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Pharmacognosy-Guided Herbal Drug Development and Innovative Pharmaceutics Strategies Addressing Modern Healthcare Challenges Worldwide

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Abstract

The future of drug development relies upon the use of a wide variety of natural materials derived from plants and animals. As more research has been done into these materials and their medicinal value, it is becoming evident that they have great promise in terms of creating safe and effective drugs. Guided development of herbal medicines involves combining ethnobotanical knowledge with methods of evaluating phytochemical activity, and evaluating pharmacological efficacy, and then utilizing sophisticated analytical methods to identify compounds in these products that are potentially useful for clinical application. In addition to conducting research to find pharmaceutical products that can be used to treat various diseases or health conditions, there are several novel pharmaceutical formulations that are being developed for use with herbal products; these include nanoformulations, phytosome formulations, liposome formulations, controlled-release systems, and targeted drug delivery systems. The novelty and advancement of these types of formulations are providing greater bioavailability, stability, and therapeutic effectiveness of herbal product use than traditional methods of product formulation. The recent advances in medicine and the medical field caused by these novel forms of drug development have addressed many of the major global healthcare issues, including antibiotic resistance; chronic illness; cancer; metabolic disorders; and newly developing/advancing viruses. Many people in today's society are seeking out natural products that are sustainable, and many researchers are looking at ways to develop evidence-based herbal therapies and personalized medicine to meet these

needs. As such, the regulatory standardization and quality control of herbal products will continue to be important to establish the global acceptance of herbal products and to ensure the safety and effectiveness of herbal formulation use. As pharmacy continues to evolve with the integration of pharmacy with biotechnology, artificial intelligence, and novel forms of pharmaceuticals, pharmacognosy-inspired innovation will help spur the discovery of drugs in the future and form multidisciplinary and sustainable approaches to improve global healthcare outcomes. In conclusion, the pharmacognosy-influenced innovation of herbal medicine will promote the discovery of safer, more cost-effective, and sustainable therapeutic products in the future through research focused on delivering health solutions.

INTRODUCTION

Pharmacognosy is a subfield of pharmacy that looks at the role and effect of naturally derived substances on health by studying plants, nature's bioactive compounds, and medicinal plants—the part of the plant that we relate to for use in medicine, nutrition, and so forth. When we think of plants and herbal medicine, we usually refer to how these have been around since man began using herbs to prevent or treat illness in every culture, tradition, or health care system around the world. More recently, there has been a spike in interest in the use of plant-based and naturally-derived formulations and their effectiveness and safety when compared to chemical or synthetic formulations. Today, many researchers are working on identifying new natural compounds with identified pharmacological activity. This is a result of the advancement of analytical techniques such as chromatography, spectroscopy, molecular biology, etc., to help identify new and innovative compounds from plant sources*. As the rates of chronic disease, antibiotic resistance, and/or reactions to medications continue to rise and as evidence of the therapeutic benefits of natural and herbal-based formulations becomes more well-known, there continues to be a substantial increase in both interest and demand for herbal therapeutics worldwide. While pharmacognosy is used to support traditional methods of healing, science is also being applied to support the creation of evidence-based herbal products for contemporary health care uses. The combination of applying scientific data to traditional herbal knowledge is allowing for many new ways to discover new and exciting therapeutic options for addressing current as well as future health care issues in developed as well as in developing countries. (Newman &Cragg, 2020)

Developing herbal drugs guided by the use of "traditional medicine knowledge" and "scientific research" to develop safe, effective and standardized herbal medicines is a multi-disciplinary process. Valuable information about how plants are used therapeutically, from ethnobotanical studies, assists researchers in identifying the

potential of these plants to be used as agents for the treatment of various diseases. Once potential medicinal plants have been identified, phytochemical and pharmacological screening is performed to evaluate the biological activity and therapeutic potential of the individual plant. The advent of modern techniques such as molecular docking, bioassays, and genomics, has significantly accelerated the identification of active constituents that can be extracted from plant sources. Moreover, the application of advanced extraction and purification techniques continues to improve the quality and consistency of herbal products. The increasing importance of herbal drug development is due to the fact that many synthetic drugs tend to be associated with either toxicity, side effects, or high treatment costs. Furthermore, many of the compounds derived from plants exhibit a wide range of pharmacological properties, so it is possible that they may be useful in treating complex diseases like cancer, diabetes, cardiovascular disease, and inflammation. Guided herbal drug research also encourages the discovery of novel lead molecules that may ultimately become modern pharmaceuticals. Therefore, integrating traditional healing systems with science and primary research will be an essential element in addressing global healthcare challenges and promoting sustainable drug discovery. (Atanasov et al., 2021)

In recent years, advances in pharmaceutic strategy have greatly enhanced the clinical use of herbal medicines and their effectiveness therapeutically. A significant factor affecting the efficacy of herbal formulations is their poor solubility and stability, low bioavailability, and limited absorption of their active phytochemicals. Innovative drug delivery systems, such as nanoparticles, liposomes, phytosomes, microspheres, nanoemulsions, and controlled-release formulations have been developed to provide new means of overcoming these limitations. All of these methods allow for enhanced stability, targeted delivery, and therapeutic efficacy of plant-based compounds while decreasing toxicity and side effects associated with those compounds. In particular, systems developed from nanotechnology enhance penetration of herbal bioactive molecular substances and allow for sustained release of those substances, which makes them a more effective therapy for chronic diseases and infectious processes. Through membrane permeability and enhanced absorption of herbal constituents into the human body, phytosomes and liposomal formulations also improve bioavailability. Furthermore, through the use of modern pharmaceutical technologies, it is possible to develop individualized herbal therapies that relate more closely to the individual needs of each patient. Novel approaches to pharmaceutics improve patient compliance, provide additional commercial and clinical opportunities for herbal products globally. Through the integration of pharmacognosy with novel pharmaceutics, the use of natural

products as therapy and improving world health will continue to expand and provide promising methods of improving the delivery and effectiveness of therapies. (Patra et al., 2018)

Numerous challenges exist in today's worldwide health systems, including a wide variety of new and emerging infectious diseases, chronic health conditions, an aging population, and escalating costs associated with medical treatment. Consequently, increased interest has resulted in a demand for more effective and affordable therapeutic options. Traditional herbal medicine, along with many of nature's remedies, has received much attention due to the wide array of pharmacological properties that many herbal medicines possess as compared to those of synthetic drugs, along with their generally lower side-effects. Accordingly, a number of medicinal plants have been identified as having some degree of efficacy against certain harmful bacteria, free radical oxidation, inflammation, viral infection, and certain types of cancer. Additionally, researchers have sought to find new herbal compounds that may help support and enhance existing treatments during global health emergencies. The increase in interest in natural healthcare products has led to a surging herbal medicine market and has incentivized pharmaceutical companies to devote resources into researching herbal medicines for potential benefits. However, despite these benefits, herbal medicines face numerous barriers to acceptance, including but not limited to the lack of standardization, quality control, regulatory approval, and scientific validation. Clinical studies, toxicological evaluations, and international regulatory guidelines are necessary to further validate the use of herbal medicines in meeting current and future health system challenges. (Ekor, 2014)

