ISSN: 2456 - 530X
PubMed - National Library of Medicine - ID: 101737738

EIJO: Journal of Ayurveda, Herbal Medicine and Innovative Research (EIJO - AHMIR)
Einstein International Journal Organization (EIJO)
Available Online at: www.eijo.in
Volume – 11, Issue – 1, January – February - 2026, Page No. : 01 - 11

Advances in Herbal Pharmacognosy: Modern Techniques in Identification, Standardization, and Plant-Based Drug Discovery

[1]Vipin Kumar Singhal, [2]Dinesh Kumar Jindal, [3]Hemant Singh, [4]Narsingh Rajpoot

[1-4]Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, Rajasthan

Corresponding Author: Vipin Kumar Singhal, Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, Rajasthan.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Herbal Pharmacognosy has evolved significantly with the integration of modern scientific tools and analytical technologies, enhancing the identification, quality control, and drug discovery potential of medicinal plants. Increasing global interest in plant-based medicines has necessitated reliable methods for authentication, standardization, and evaluation of herbal products. Traditional morphological and microscopic identification techniques are now complemented by molecular approaches such as DNA barcoding, chromatographic fingerprinting, metabolomics, and advanced spectroscopic analyses. These methods improve accuracy in plant authentication, detect adulteration, and ensure consistency in herbal formulations. Furthermore, modern Pharmacognosy incorporates high-throughput screening, bioinformatics, and computational drug design to accelerate plant-based drug discovery. Despite these advancements, challenges such as variability in plant materials, regulatory differences, and quality control remain. This review highlights recent developments in herbal Pharmacognosy, focusing on contemporary identification techniques, standardization strategies, and emerging approaches in plant-derived drug discovery, emphasizing their significance in ensuring safety, efficacy, and global acceptance of herbal medicines.

Keywords: Herbal Pharmacognosy, Medicinal Plants, DNA Barcoding, Standardization, Phytochemical Analysis, Plant-Based Drug Discovery, Metabolomics, Chromatography.

1.Introduction

Herbal Pharmacognosy is a specialized branch of pharmaceutical science that focuses on the study of medicinal plants, their bioactive constituents, therapeutic properties, and applications in healthcare. Since ancient times, plants have served as an essential source of remedies for various diseases, forming the basis of traditional systems of medicine such as Ayurveda, Traditional Chinese Medicine, Unani, and other indigenous healing practices. Even in modern medicine, natural products continue to play a significant role, as many widely used drugs originate directly or indirectly from plant sources. These include compounds used for the treatment of cancer, cardiovascular disorders, infectious diseases, and metabolic conditions. The enduring relevance of plant-derived medicines reflects their chemical diversity, biological compatibility, and therapeutic potential.

Historically, pharmacognosy relied primarily on classical methods such as macroscopic and microscopic identification, organoleptic evaluation, and basic chemical tests to authenticate medicinal plants. While these techniques provided foundational knowledge, they were often limited in accuracy, especially when dealing with closely related species, processed herbal materials, or adulterated products. Over time, the increasing commercialization of herbal medicines, coupled with rising global demand for natural healthcare products, highlighted the need for more reliable, precise, and standardized approaches for identification and quality assurance.

The integration of advanced analytical technologies has revolutionized herbal pharmacognosy, transforming it into a multidisciplinary field that bridges botany, phytochemistry, pharmacology, biotechnology, and molecular biology. Modern instrumentation such as chromatography, spectroscopy, and molecular genetic tools now enables detailed characterization of plant materials at chemical, structural, and genetic levels. These developments allow researchers to identify active constituents more accurately, detect adulterants, and ensure the consistency and safety of herbal products. Consequently, pharmacognosy has evolved from descriptive plant studies into a sophisticated scientific discipline that supports drug discovery, quality control, and evidence-based herbal medicine.

One of the most significant advancements in this field is the adoption of molecular identification techniques. DNA-based authentication methods provide precise species identification, even in powdered or processed plant materials where traditional morphological features are absent. Such approaches help prevent adulteration, substitution, and contamination, which are common challenges in the herbal industry. Reliable authentication not only safeguards consumer health but also enhances confidence in herbal medicines among healthcare professionals and regulatory authorities.

