bioavailability of these compounds resulting in enhanced pharmacological response. Additionally, through the use of nanotechnology multiple therapeutic agents can be loaded into one delivery system to achieve an enhanced synergistic therapeutic response. These benefits provide nanotechnology with a very efficient method to enhance the overall therapeutic potential of herbal medicine and natural products in contemporary medicine (Wagner et al., 2006)

The introduction of nanotechnology has changed how we deliver medications from new methods of targeting specific cells (targeted delivery) to how the medication is released (controlled release). This has increased the effectiveness, safety, and reliability of using herbal products because of their improved effectiveness, safety, and reliability. In addition, these new technologies help apply some of the same techniques used in developing traditional herbal medicines to help develop new types of medicines. Nanotechnology will continue to advance the use of personalized medicine and treat diseases in the future. It is also helping connect traditional product research to modern drug development, improving the quality of care available to people worldwide (De Jong &Borm, 2008)

Herbal Nanomedicine Supports Modern Healthcare And Drug Discovery

Integrating ancient knowledge of using herbs for health with new methods of drug delivery and development has created a new revolutionary field called "Herbal Nanomedicine." Researchers in this area are utilizing various nanoparticles, liposomes, phytosomes, dendrimers, and nanoemulsions to improve the effectiveness of traditional herbal medicines through increased absorption, improved stability, and more precise targeting of drugs to the body. Medicinal plants generally provide many different types of bioactive compounds, many with very strong pharmacological activity; however, these compounds often have limited clinical usefulness because they have low solubility, instability, and/or low bioavailability. By using nanotechnology to create novel forms of herbal medicines, researchers can overcome these limitations and thereby make plants containing bioactive compounds significantly more effective in treating diseases. In conclusion, herbal nanomedicine allows for a seamless transition of herbal medicines into modern medicine by providing validated scientific proof of the effectiveness of traditional plant-based treatments within modern healthcare systems. In addition, herbal nanomedicine can serve as a critical link between ethnomedicine and pharmaceutical science because it provides a more efficient method for developing and formulating pharmaceuticals. Consequently, herbal nanomedicine has gained tremendous attention in the biomedical research community, and many researchers believe that it offers significant opportunities for improving patient care globally through a new paradigm of developing therapies based on natural products (Patra et al., 2017)

Herbal Nanomedicine can Increase Targeted Drug Delivery: The use of nanocarriers (nanoscale carriers) in designing targeted delivery of phytochemicals (the active ingredient in many herbal medicines and foods) directly to diseased tissues or certain cells (tumour or infected sites), increases the amount of the active compounds available at their intended destination (diseased). This results in a reduced amount of damage to healthy tissue, reduces the potential for side effects and overall improves therapeutic efficacy. In addition, nanoparticles improve cellular uptake of the drug by increasing the permeability of the biological membranes and overcoming natural barriers of the body. This means greater distribution of drugs throughout the body and increased efficacy at lower doses. In cancer therapy, herbal nanomedicine allows for selective targeting of cancer cells, increasing the likelihood of improved treatment outcomes, while decreasing the level of toxicity experienced as a result of traditional chemotherapy. The ability to control drug localization is one reason why nanotechnology is a powerful new development in the field of modern medicine. As a result of the improvements to the performance of plant-based medicines created by targeted delivery systems, these medicines have seen vast increases in their potential applications for the treatment of various diseases (Gao et al., 2011)

Herbal nanomedicine significantly impacts speeding up drug discovery and development. Many phytochemicals previously identified as unsuitable for pharmaceutical applications due to poor solubility or instability are starting to be reformulated using nanotechnology, opening the door to identifying new drug candidates from medicinal plants. Nanotechnology-based systems allow researchers to study the pharmacological properties of plant molecules more effectively through increased levels of stability and bioavailability, therefore, helping researchers to gain insights into the mechanisms of action of phytochemicals at the molecular level. This enhances the screening efficiency and reduces the time necessary for drug development. Additionally, herbal nanomedicine supports high-throughput screening techniques, enabling the rapid screening of numerous plant extracts for therapeutic use. By combining traditional medicinal knowledge with cutting-edge science, researchers will be able to identify new treatment options for complex diseases. By advancing the field of natural products research, this approach has added breadth and strengthened the

role of natural products in contemporary pharmaceutical advancements (Yong et al., 2015)