The future of herbal medicine development using pharmacognosy, will depend largely on integrating current natural products research with more recently formed technology fields, such as biotechnology, artificial intelligence, nanotechnology and computer-aided drug design technology. These science advances have the potential to speed up the search for new phytochemicals and create more effective herbal remedies for complex diseases. Artificial Intelligence and Bioinformatics-based tools are play a larger role than ever in terms of modeling biological activity, maximizing formulations for drug development, and identifying new therapeutic targets based upon large databases of potential medicinal compounds found in plants. Likewise, biotechnology based strategies such as plant tissue culture and genetic engineering are providing methods for increasing the supply chain of valuable compounds derived from rare and endangered plant species. An additional focus of herbal drug development has become sustainable use of the planet's natural resources through the protection of biodiversity

and environmental balance. Furthermore, global collaboration between both researchers and research institutions, healthcare providers, pharmaceutical companies, and regulatory agencies will be critical in helping to identify internationally accepted standards for the use of herbal medicines. Raising public consciousness related to the use of evidence-based herbal medicine will also promote safe and rational usage of herbal medicine products within the worldwide healthcare systems. In conclusion, the multidisciplinary and sustainable approach associated with the pharmacognosy based innovation and development of herbal medicines will play an important role in improving medically-related healthcare delivery systems, facilitating safer therapeutics, and addressing future international medical challenges more effectively. (Atanasov et al., 2021)

Importance of pharmacognosy in modern drug discovery

Pharmacognosy, the study of how natural compounds can be used for therapeutic purposes, is one of the most critical disciplines involved with modern drug development because it supplies scientists with numerous naturally occurring compounds that can be used to develop medications. Natural sources (plants, microorganisms, marine organisms) have been utilized as a source of treatment for diseases since the beginning of civilization and many current medications are manufactured directly or indirectly from naturally occurring substances. Pharmacognosy also allows for exploration into the chemical makeup of medicinal plants and assists in the identification of biologically active compounds that possess considerable pharmacological activity. A number of very important medications, such as anticancer, antimycobacterial, and cardiovascular agents, originate from naturally occurring sources. Due in part to the increasing development of resistance among bacteria to synthetic antibiotics and the number and severity of side effects associated with medicinal chemicals; an increasing number of researchers are beginning to focus on finding safe alternatives to chemical medications by investigating the therapeutic use of medicinal plants and their products. In addition, pharmacognosy is involved with the discovery of new molecules and their unique mechanisms of action that can be further developed into effective therapeutic agents. For this reason, continued advancement in scientific technology (chromatography, spectroscopy and molecular biology) has led to greater opportunities for the isolation and characterization of phytochemicals. These advances have resulted in a much stronger emphasis on the role of pharmacognosy within the field of pharmaceutical research and a greatly enhanced role for pharmacognosy in the identification and development of innovative health care solutions. As such, pharmacognosy is an essential field for the continued

discovery of safe and effective ways to produce quality medications for the world's health care systems. (Balunas&Kinghorn, 2005)

Modern drug discovery relies heavily on natural and sustainable means to meet people's needs. And with the increasing use of medicinal plants as medicine throughout the world, the significance of pharmacognosy continues to grow; this is due to the availability of numerous phytochemicals found within these plants such as alkaloids, flavonoids, terpenes, glycosides, and phenols, which all have some form of therapeutic action. Pharmacognostic research allows researchers to evaluate these specific phytochemicals for their various medicinal actions (e.g. antimicrobial, antioxidant, anti-inflammatory, antidiabetic, anticancer), thereby expanding the pharmacology of traditional medicinal plants. In light of the recent global increase in chronic diseases (e.g. diabetes, hypertension, cancer, neurodegenerative diseases), additional demand has creased to develop safer and more reliable therapeutic options for treatment and prevention of these disorders. At the same time, pharmacognosy provides researchers opportunities to identify natural compounds that demonstrate multiple pathway targets for the potential treatment of chronic disease. Furthermore, the use of herbal medicine has generally been recognized as being affordable and accessible for many individuals in developing countries where access to conventional modern healthcare services is not as available. Moreover, validation of the efficacy of many of these traditional medicinal plants through the completion of pharmacognostic studies enables practitioners who utilize herbal medicine to provide a higher standard of care to their patients based upon evidence-based medicine principles; this helps to promote the global acceptance of herbal medicine. Additionally, through the study of medicinal plants, there is an increase in efforts towards the conservation of biodiversity and sustainable management of natural resources. Overall, pharmacognosy will continue to have a major impact on advancement and success of the pharmaceutical industry, as well as public health, through the study, research, and development of natural products.(Harvey et al., 2015)

In today's pharmaceutical industry, scientists have relied on the study of pharmacognosy as the primary means of finding and developing lead compounds for new medicines. Natural products are often recognized for the vast difference between their chemical structures and their potential for biological activity when compared to synthetic chemicals, therefore making them highly valuable for drug discovery and development. In addition, through research and development of pharmacognostic methods, active compounds can be isolated from the plant species in which they were discovered; these compounds can then be chemically modified to create more effective and safer drugs. Some of the most commercially successful drugs, including paclitaxel, quinine, morphine,

and artemisinin, have been discovered through the study of naturally occurring compounds. Additionally, pharmacognosy provides information on the pharmacodynamic and toxicological characteristics of herbal-based materials, as well as pharmacokinetics, which is the process by which substances are absorbed and transported within the body. The use of advanced screening methods in combination with computer-generated designs has significantly reduced the time required for the discovery of bioactive substances from many different species of plants. In addition, the combination of pharmacognosy with biotechnology and genetic engineering has allowed for large-scale manufacturing of high-value phytochemicals for medicinal purposes. Finally, pharmacognosy has helped the industry to create standards for quality control and final product acceptance, thereby improving therapeutic effectiveness and safety through uniformity across all herbal medicines. Overall, the science of pharmacognosy serves as an important link between traditional knowledge of healing and the more contemporary sciences used in the development of new drugs, allowing for improved access to innovative medicines and continued growth within the field of drug discovery and development. (Dias et al., 2012)

Pharmacognosy has a significant role in solving new global health problems such as resistance to antimicrobials, outbreaks of viruses, and rising health-care costs. The rampant use of synthetic antibiotics has caused bacteria to develop into resistant strains, thus making many traditional therapies ineffective. In contrast, natural products represent a novel source of potential new antimicrobial agents that display different chemical structures and/or mechanisms of action that will likely help solve the resistance problem. In addition, there are many medicinal plants that may have antiviral and/or immunomodulatory activity that can help prevent and treat infectious diseases. Recently, there has been an increased interest in studying and examining the potential roles of many herbal compounds as therapeutic agents for viral infections or inflammatory conditions due to recent public health crises. As well, pharmacognosy promotes developing economical therapies that can alleviate the economic burden on the health-care system, primarily in countries classified as low- or middle-income. Additionally, it is important to note that herbal products can typically be produced by the manufacturer with less material consumed compared to synthetic alternatives; therefore, they are also more readily accepted because of their historical and cultural significance. Finally, pharmacognostic studies allow consumers and regulatory bodies to be confident in the safety and quality of herbal products by identifying issues related to contamination or adulteration. With the continued advancement of health-care systems, pharmacognosy

provides new, innovative, and sustainable solutions to improve the management of disease and enhance global public health outcomes. (Cragg& Newman, 2013)