Alongside molecular tools, chromatographic and spectroscopic techniques have become indispensable in phytochemical analysis. Methods such as high-performance liquid chromatography, gas chromatography, mass spectrometry, and nuclear magnetic resonance spectroscopy enable comprehensive profiling of plant constituents. These techniques generate chemical fingerprints that serve as benchmarks for quality control and standardization. They also facilitate the isolation, identification, and quantification of bioactive compounds responsible for therapeutic effects. Such detailed chemical characterization is crucial for ensuring reproducibility, efficacy, and safety in herbal formulations.

Standardization has emerged as a central focus in modern herbal pharmacognosy due to the inherent variability of plant materials. Factors such as geographical origin, climate, soil conditions, harvesting time, processing methods, and storage conditions can significantly influence the chemical composition of medicinal plants. Without proper standardization, variations in phytochemical content may lead to inconsistent therapeutic outcomes or potential safety concerns. Therefore, comprehensive quality control measures—including botanical authentication, physicochemical evaluation, phytochemical profiling, and biological activity assessment—are essential components of contemporary pharmacognostic research.

In addition to quality assurance, herbal pharmacognosy plays a pivotal role in plant-based drug discovery. Medicinal plants represent a vast reservoir of structurally diverse compounds with potential pharmacological activities. Advances in extraction techniques, bioassay-guided fractionation, high-throughput screening, and computational modeling have accelerated the identification of promising therapeutic agents from natural sources. Many plant-derived compounds serve

as lead molecules for drug development, either used directly as medicines or modified chemically to improve efficacy and safety. This approach has contributed significantly to the development of novel treatments for complex diseases.

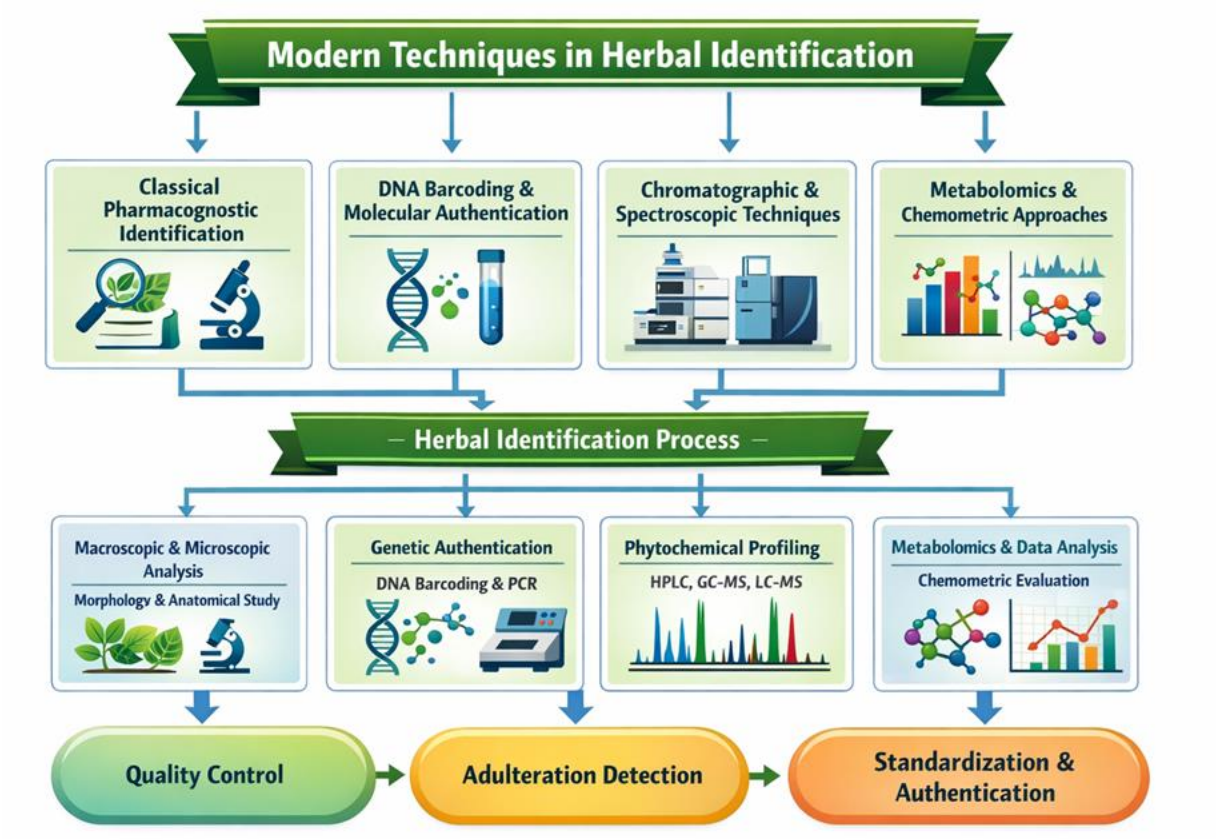
The increasing interest in natural and plant-based products is also driven by consumer preference for safer, eco-friendly, and holistic healthcare options. Public awareness regarding the adverse effects of synthetic drugs, combined with the growing emphasis on sustainability, has encouraged the exploration of herbal alternatives. As a result, the global herbal medicine market has expanded rapidly, creating opportunities as well as challenges related to quality control, regulatory compliance, and scientific validation. Pharmacognosy thus plays a crucial role in ensuring that herbal products meet established standards of safety, efficacy, and quality.