Another advantage of the use of herbal nanomedicine is that they allow for better controlled release and enhancing the bioavailability of phytochemicals. Nanocarriers can be engineered to provide a sustained and controlled rate of release of active (e.g. phytochemical) compounds into the body over an extended period of time, so that there is a consistent concentration of drug(s) in the body. This allows for regular dosing and improves the patient's ability to follow the dosing schedule. Controlled release also reduces the amount of fluctuation in drug concentration, which can reduce the likelihood of toxicity and side effects. In addition, modifying phytochemicals with nanotechnology improves their solubility and absorption into the body by increasing their surface area and permeability; when phytochemicals are modified, they can penetrate membranes easier. Encapsulating active compounds in a protective manner prevents degradation by environmental conditions (e.g., light, temperature, and/or enzymes) that can occur prior to their therapeutic use; therefore, there will be a longer duration of therapeutic effect. The increased bioavailability of drugs resulting from using nanotechnology means that drugs can exert their pharmacological action more efficiently at lower doses; therefore, they are safer to use, and less expensive to provide, when compared with conventional pharmaceuticals. This is particularly significant in situations of long-term management of chronic diseases because they require an extended duration of treatment with minimal patient adherence. Overall, improved controlled release and enhancement of bioavailability are major factors contributing positively to the clinical efficacy of herbal medicines (Ahmed et al., 2016)

In conclusion, herbal nanomedicine is one of the first significant partnerships between traditional herbal medicine/therapeutics and modern pharmacy. It has increased the therapeutic capabilities of phytopharmaceuticals through increased bioavailability, stability, and efficacy. In addition to developing safe, efficacious, standardisedphytopharmaceuticals for global health, it promotes sustainable ways to discover new drugs from natural sources using innovative technologies. Several serious public health issues (including cancer, infectious diseases, diabetes and cardiovascular disease) may be addressed with herbal nanomedicine. With continued research and

technical advances, it is anticipated that this burgeoning field will significantly contribute to the future of personalised medicine and precision therapy. As the field of both herbal science and nanotechnology continues to grow, so too will the opportunities to create innovative therapeutic modalities. Ultimately, herbal nanomedicine represents a synergistic link between ancient healing systems and contemporary biomedicine, providing new avenues for safe and effective natural healthcare solutions around the world (Chenthamara et al., 2019)

Conclusion

The international medicinal value of traditional herbal medicine has been enhanced through the combination of phytochemical analysis and advanced drug delivery technologies. The world produces medicinal plants which contain multiple bioactive compounds that include alkaloids and flavonoids and terpenoids and tannins and phenolic compounds. The compounds produce various medical effects which include antioxidant protection and antimicrobial defense and anti-inflammatory treatment and anticancer therapy and antidiabeticcontrol. The researchers use advanced phytochemical profiling methods to identify and isolate and standardize these compounds which permit them to study the compounds chemical properties and their biological effects. Multiple plant-based compounds require further study to establish their clinical value because their development faces multiple challenges which include poor solubility and low bioavailability and unstable characteristics and rapid metabolic breakdown. Researchers developed new drug delivery systems through the development of innovative delivery technologies which utilize nanoparticles and liposomes and phytosomes and nanoemulsions and polymer-based delivery systems. The systems enable precise delivery of phytochemicals which allows controlled release of the substances while maintaining their stability and enhancing their absorption capacity to improve therapeutic results and safety. The combination of traditional herbal medicine with contemporary pharmaceutical science and nanotechnology results in new possibilities for discovering and developing drugs

References

Ahmed, K., Li, Y., &McClements, D. J. (2016).Nanoemulsion-based delivery systems for improving bioavailability of bioactive compounds.*Food & Function*, 7(1), 33–46.

Anand, P., Kunnumakkara, A. B., Newman, R. A., &Aggarwal, B. B. (2007). Bioavailability of curcumin: Problems and promises. *Molecular Pharmaceutics*, 4(6), 807–818.

Balunas, M. J., &Kinghorn, A. D. (2005).Drug discovery from medicinal plants.*Life Sciences*, 78(5), 431–441.