Pharmacognosy's future significance will increase with new and emerging technologies and interdisciplinary methods. Technologies like artificial intelligence, machine learning, and bioinformatics are used in current pharmacognosy research to analyze large phytochemical databases and predict natural products' biological activity. This innovative technology will lead to faster identification of potential drug candidates and reduced time in the pharmaceutical development phase. Drug delivery systems using nanotechnology have advanced the therapeutic use of natural materials derived from plants through improved stability, increased bioavailability, and targeted delivery. Biotechnology methods such as plant tissue culture and metabolic engineering also provide for the sustainable production of large quantities of commercially valuable medicinal substances without excessive use of natural resources. In addition, predictive analysis of genetic and physiological differences helps pharmacognosy identify botanical-based therapies to provide individualized healthcare. With increased collaboration on a global scale between researchers, healthcare providers, and pharmaceutical companies, there are many opportunities for expanding the use of natural products for research and clinical applications. In conclusion, continued pharmacognostic research will provide ongoing innovation in the field of drug discovery, support sustainable healthcare, and meet the future global healthcare challenges by exploring science of natural resources and traditional herbal medicine. (Li &Vederas, 2009)

Role of medicinal plants in healthcare systems

Since ancient times, medicinal plants have been a central part of healthcare systems around the world. They are still a significant resource for treatment and prevention of many diseases. Many of the world's cultures have developed traditional systems of medicine that make intensive use of plants as therapeutics for managing a great many different types of illnesses. Some of the several traditional systems of medicine that depend heavily on plant-derived remedies for the treatment and management of various health conditions include Ayurveda, Traditional Chinese Medicine, and Unani Medicine. The therapeutic effects of medicinal plants are due to the presence of various classes of bioactive compounds, including: alkaloids, flavonoids, tannins, terpenoids and glycosides. Herbs are used to create herbal medicines that treat infections, control inflammation, aid in digestion, provide respiratory relief, and manage chronic diseases. Medicinal plants are still the main source of healthcare in many developing countries due to their low cost, accessibility and widespread cultural acceptance. Global health

statistics estimate that a large percentage of the global population relies on using herbal medicine to meet their primary healthcare needs. An increasing number of people are turning to plant-derived therapies because they want alternatives to taking synthetic drugs due to the side effects associated with many synthetic drugs. Scientific studies have corroborated the therapeutic effects of many medicinal plants, resulting in greater acceptance of these types of therapies within current healthcare delivery systems. Thus, medicinal plants continue to contribute to global healthcare systems by supplying diverse populations with safe, affordable and effective therapeutic options. (Fabricant & Farnsworth, 2001)

The significance of medicinal plants in health care systems has increased considerably because of their role in modern drug discovery and drug development. Many important drugs for the treatment of diseases originate from plant resources, showing the pharmacological potential of natural products. Numerous pharmacological activities such as anti-microbic, anti-cancer, anti-diabetic, anti-hypertensive, anti-oxidant and anti-inflammatory are also demonstrated by medicinal plant-derived materials. The continual research into this category of plants aids researchers in the identification of new molecules with biological activity, which may be beneficial to the treatment of new and emerging diseases and will alleviate some of the limitations to conventional (or synthetic) pharmaceuticals. In addition to being the source of pharmacologically active natural products, medicinal plants are also being used to produce lead compounds that can be chemically modified to produce safer or stronger pharmaceuticals. Because of the varied structural diversity and biologic specificity of these plant materials, more pharmaceutical companies are recognising the value of plant-derived substances. Many countries are also incorporating plant-based preparations into their complementary/alternative medicine practices. Current advancements in biotechnology, phytochemistry and pharmacology have improved the identification and extension of medicinal plant-derived compounds. Therefore, in addition to their traditional function in the healing arts, the continued use of medicinal plants will contribute to scientific progress and innovations in modern medicine. Given their increasing value, medicinal plants must be sustainably grown and collected, as well as used according to best scientific evidence, in order to support the medical care systems around the world. (Rates, 2001)

Medicinal plants have a significant impact on the public health system because they provide individuals with affordable alternative treatment options for their health issues (e.g., those who have limited access to traditional healthcare). Generally, traditional medicine is usually more readily available than modern healthcare within rural and

undeveloped parts of the world due to the inability to access adequate healthcare duplicating the need for traditional medicine, which is used by traditional healers and local practitioners as a remedy for illnesses associated with fever, pain, infection and several other disorders/diseases. The use of herbs for medicinal purposes is an economical way to treat all of these conditions has been a long-standing tradition in these communities and provides many individuals in developing countries with the means to maintain their well-being without the costs associated with synthetic drugs. Additionally, herbal products are part of preventive health by providing individuals with enhanced immunity and promoting well-being. Herbal products are also widely used as food and supplement sources of nutritional support (i.e., functional food) and wellness formulations. As such, the importance of incorporating traditional herbal medicine into a national health policy is being recognized by governments and international health organizations. Educational programs and scientific research are also emphasizing the safe and rational use of herbs for health. Unfortunately, current issues related to the under-recognition of traditional herbal medicine (e.g., incorrect identification, cross-contamination, non-standardized dosing) remain widespread among many groups in the community. Thus, proper controls over the quality of all aspects of herbal medicines need to be put in place to maximise their overall public health benefits across the globe.(WHO, 2013)

The spread of chronic diseases and the rise of new infections has grown the importance of using medicinal plants within present healthcare frameworks. Chronic illnesses such as diabetes, cancer, cardiovascular, obesity, and neurodegenerative disorders require long periods of treatment and generally involve significant treatment costs as well as significant negative side effects from the use of synthetic medications. Due to the multitude of pharmacological effects found in many medicinal plants and their relative lack of toxicity compared to synthetic drugs, they provide promising alternative medications. The antioxidant and anti-inflammatory activities of most herbal compounds may help reduce oxidative stress to prevent the onset of diseases. In addition, due to the emergence of antimicrobial resistance, which has now become a major global health issue, the use of medicinal plants has demonstrated great potential to treat infections caused by resistant bacteria, fungi and viruses. Researchers are examining previously used plant-based substances for their ability to inhibit the growth of resistant organisms. A number of commonly used medicinal plants were evaluated during recent viral outbreaks for their potential immunomodulatory and antiviral effects. The integration of medicinal plants into integrative approaches to healthcare has led many patients to seek holistic treatment options. With an increasing body of research

supporting the use of herbal medicines, healthcare practitioners are open to using plant-based treatments in their practice. Therefore, medicinal plants constitute an essential resource to help meet many of the challenges in healthcare today and to promote innovative and environmentally sound therapies in healthcare. (Calixto, 2019)