Furthermore, emerging fields such as metabolomics, nanotechnology, biotechnology, and artificial intelligence are opening new avenues in pharmacognostic research. Metabolomics enables comprehensive analysis of plant metabolites, providing insights into complex phytochemical interactions and therapeutic mechanisms. Nanotechnology is being explored to enhance the bioavailability and targeted delivery of plant-derived compounds. Meanwhile, computational tools and bioinformatics facilitate prediction of biological targets, accelerating the drug discovery process. These interdisciplinary innovations are expanding the scope and impact of herbal pharmacognosy in modern pharmaceutical science.

Despite these advancements, several challenges persist. Variability in plant raw materials, lack of standardized cultivation practices, limited clinical evidence, and differences in international regulatory frameworks continue to hinder the global acceptance of herbal medicines. Addressing these issues requires collaborative research, harmonized regulatory guidelines, and rigorous scientific validation to ensure that plant-based therapies are both safe and effective.

2. Modern Techniques in Herbal Identification

Accurate identification of medicinal plants is fundamental to herbal pharmacognosy because the safety, efficacy, and quality of herbal medicines depend largely on the authenticity of the plant material used. Misidentification, adulteration, and substitution of medicinal plants can lead to reduced therapeutic effectiveness or potential health risks. Traditionally, identification relied on morphological and microscopic examination, but advances in analytical chemistry, molecular biology, and data analysis have introduced more precise and reliable techniques. Modern herbal identification now integrates classical pharmacognostic evaluation with molecular authentication, chromatographic profiling, spectroscopic analysis, and metabolomics-based approaches to ensure comprehensive quality control and accurate plant characterization.



2.1 Classical Pharmacognostic Identification

Classical pharmacognostic identification forms the foundation of herbal drug authentication and continues to be widely used due to its simplicity, cost-effectiveness, and practical applicability. This approach primarily involves macroscopic, microscopic, and physicochemical evaluation of plant materials. Macroscopic examination includes the observation of external morphological features such as size, shape, color, texture, odor, and taste. These characteristics often provide preliminary identification and help distinguish genuine plant materials from adulterants or substitutes. For example, leaf venation patterns, surface texture, or characteristic odors can be useful markers for identification.

Microscopic evaluation involves studying the internal anatomical structures of plant tissues using light microscopy or other imaging techniques. Features such as stomatal type, trichomes, vascular bundle arrangement, calcium oxalate crystals, starch grains, and cell wall characteristics are diagnostic indicators used in pharmacognostic identification. Powder microscopy, in particular, is valuable when plant materials are processed into powdered form, as it helps detect adulteration or substitution that may not be visible macroscopically.

Physicochemical parameters further support authentication and quality evaluation. Determination of ash values (total ash, acid-insoluble ash, and water-soluble ash) helps assess inorganic content and detect contamination with soil, sand, or other extraneous matter. Extractive values indicate the amount of active constituents soluble in specific solvents and provide insight into the chemical composition of plant materials. Moisture content, volatile oil content, and other physicochemical constants are also important indicators of quality, stability, and storage conditions.

Although classical identification methods are valuable, they have limitations. Morphological characteristics may vary due to environmental factors, and processed herbal materials often lack identifiable features. Consequently, these traditional approaches are increasingly supplemented with modern analytical techniques for improved reliability and precision.

2.2 DNA Barcoding and Molecular Authentication

Molecular authentication techniques, particularly DNA barcoding, have significantly improved the accuracy of medicinal plant identification. DNA barcoding involves analyzing short, standardized regions of genetic material that are unique to specific plant species. These genetic markers serve as molecular signatures, enabling precise identification even when morphological features are absent or ambiguous.