Chenthamara, D., Subramaniam, S., Ramakrishnan, S. G., et al. (2019). Nanoparticles: A review of their synthesis and biomedical applications. *BiochimicaetBiophysicaActa*, 1863(9), 233–246.

Cowan, M. M. (2019). Plant products as antimicrobial agents.*Clinical Microbiology Reviews*, 12(4), 564–582.

Cragg, G. M., & Newman, D. J. (2013).Natural products as drug leads.*BiochimicaetBiophysicaActa*, 1830(6), 3670–3695.

Dai, J., &Mumper, R. J. (2010). Plant phenolics and drug discovery. *Molecules*, 15(10), 7313–7352.

Dias, D. A., Urban, S., &Roessner, U. (2012). A historical overview of natural products.*Metabolites*, 2(2), 303–336.

Emerich, D. F., &Thanos, C. G. (2007).Nanomedicine and drug delivery.*Pharmaceutical Research*, 24(5), 1154–1161.

Gao, W., Chan, J., &Farokhzad, O. C. (2011). Nanotechnology in drug delivery.*Chemical Society Reviews*, 40(1), 313–332.

Gautam, V., et al. (2016).Bioinformatics in phytochemical analysis.*Briefings in Bioinformatics*, 17(6), 1151–1162.

Ghasemzadeh, A., &Ghasemzadeh, N. (2011).Flavonoids and phenolics in medicinal plants.*International Journal of Molecular Sciences*, 12(11), 6535–6557.

Harborne, J. B. (1998). *Phytochemical Methods*.Springer.

Kohli, K., Chopra, S., & Gupta, R. (2014). Nanoparticles in drug delivery.*International Journal of Nanomedicine*, 9, 1005–1023.

Kumar, P., Singh, S., & Sharma, A. (2020).Herbal medicines and nanotechnology integration.*Phytomedicine*, 67, 153–162.

Middleton, E., Kandaswami, C., &Theoharides, T. C. (2000).Plant flavonoids in health.*Pharmacological Reviews*, 52(4), 673–751.

Mukherjee, P. K., et al. (2009). Herbal drug delivery systems.*Phytomedicine*, 16(5), 493–505.

Newman, D. J., &Cragg, G. M. (2016). Natural products as drug sources.*Journal of Natural Products*, 79(3), 629–661.

Pandey, M. M., &Tripathi, S. (2014). Phytochemical profiling of medicinal plants.*Asian Pacific Journal of Tropical Biomedicine*, 4(2), 145–152.

Pardeike, J., Hommoss, A., & Müller, R. H. (2011).Lipid nanoparticles.*Advanced Drug Delivery Reviews*, 63(6), 417–431.

Patel, D. K., Kumar, R., &Laloo, D. (2012). Bioavailability of herbal drugs.*Journal of Advanced Pharmaceutical Technology*, 3(2), 99–105.

Patra, J. K., et al. (2017). Nano drug delivery systems.*Journal of Nanobiotechnology*, 15(1), 1–27.

Sasidharan, S., et al. (2011).Phytochemical screening methods.*Molecules*, 16(4), 2593–2606.

Shah, N., et al. (2014).Herbal drug delivery systems.*International Journal of Pharmaceutics*, 472(1–2), 1–9.

Singh, R., et al. (2017). Nanotechnology in herbal delivery.*International Journal of Pharmaceutical Sciences Review*, 45(1), 45–52.

Sumner, L. W., et al. (2003). Metabolomics in plants.*Phytochemistry*, 62(6), 817–836.

Tiwari, S., &Rana, A. (2015).Phytochemicals and biological activities.*Journal of Pharmacognosy*, 7(3), 123–130.

Williamson, E. M. (2001). Bioavailability of herbal medicines.*Phytotherapy Research*, 15(7), 601–606.

Wolfender, J. L., et al. (2015). Phytochemical analysis techniques.*Phytochemistry Reviews*, 14(1), 1–22.

Yadav, R., et al. (2011). Herbal drug limitations.*Journal of Pharmaceutical Sciences*, 100(9), 345–358.

Yong, Y. C., et al. (2015). Nanotechnology in drug discovery.*Biotechnology Advances*, 33(4), 103–115.