Medicinal plants will continue to play an essential role in healthcare systems worldwide due to advancements in science, sustainable resource management, and global collaboration on herbal medicine research. New technologies, such as genomics, metabolomics, AI, and nanotechnology, are rapidly enhancing the discovery and development of plant-based therapeutic agents by enabling researchers to efficiently identify active ingredients, as well as to improve the delivery and effectiveness of herbal medicines. Biotechnological techniques (e.g., plant tissue culture and genetic modification) will increase the degree of sustainable production of valuable medicinal compounds, while reducing the impact of harvesting on endangered or threatened plants. The increased global demand for natural and environmentally friendly products has led the pharmaceutical industry to invest more resources into researching and commercializing herbal drugs. Regulatory agencies worldwide are implementing guidelines for evaluating the quality, safety, and efficacy of herbal medicines, which will help protect consumers. Public education about evidence-based herbal therapies is also leading to the responsible and informed use of medicinal plants. In addition, cooperation among traditional health practitioners, researchers, and health professionals will facilitate the preservation of traditional healing knowledge while advancing scientific research. As such, medicinal plants will continue to play a vital role in supporting disease prevention, innovative therapies, and sustainable health care development for future generations worldwide. (Petrovska, 2012)

Guided herbal drug development approaches

The process of developing new drugs from herbs is done through discovering natural products and plants that have health benefits and developing those products according to quality, safety, and effectiveness as per scientific principles. Guided herbal drug development uses information about traditional medicines along with modern methods to find compounds with important therapeutic activity. Traditional healthcare systems, such as Ayurveda, Traditional Chinese Medicine, and Unani medicine, provide researchers with valuable knowledge about how certain plants have been used for their therapeutic properties. Following the selection of plants, scientists use various methods of pharmacognosy and phytochemistry to isolate and identify the active ingredients in the selected herbal materials. Various modern analytical methods are used in the identification of biologically active chemicals obtained from herbal resources. Another

aspect of guided herbal drug development includes performing biological studies (in vitro and in vivo) to evaluate the safety, effectiveness, and mechanism(s) of action of the identified herbal chemicals. Guided herbal drug development approaches have become more necessary because currently, many synthetic drugs produce many side effects, are toxic, and create resistance by bacteria to antibiotics. Therefore, developing herbal medicines represents an exciting source of discovery for new types of therapies, which will help solve modern healthcare problems, while allowing for careful management of our natural resources and traditional medicines. (Sasidharan et al., 2011)

Traditionally, Ethnopharmacology is often viewed as the most significant approach to guided herbal drug development. Guided herbal drug development through ethnopharmacology includes conducting ethnopharmacological surveys to understand how medicinal plants are/ were used in traditional medicine for the treatment of various diseases, and will identify those plants that have been used historically as herbal medicines for particular therapeutic purposes. This information is important because it provides the basis for scientific studies that will establish the effectiveness of the medicinal plants and speed up the drug discovery process while reducing the financial costs of drug screening programs based solely on random selection of plants. Once suitable plants are selected, phytochemical screening is conducted to assess the presence of secondary metabolites such as alkaloids, flavonoids, saponins, tannins, and terpenoids. After identifying secondary metabolites in the plants, pharmacological studies will be carried out to assess the activities of the secondary metabolites as antimicrobial, antioxidant, anti-inflammatory, anticancer, antidiabetic, and antiviral agents. Additionally, molecular docking studies and bioinformatics technology are being utilized more frequently to predict the interactions between the secondary metabolites and the biological targets of the metabolites. Therefore, through the use of these modern technologies there will be more rapid drug discovery as well as increased likelihood of identifying the lead molecules. Through the use of ethnopharmacology as an intermediary between traditional methods of healing and modern methodologies in pharmaceutical research, a significant contribution has been made to the development of evidence-based natural medicines and the development of innovative approaches to providing effective and equitable therapeutic interventions throughout the world's health care systems.(Heinrich & Gibbons, 2001)

Phytochemical and pharmacological evaluation is an integral part of the development of herbal medicines because it provides scientific evidence for the therapeutic value of medicinal plants. Phytochemical evaluation involves the extraction, isolation, purification, and characterization of biological active compounds from herbal sources using

advanced techniques based on chemistry. Such techniques as high-performance liquid chromatography (HPLC), gas chromatography (GC), and mass spectroscopy (MS) can be used to accurately identify the chemical constituents found in medicinal plants and their properties. Once the compounds are identified, pharmacological testing is performed to evaluate the biological activity of those compounds and their potential for treating various medical conditions. In vitro and in vivo testing is typically used to evaluate the potential effects of the various herbal compounds on a variety of disease states. Toxicological testing is also performed to assess whether or not there are any adverse side effects associated with the use of the herbal agents prior to being used in clinical settings. In addition to phytochemical and pharmacological testing, the guided development of herbal medicines will also focus on establishing standards of quality control and proper standardization so that patients can receive herbal medicines that have been prepared with consistency, quality, and efficacy. By using adequate standards of quality, it is possible to minimize potential for contamination and/or adulteration and also variability of effectiveness of herbal medicines. Phytochemical and pharmacological evaluations help to provide scientific support for the use of herbal medicine as safe and effective treatment options by enhancing the scientific credibility of the use of herbal medicine and by advancing the integration of herbal medicine within our current healthcare system. (Mukherjee, 2019)

The current methods of guided development of herbal drugs also encompass advanced drug formulation technologies that enhance the medicinal effectiveness of herbal products. Modern herbal products have significant limitations that include low solubility, lack of stability, rapid metabolism, and low bioavailability, all of which decrease their potential clinical usefulness. For this reason, researchers continue to develop advanced drug delivery systems, e.g., nanoparticles, liposomes, phytosomes, nanoemulsions, microspheres, and controlled-release formulations to address these limitations. Using these drug delivery systems, the absorption rates, stability and site-specificity of medicinal herbal products will be enhanced. For example, nanotechnology methods of formulating herbal medicines will increase the penetration and prolonged release of herbal-derived bioactive compounds, thus increasing their effectiveness in diseases and infections caused by chronic illness. Additionally, using current pharmaceutical techniques can enhance patient safety and compliance. Current medicinal herbal formulations are now often used in conjunction with traditional pharmaceuticals in order to provide synergistic therapeutic benefits for patients, thus improving patient outcomes. The combination of biotechnology and pharmaceutical science has dramatically increased the availability and developable capabilities of plant medicine

products by aiding in the production and development of plant medicines on a large scale. Therefore, advanced pharmaceutical approaches will play a large role in guided development of herbal drug development to provide the scientific data needed to ensure the continuation of herb-based medicine products as safe, effective, and universally accepted in the marketplace. (Yadav et al., 2011)

Collaboration across disciplines, innovation through technology and sustainable use of medicine plant resources will all play crucial roles in the future of guided herbal drug development. New technologies are revolutionizing research into natural products and speeding up the search for new therapeutic agents through the use of technology such as artificial intelligence and machine learning, genomics, metabolomics, computational biology etc., to analyze large amounts of phytochemical data from multiple sources and predict the potential biological activities of molecules derived from plant materials. This helps to reduce the timeframe required to obtain regulatory approval to utilize pharmaceutical products as a new product. Biotechnology-based methods such as the use of plant tissue culture and metabolic engineering will also allow for the creation of large amounts of valuable medicinal compounds through sustainable means (i.e., without excessive harvesting from wild sources), in order to help preserve medicinal plant species that have been used in traditional medicine, while satisfying current and future demand for medicinal products. There is also an ongoing emphasis from regulatory agencies globally on quality assurance, good manufacturing practice, clinical trial design and evidence-based substantiation of herbal medicines as part of the regulatory approval to sell herbal medicines in order to help ensure patient safety and to promote therapeutic benefits. Public interest in using natural health care products and using preventative healthcare methods is also increasing demand for scientifically developed herbal products for use in clinical practice. There is also much potential for cooperation among traditional medicine practitioners, practitioners of modern medicine, and researchers in the areas of scientific innovation and the preservation of traditional knowledge. These factors demonstrate that guided herbal drug development represents a multi-faceted and sustainable approach to solving the current and future healthcare crises through the discovery and development of safe, effective and eco-friendly therapeutic agents. (Pan et al., 2013)