DNA-based identification offers several advantages over traditional methods. It is highly specific, unaffected by environmental conditions, and applicable to processed herbal materials such as powders, extracts, or finished formulations. This makes it particularly useful for detecting adulteration, substitution, or contamination in herbal products. DNA barcoding also supports conservation efforts by helping identify endangered or protected plant species in commercial trade.

Various molecular techniques, including polymerase chain reaction (PCR), DNA sequencing, and next-generation sequencing technologies, are employed in herbal authentication. These methods can differentiate closely related species, confirm botanical identity, and establish genetic consistency among plant samples. Additionally, combining molecular authentication with chemical profiling enhances reliability by providing both genetic and phytochemical confirmation.

Despite its advantages, DNA-based identification has certain limitations, such as the degradation of DNA during processing, high costs of advanced sequencing technologies, and the need for specialized expertise. Nevertheless, ongoing technological advancements are making these methods more accessible and cost-effective, promoting their widespread adoption in pharmacognostic research and quality control.

2.3 Chromatographic and Spectroscopic Techniques

Chromatographic and spectroscopic techniques are essential tools in modern herbal identification and quality assessment. These analytical methods allow detailed characterization of plant constituents, enabling researchers to identify, quantify, and monitor bioactive compounds responsible for therapeutic effects.

Chromatographic techniques such as high-performance liquid chromatography (HPLC), gas chromatography–mass spectrometry (GC-MS), and liquid chromatography–mass spectrometry (LC-MS) are widely used for phytochemical profiling. These methods separate complex mixtures into individual components, providing chemical fingerprints that serve as reference standards for authentication and quality control. Chromatographic fingerprinting helps detect adulteration, confirm plant identity, and ensure batch-to-batch consistency in herbal products.

Spectroscopic techniques, including nuclear magnetic resonance (NMR), infrared spectroscopy (IR), and ultraviolet-visible spectroscopy (UV-Vis), complement chromatographic methods by providing structural information about plant constituents. These techniques help identify functional groups, molecular structures, and chemical interactions within herbal materials. Combined chromatographic and spectroscopic approaches enhance the accuracy of phytochemical analysis and support comprehensive characterization of medicinal plants.

Advances in hyphenated techniques, such as LC-MS/MS and GC-MS/MS, have further improved sensitivity, specificity, and analytical precision. These technologies facilitate rapid identification of trace compounds, detection of contaminants, and evaluation of complex herbal formulations. As a result, chromatographic and spectroscopic analyses have become indispensable in modern pharmacognostic research and industrial quality control.

2.4 Metabolomics and Chemometric Approaches

Metabolomics represents a holistic approach to studying the complete set of metabolites present in a biological system. In herbal pharmacognosy, metabolomic fingerprinting provides comprehensive chemical profiling of medicinal plants, enabling better understanding of their therapeutic potential, quality, and authenticity.

This approach integrates advanced chromatographic or spectroscopic data with statistical and computational tools known as chemometrics. Chemometric analysis involves multivariate statistical techniques such as principal component analysis, cluster analysis, and pattern recognition to interpret complex datasets. These methods help distinguish between authentic and adulterated samples, evaluate geographic or seasonal variations, and establish quality benchmarks for herbal products.

Metabolomics is particularly valuable for analyzing complex herbal formulations containing multiple active constituents. It enables identification of synergistic interactions among phytochemicals and supports evidence-based standardization of herbal medicines. Furthermore, metabolomic data contribute to drug discovery by identifying novel bioactive compounds and understanding their mechanisms of action.

Although metabolomics requires sophisticated instrumentation and expertise, its ability to provide comprehensive chemical insights makes it a powerful tool in modern pharmacognosy. As computational technologies continue to advance, metabolomics is expected to play an increasingly important role in herbal identification, quality control, and pharmaceutical research.

3. Standardization of Herbal Medicines

Standardization of herbal medicines is a critical aspect of modern pharmacognosy aimed at ensuring the safety, efficacy, quality, and reproducibility of plant-based therapeutic products. Unlike synthetic drugs, herbal medicines often exhibit significant variability due to differences in plant species, geographical origin, cultivation conditions, harvesting time, processing methods, and storage conditions. Such variability can affect the concentration of active phytochemicals, thereby influencing therapeutic outcomes. Standardization establishes defined quality parameters and consistent procedures to minimize these variations and ensure uniformity in herbal products. This process is essential not only for maintaining consumer confidence but also for facilitating regulatory approval and global acceptance of herbal medicines.