Ethnobotanical knowledge in herbal medicine research

Traditional (ethnobotanical) knowledge is integral in supporting research in herbal medicine because it provides information about how people from many different cultures and communities have used plants medicinally since ancient times. Ethnobotany is the scientific study of the interactions between humans and plants, and

includes such things as how people use plants as food, medicine, and for cultural purposes. For centuries indigenous groups and traditional healers have used medicinal plants to help cure many ailments and/or keep people healthy. Traditional ethnobotanical knowledge has been passed down through generations and is an important basis for modern herbal medicine research. Ethnobotanical surveys are used by scientists to determine which plants may have therapeutic properties, and help to prioritize these plants for subsequent phytochemistry and pharmacology studies. These studies are less expensive and less time-consuming than randomly screening entire plant populations for potential drugs. Many of today's medicines were originally derived from plants that have long been utilized in folk medicine systems. In addition, ethnobotanical knowledge contributes to the preservation of cultural heritage and biodiversity by documenting the traditional use of plants prior to the loss of that information. Thus, ethnobotanical research has both a direct and indirect effect on supporting the discovery of new therapeutic agents and on strengthening the incorporation of traditional healing modalities into contemporary healthcare systems as well as on sustainable use of medicinal plants. (Cotton, 1996)

Ethnobotanical knowledge is becoming increasingly relevant to research on herbal medicine as traditional systems of medicinal care are still functioning today to effectively give healthcare to millions of people across the globe. Indigenous populations have amazing knowledge regarding the preparation, dosage and therapeutic usage of plants for treating various diseases (like infections, inflammation, fever, diabetes and digestive issues). That traditional knowledge is then analyzed by researchers that will study the medicinal plant for bioactive compounds with potential significant clinical implications. Ethnobotanical studies often consist of field work, through interviewing local healers and documenting the many different plant species used for traditional medicine. This information assists researchers in delineating which plants are candidates for scientific research based on the historical use of those species as medicinal agents. In addition to providing candidates for current research, ethnobotanical methods also assist in conserving the different types of medicinal plants by demonstrating how important those plants are to both local healthcare systems as well as their local economies. The use of ethnobotanical methods to validate traditional herbal medicines through conducting pharmacological and phytochemical studies has greatly contributed to the increasing worldwide acceptance of herbal medicines. Today, in many developing countries, medicinal plants remain a vital component of primary healthcare systems because of the lack of access to modern medical facilities. As such, ethnobotanical knowledge is a major connection between the world of traditional medicine and that of

modern pharmaceutical researchers in supporting the evidence-based development of herbal therapeutics and developing sustainable methods of healthcare implementation. (Balick& Cox, 2020)

Through ethnobotanical knowledge, scientists are able to find new drugs based on the medicinal uses of plants and how they are used in traditional healing. Ethnobotanical information is helpful to researchers when they search for plants that may have pharmacological properties based on the traditional uses of the plants. Researchers systematically examine the chemical makeup of the plants that were identified in ethnobotanical studies to determine if any pharmacologically active compounds can be found in those plants. The initial step of the research typified an ethnobotanical study; phytochemical screening was carried out to determine the presence of potential pharmacologically active natural products, e.g., alkaloids, flavonoids, glycosides, phenolics, and terpenes, in the plants that were evaluated. Researchers used biological assays and other pharmacological tests to evaluate the plants' pharmacological activities as well as the mechanism of action of pharmacologically active compounds. For instance, many of the plant materials used to develop modern drugs, such as quinine, artemisinin, and aspirin, had been used in traditional medicine by cultures prior to their commercial development as drugs. Therefore, ethnobotanical information may be an important starting point for developing new medicines to treat chronic diseases, infectious diseases and emerging health conditions. Integrated use of traditional uses of plants with new technologies such as genomics, molecular biology, and bioinformatics has greatly improved the efficiency of discovering natural products for use in herbal medicine and has accelerated the research of herbal medicine products. Through the use of an ethnobotanical approach, researchers are able to work together through collaborative interdisciplinary efforts in the fields of botany, pharmacology, chemistry, and health care. Ethnobotanical research continues to be integral in advancing pharmaceutical science and developing new therapeutic agents from natural products. (Farnsworth, 1988)

While ethnobotanical knowledge is important, there are a number of challenges surrounding it. These include challenges related to documentation; intellectual property rights; and the conservation of biodiversity. Traditional medicinal knowledge is disappearing in many indigenous communities due to urbanization, environmental degradation, and modernization. Many younger family members of indigenous peoples are not as interested in using traditional forms of healing; thus, this body of ethnobotanical knowledge is becoming less available. In addition, the overharvesting of plants used in traditional medicine and the destruction of habitats for those same plants

is threatening the continued survival of many significant plant species. Many ethical issues arise when indigenous knowledge is acquired and used commercially without the proper recognition of, or benefit to, the indigenous communities providing the knowledge. Therefore, a legal framework or mechanism is needed to protect traditional knowledge and sustainably manage the resources associated with these plants. The preservation of ethnobotanical knowledge through proper documentation with the use of ethnobotanical surveys and documentation via electronic databases is a viable way of preserving these valuable forms of knowledge for future applications in science and medicine. Organizations around the world are assisting with the conservation of biodiversity and the equitable sharing of benefits resulting from research using these plants. The importance of protecting ethnobotanical knowledge, therefore, is not only related to preserving an individual's cultural heritage but also to providing medicinal plant resources available for drug development and healthcare innovations in the future. (Hamilton, 2004)

The integration of traditional knowledge with new medical technology to form a basis for research into Ethnobotany's future in the development of herbal medicines will ultimately determine what we can accomplish as a society. The use of advanced research tools (AI), metabolomics, genomics and computational biology are playing a significant role in how researchers can identify and analyse bioactive ingredients derived from Medicinal Plants much more easily and accurately predict the therapeutic effects. The globalisation of traditional medicine systems is also benefiting through inter-disciplinary partnerships between the researcher(s) and the various organisations that include but may not be limited to; traditional healers, scientists, pharmaceutical industries and healthcare agencies working collaboratively in evidence-based herbal medicine development. The need to educate and include the communities in preserving indigenous knowledge and supporting the appropriate use of medicinal plants sustainably through the use of new biotechnological methods will help ensure that there are viable medicinal planetary resources for future use. With governments around the world, including the World Health Organisation, increasingly recognising that Traditional Medicines have a key role to play in achieving global Universal Healthcare goals; through ongoing clinical studies, quality assurance and validation programs, the credibility and acceptance of herbal medicines as viable treatment options within the healthcare system will continue to grow. Furthermore, as new biotechnology methods develop to assist in producing medicinal plants on a sustainable basis will further mitigate the impact on existing naturally occurring plant populations while ensuring a continuous supply of raw materials. Ethnobotanical knowledge will therefore remain an

essential resource for identifying new and innovative medicines, maintaining cultural heritage and supporting the long term sustainable growth of healthcare delivery systems throughout the world. (Schultes&Raffauf, 1990)

Phytochemical screening and bioactive compound isolation

Phytochemical screening and the isolation of bioactive compounds are fundamental steps in herbal medicine research and the modern drug development process. Different categories of compounds exist within the classification of phytochemicals, which are defined as the many chemical constituents of medicinal plants that produce healing (medicinal) effects. Common phytochemicals include alkaloids, flavonoids, tannins, glycosides, terpenoids, saponins, phenolics, and steroids. Phytochemical screening involves the preliminary identification of phytochemical compound types using qualitative and quantitative methods of analysis. The researcher gathers all available plant material from the plant (i.e., leaves, roots, bark, flowers, and seeds) and subsequently extracts them with various solvents (e.g., ethanol, methanol, water, and chloroform). Once produced (from the solvents), researchers use chemical tests and advanced analytical methods (e.g., gas chromatography, mass spectrometry, high-performance liquid chromatography, etc.) to screen for the presence of any active biological compounds. Phytochemical screening not only helps identify plants with medicinal properties, but it also provides a foundation from which a researcher can perform subsequent pharmacological studies to further prove the medicinal properties of the plant. In recent years, there has been an increased interest in using natural products as a source for drug development due to increasing skepticism regarding the toxicity, negative side effects, and increasing levels of antimicrobial resistance associated with many synthetic drugs. Thus, the importance of phytochemical research has become more prevalent for developing safer, more effective therapies from natural sources. Research on phytochemicals aids in the creation of evidence-based herbal medicines while simultaneously providing considerable contributions to the fields of pharmaceutical science and innovation in healthcare globally. (Tiwari et al., 2011)

Natural product research as well as the development of pharmaceuticals begins with the isolation of the bioactive compound(s) from plants that are used for medicinal purposes. The identification of bioactive chemicals that have therapeutic potential starts with screening of the Dr. George P. Shattuck's Phytochemical Research database. Once a phytochemical screening identified a bioactive chemical with therapeutic potential, methods for extraction and purification of bioactive compounds are tested. Methods for extracting plant materials include solvent extraction, steam distillation, Soxhlet extraction, maceration, or supercritical fluid extraction. Chromatographic methods

including thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC), gas chromatography (GC), and column chromatography are often used to isolate the active ingredients / molecules from the extracted or purified material. Spectroscopic methods including nuclear magnetic resonance (NMR), UV-visible spectrophotometry, and mass spectrometry will then be used to determine the structure of the bioactive molecules that have been isolated. Through these methods, bioactive compounds can be identified that exhibit antimicrobial, antioxidant, anti-inflammatory, anticancer, antiviral and antidiabetic activities. The isolation of bioactive compounds and their corresponding chemical structures provide the basis for developing new pharmaceuticals based on these compounds. For example, some clinically important medicines such as morphine, quinine, and artemisinin have been isolated from plants using the above described methods. Therefore, isolating bioactive compounds from greener sources is essential to convert traditional knowledge on herbal medicine into scientifically and clinically valid products for contemporary healthcare. (Sarker&Nahar, 2012)

Through phytochemical screening (bioassay) for active compounds and bioassay for biological activity, researchers can better comprehend how herbal substances work to treat a number of diseases. Following isolation of active components, pharmacological studies and/or biological assays on extracted samples are performed in order to assess their biological effects on diseases. The physiological effects of the active components may be investigated using in vitro experiments or in vivo studies. The biological effects of active compounds isolated from plants may include antimicrobial, antioxidant, antitumour, anti-inflammatory, hepatoprotective, cardioprotective, and neuroprotective activities. The biological assays also provide some information on toxicity, dosing and safety. The use of current molecular biology and computational approaches may also assist investigators in understanding how phytochemicals interact with biological targets such as enzymes, receptors and genetic pathways. Understanding how active phytochemicals work is critical for creating and executing efficient and targeted treatments for chronic diseases and infections. Furthermore, the results of phytochemical research may allow identification of plant constituent combinations that could provide synergistic benefit in treating disease. Scientific validation of the therapeutic properties of traditional medicine through phytochemical (and pharmacological) studies has led to an increase in worldwide recognition of herbal medicines. Therefore, phytochemical screening and compound identification not only support the study of natural products, but also provide a means for integrating

traditional medicines with evidence-based healthcare and modern pharmaceutical sciences (Pandey&Tripathi, 2014)

Phytochemical screening and the isolation of bioactive compounds from plants face several obstacles related to variability, extraction efficiency, standardization, and quality control. Phytochemicals can vary in concentration and types present in medicinal plants due to factors such as environment, geographic location, harvest time, soil composition, and processing methods. These differences may alter the therapeutic activity and consistency of herbal products. Additionally, isolating pure bioactive compounds often requires complex and time-consuming processes using sophisticated laboratory equipment and highly skilled professionals. Some bioactive compounds may also be present in tiny amounts, making them difficult to isolate and purify. Contamination, adulteration, and improper storage of plant material add to the complexity of performing phytochemical investigations. Therefore, it is crucial to establish standards and quality assurance to ensure safe, pure, and effective herbal medicines. Regulatory authorities and researchers are increasingly focused on developing guidelines for assessing and manufacturing herbal products. The use of cutting-edge analytical technology and biotechnology will continue to help to resolve many of these challenges by improving the precision and efficiency of phytochemical analyses. Nevertheless, continued scientific improvement is required to allow for the full therapeutic potential of medicinal plants and to guarantee the reliability of natural-product-based medicines for use in health care. (Jones &Kinghorn, 2006)

There is a bright outlook for phytochemical screening and the isolation of bioactive compounds, especially because of the fast-paced development of new scientific and technological advances. In particular, the advancement of new technologies such as metabolomics and proteomics, artificial intelligence, nanotechnology and bioinformatics will completely change the way researchers study natural products, and will significantly accelerate the discovery of novel therapeutic compounds. Artificial intelligence and computational tools allow researchers to analyze large phytochemical databases and predict the biological activity of plant-derived molecules, providing the ability to shorten both the time and the cost of drug discovery. Nanotechnology-based delivery systems are facilitating the enhanced bioavailability and targeted delivery of isolated bioactive compounds. Additionally, biotechnology techniques such as plant tissue culture and genetic engineering provide researchers with new tools to sustainably produce valuable medicinal compounds while minimizing the pressure on natural plant populations. International collaboration between researchers, the pharmaceutical industry and health organizations is creating more opportunities to develop evidence-based herbal

medicines. There is also increasing public interest in natural health care products and preventive medicine, leading to increased investment in phytochemical research globally. As a result, phytochemical screening and the isolation of bioactive compounds will continue to play a vital role in the discovery of novel therapeutic drugs, the continued support of sustainable health care systems, and the resolution of future medical problems by scientifically studying medicinal plants and natural sources. (Verpoorte et al., 2005)

Pharmacological evaluation of herbal medicines

This is the process of evaluating the pharmacological properties of herbs to determine their effectiveness as therapeutic agents in both traditional and modern health care systems. All herbal products contain active ingredients that have pharmacological properties against different types of illness and health conditions; therefore, pharmacology is the science that investigates how these active ingredients are metabolized and used by the body. A pharmacological study includes a scientific examination of how a compound or an herbal extract has the ability to affect a living organism biologically. Additionally, a pharmacological study offers valuable information for researchers looking to understand how a particular herbal formulation works, how effective it is, if it is toxic, what the proper dosage would be, and if it would produce any possible adverse side effects. The selection of a plant material to conduct pharmacological studies is typically based on the traditional use of the plant, any available ethnobotanical data, and/or the results of previous scientific studies. After the plant is selected, the active ingredients are then extracted from the plant using the appropriate solvent and subjected to biological screening by way of laboratory experiments. The pharmacological evaluation process consists of both in vivo and in vitro studies evaluating the ability of active ingredients in herbs to produce specific pharmacological effects, such as antimicrobial, anti-inflammatory, antioxidant, antidiabetic, anticancer, hepatoprotective and/or neuroprotective activities. The scientific validation provided by the pharmacological evaluation process is even more significant when you consider that many herbal products are used or consumed without the user having complete knowledge of the pharmacological properties of the herbal product. Therefore, at the global level, when you consider the increasing number of people turning to herbal medicine, a pharmacological evaluation of an herbal product is important to ensure that it is a safe and effective therapeutic agent and to assist researchers in the development of new drug therapies for modern health care systems. (Viegas et al., 2006)

In vitro drug testing is one of the first methods for assessing the efficacy of herbal drugs. This type of testing involves using isolated cells, tissues, enzymes, or bacteria to study the effects of an extract or plant-based substances. Researchers prefer using in vitro methods because they are relatively inexpensive, taking less time, and have fewer ethical concerns than animal experimentation. The biological activity of plant compounds can be examined using different biochemical and molecular methods (e.g., assessing antimicrobial, antioxidant, anticancer, antiviral, and anti-inflammatory effects) to help identify the active ingredients responsible for producing a desired therapeutic effect and/or determining the potential for clinical applicability. In addition, in vitro research allows scientists to investigate how plant compounds interact with specific biological targets such as enzymes/receptors/genetic pathways. New technologies such as cell culture techniques, molecular docking, and bioinformatics have greatly enhanced the accuracy and efficiency of pharmacological research. Since in vitro data do not completely reflect the many physiological changes occurring within a human body, promising candidates from in vitro testing usually undergo additional evaluation biologically through testing in animals to better assess their potential for therapeutic efficacy. (Cos et al., 2006)

Pharmacological studies involving entire live organisms, primarily through the use of laboratory animals, are fundamental for evaluating both the therapeutic efficacy and safety of herbal medicines. The data from in vivo studies provide critical information about how herbal drugs are absorbed, distributed, metabolized, excreted and toxic within biological systems. In vivo studies allow scientists to gain insights into how herbal drugs interact with organs, tissues and pathways, allowing for a more realistic assessment of their pharmacodynamic actions. Animal models are widely used to assess the effectiveness of herbal formulations exhibiting antidiabetic, analgesic, anti-inflammatory, antihypertensive, anticancer, and neuroprotective properties. Assessment of the safety of herbal products, including determination of safe dosage ranges and identification of potential adverse effects associated with long-term use, is also assessed through toxicological studies. The acute, subacute, and chronic toxicity studies are valuable in providing critical information on the safety of medicinal plants prior to their testing in humans through clinical trials. In addition, pharmacokinetic and pharmacodynamic studies assist researchers with optimizing dosage forms and improving patient response rates. Ethical and global guidelines and regulations for animal use are strictly adhered to in order to ensure both humane care of the animals, and scientific validity. Overall, in vivo pharmacological evaluation is an integral part of converting traditional herbal treatments into safe and effective evidence-based

medicines that can be utilized in clinical settings and developed into contemporary pharmaceutical products. (Parasuraman, 2011)

Pharmacological evaluations provide a large amount of information on quality control, standardization and regulatory approval of herbal medications. Due to the fact that herbal medicines typically have variable chemical compositions depending on where they come from; how, when and where they were obtained; what conditions they were grown in and how they were processed, the efficacy and safety of herbal products may vary based on those variables. Phamacological studies are used to standardize dosage forms of herbal medications, to establish active marker compounds associated with biological activity and to allow for use of advanced analytical techniques like chromatography, spectroscopy, and molecular analysis to verify consistency and purity of herbal products. Before regulatory bodies can approve herbal drugs for sale to the public, they require scientific evidence that demonstrates the pharmacological properties, toxicological properties and quality assurance of those drugs. In addition, pharmacological evaluations allow for the identification of herb-drug interactions and/or contraindications which could adversely impact patient safety when used together. As demand for herbal medicines continues to grow worldwide, so does the necessity for evidence-based validation, regulatory oversight and pharmacological evaluations of herbal products. As such, pharmacological evaluations provide an important framework for establishing public trust in the efficacy of herbal treatment options and their integration in to traditional healthcare systems. Therefore, pharmacological evaluations play a critical role in both the research of herbal medicines and in providing pharmaceutical quality assurance for herbal medicines. (Mukherjee et al., 2018)

Emerging technologies and interdisciplinary approaches to science are changing the future of the Pharmacological Evaluation of Herbal Medicines. New technologies like genomics, proteomics, and metabolomics, as well as Artificial Intelligence and Computational Pharmacology, help researchers better identify and analyze bioactive compounds found in medicinal plants. Additionally, Artificial Intelligence and Machine Learning are enabling researchers to analyze substantial amounts of biological data more expeditiously and to predict the therapeutic activity of herbal medicines. The development of Nanotechnology-Based Drug Delivery Systems is also enabling more effective delivery and targeting of herbal medicines to patients through improved Bioavailability and Therapeutic Action. Biotechnology techniques, such as cell culturing and genetic engineering, will provide a sustainable supply of bioactive compounds for pharmacological research purposes. Furthermore, an increasing number of clinical trials

and evidence-based studies will be performed to support the efficacy and safety of herbal medicines for use in human populations. International collaboration between researchers, pharmaceutical companies, and healthcare organisations will continue to advance the production of scientifically standardised herbal therapeutics. Heightened awareness among the public about natural health care and preventive medicine is contributing to a greater investment in herbal pharmacology research globally. Therefore, the Pharmacological Evaluation of herbal medicines will continue to be essential in developing innovative therapies; assuring patient safety; and integrating herbal medicines into modern healthcare for future advancement of medicine. (Efferth& Koch, 2011)

Application of nanotechnology in herbal formulations

Nanotechnology is revolutionizing herbal formulations, as it enhances the therapeutic efficacy of plant medicines. Many herbal drugs have struggled to achieve their full clinical potential, as they often exhibit poor solubility/low bioavailability, rapid elimination from the body, and lack of stability. By reducing the size of particles found in herbal drugs to the nano-scale, nanotechnology addresses these limitations by enhancing the absorption and biological activity of the herbal compound. By greatly increasing the surface area of the herbal constituents, nanoparticles also enable more efficient interaction with biological membranes and improved delivery of the herbal product to the body. Through this technology, many traditional herbal medicines are able to provide greater effects on complex diseases than was previously possible. Many plant-derived compounds that exhibited little therapeutic effect are being reformulated using nanotechnology to deliver improved clinical benefits. In addition, nanotechnology serves to protect heat and light sensitive phytochemicals from degradation due to exposure to environmental changes such as heat or extremes in pH. Therefore, we see an increasing significance of nano-based herbal formulations in current pharmaceutical research. They create a link between the traditional herbal medicine and the more advanced drug delivery methods, thus making safer, more efficient, and more focused treatment options available to people around the globe. (Patra et al., 2018)

The introduction of nanotechnology in herbal medicine has changed the field by making herbal products much more effective than ever before. Herbal medicines have troubles because they are poorly absorbed into the body (by having difficulty dissolving). They also do not get absorbed effectively (due to their low bioavailability). Herbal medicines tend to break down quickly (as a result of metabolism), and they can also become unstable during storage or use. The use of nanotechnology can address these problems by producing herbal formulations at the nano-level (1 - 100 nm). This enables increased

absorption and increased biological activity of herbal products. Nanoparticles created from particles of the herbal constituents are used to increase the surface area for contact between the herbal constituent and biological membranes (cells) and improve the delivery of the drug to the cells. Because of these advantages of nanotechnology, the effectiveness of herbal products for complex diseases has improved substantially in many instances. In fact, many previously "ineffective" herbal products are now able to provide clinical benefits. Additionally, the reduction of size (from micro- to nano-size) provides a method for protecting sensitive phytochemicals from being broken down by various environmental factors such as light, heat, or changes in pH. As a result, nano-based herbal products are becoming increasingly important in modern-day pharmaceutical research. They represent a means for integrating traditional herbal medicine with advanced drug delivery systems, providing patients worldwide access to safer, more effective, and targeted therapies. (Yallapu et al., 2010)

The use of two types of nanotechnology-based delivery methods (liposomes and phytosomes) to increase the effectiveness of herbal medicines is a major breakthrough in herbal medicine. A liposome consists of a phospholipid bilayer and is a spherical vesicle that can include both hydrophilic and lipophilic items. They will help with stability, solubility and absorption of a herbal ingredient in the human body. Phytosomes are also found to improve the ability of a plant to be absorbed by the human body because they are a complex made up of a phytocomplex (Plant) and a phospholipid. Both systems will allow the active ingredient of a herbal to remain protected from deterioration in the intestine, and increase the amount of active ingredient that enters the general circulation. A large number of different plant materials have shown dramatically increased pharmacological effects with liposome or phytosome formulations (ginkgo biloba, green tea, milk thistle, etc.). Both of these methods of delivering herbal products will also provide the ability to deliver the active ingredient to specific targeted organs or tissues. Because of this method of targeting, the amount of active ingredient of a herbal medicine that is necessary to achieve the desired pharmacological effect has been greatly reduced, thereby reducing potential toxicity and side effects of herbal medicines. Liposomal and phytosomal technology is a powerful innovation in providing drug delivery systems for herbal medicines and a major way to bridge the gap between traditional herbal medicine and modern pharmaceutical science. (Singh et al., 2011)

Nanotechnology is an important way to help improve the storage and release of herbal products. There are many plant-derived substances whose chemical structures and activity can be negatively impacted by conditions in the environment. Examples of such environmental factors are heat, light, oxygen, and moisture; if any of these

environmental factors become unfavorable, the active ingredients in some of these herbal formulations would lose their potency. Nanoencapsulation encapsulates these active ingredients in nanocarrier systems that provide a protective shield that will protect these active ingredients both during the storage period and upon administration, thereby prolonging the shelf life of herbal medicines. Controlled-release technologies allow the controlled or gradual discharge of active ingredients into circulation, which helps to maintain a more constant level of active ingredients in the bloodstream over time, and will result in better therapeutic outcomes compared to alternative means of administering herbal medicines. This would also reduce the frequency of administration and increase patient compliance with the prescribed therapy. In addition to helping maintain consistent levels of pharmaceuticals in the blood stream via controlled-release technology, nanocarrier systems also allow for the simultaneous delivery of multiple herbal products. This potentially allows for multiple herb ingredients to work together (synergistically) to provide the desired therapeutic outcomes. The advancement of delivery systems through nanotechnology may also be of great value for treating chronic diseases that require long-term therapeutic intervention. Finally, nanoformulations can be designed to release their contents in response to specific physiological parameters, such as the pH of the gastrointestinal tract, and/or temperature, thereby allowing for the targeted or localized delivery of these pharmaceuticals. This was not possible with previously developed herbal medicines. Thus, it is obvious that nanotechnology provides a significant improvement in the reliability, efficiency and clinical application of herbal medicines in modern medical care settings.(Bhattacharyya et al., 2019)

The future possibilities of combining nanotechnology and herbal medicine are exciting, based on advances made as a result of research conducted in nanotechnology and nanoscience, biotechnology and pharmaceutical industries around the world, as well as using artificial intelligence (AI) and computational modelling to help develop new types of intelligent nano-carriers for controlled/restricted delivery of herbal medicines, and responses to biological signals. New developments in the use of nanotechnology and herbal medicine could greatly improve the level of success achieved through treating diseases with complex aetiologies such as cancer, neurological disorders, glucose intolerance and metabolic syndrome, but some of the remaining hurdles include concerns about toxicity, large-scale production, regulatory approval and cost-effectiveness. Rigorous clinical trials will be necessary to establish the safety and efficacy of nano-therapy based herbal medicines before their implementation into health care systems worldwide. In summary, the combination of nanotechnology and herbal

medicine is creating exciting opportunities to advance drug development in new ways. This combination represents a sustainable and efficient way to maximize the therapeutic potential of natural products. Ultimately, nanotechnology will continue to be an important means of modernizing herbal formulations and advancing global healthcare through new and innovative drug delivery systems. (Wang et al., 2012)

Conclusion

Developing new herbal drugs through pharmacognosy and innovative ways of making them is an effective and environmentally friendly way of addressing global healthcare issues. By combining traditional herbal medicine and contemporary science/technology together, many new therapeutic bioactive compounds have been discovered and carefully documented. The phytochemical analysis, pharmacological testing, and isolation process of bioactive compounds have established a solid scientific foundation for herbal medicine research. In addition, the novel delivery methods for herbal medicine, including nanoparticles, liposomes, phytosomes and controlled-release formulations, have enhanced the safety, effectiveness, bioavailability, and stability of herbal medicine. Using these new developments will be useful for fighting against worldwide health concerns likeantibiotic resistance, chronic disease, cancer and new/temporary infections. However, there remain some barriers to the successful use of herbal medicine including issues with the standardizing, regulating (eg; establishing quality), producing (large-scale), and distributing herbal products. To meet the demands for herbal products in today's world and into the future, we will require inter-professional working together, as well as continued advances in technology and continued sustainable use of our medicinal plant resources.

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