3.1 Importance of Standardization

The importance of standardization lies primarily in ensuring consistent therapeutic effectiveness and safety of herbal formulations. Variations in environmental conditions such as soil quality, climate, altitude, and seasonal changes can significantly alter phytochemical composition. Additionally, improper harvesting, drying, storage, or processing methods may lead to degradation of active constituents or contamination with microorganisms, heavy metals, or pesticides. Standardization helps address these issues by establishing quality benchmarks for raw materials and finished products. It also reduces the risk of adulteration or substitution, which can compromise safety and efficacy. Furthermore, consistent

quality control supports scientific validation, clinical acceptance, and integration of herbal medicines into mainstream healthcare systems.

3.2 Analytical Parameters and Quality Control

Standardization involves comprehensive evaluation of physicochemical, phytochemical, and biological parameters. Physicochemical assessments include determination of ash values, extractive values, moisture content, pH, and other constants that indicate purity and quality. Phytochemical profiling through chromatographic techniques such as high-performance liquid chromatography (HPLC), gas chromatography (GC), and mass spectrometry (MS) provides chemical fingerprints that help identify and quantify active constituents. Molecular authentication techniques such as DNA analysis further confirm botanical identity and detect adulteration. In addition, contaminant testing for microbial load, heavy metals, pesticides, and aflatoxins is essential for ensuring product safety. Biological evaluation, including pharmacological or bioactivity studies, may also be conducted to confirm therapeutic effectiveness and support product claims.

3.3 WHO Guidelines and Regulatory Perspectives

International regulatory frameworks play an important role in promoting the safe and effective use of herbal medicines. Organizations such as the World Health Organization have developed guidelines emphasizing authentication, quality control, safety evaluation, and good manufacturing practices for herbal products. These guidelines encourage standardized cultivation, processing, packaging, labeling, and storage procedures to maintain consistent quality. Regulatory agencies in different countries also establish pharmacopoeial standards and quality specifications for herbal medicines. Adherence to these guidelines helps reduce adulteration, ensure therapeutic consistency, and facilitate global trade of herbal products. Ultimately, harmonized regulatory approaches and robust standardization practices are essential for enhancing the credibility, safety, and acceptance of herbal medicines worldwide.

4. Plant-Based Drug Discovery

Plant-based drug discovery represents a vital area of pharmaceutical research, focusing on the identification, isolation, and development of bioactive compounds from medicinal plants for therapeutic applications. Historically, many important drugs have originated from natural sources, highlighting the immense pharmacological potential of plant-derived compounds. Advances in analytical chemistry, molecular biology, biotechnology, and computational sciences have significantly enhanced the efficiency and reliability of discovering novel therapeutic agents from plants. Modern pharmacognosy now combines traditional ethnobotanical knowledge with advanced scientific methodologies to explore plant biodiversity as a valuable resource for new drug development.

4.1 Role of Natural Products in Drug Development

Plants produce a wide variety of secondary metabolites such as alkaloids, flavonoids, terpenoids, glycosides, tannins, and phenolic compounds, many of which exhibit significant pharmacological activities. These phytochemicals serve as lead compounds for pharmaceutical research due to their structural diversity and biological compatibility. A substantial proportion of modern medicines used in treating cancer, cardiovascular diseases, infections, and metabolic disorders have

origins in plant-derived compounds or their synthetic analogs. Natural products often provide novel chemical scaffolds that inspire the design of new drugs with improved efficacy and safety profiles.

In addition to their therapeutic potential, medicinal plants are closely associated with traditional healthcare systems worldwide. Ethnopharmacological knowledge offers valuable insights into potential drug candidates, guiding researchers toward plants with documented therapeutic uses. This integration of traditional knowledge with modern scientific validation accelerates the identification of promising bioactive molecules while preserving valuable cultural and medicinal heritage.

4.2 Advanced Analytical and Screening Techniques

Modern plant-based drug discovery relies heavily on advanced analytical techniques to isolate, characterize, and evaluate bioactive compounds. Chromatographic methods such as high-performance liquid chromatography, gas chromatography, and liquid chromatography coupled with mass spectrometry enable precise separation and identification of phytochemicals. Spectroscopic techniques, including nuclear magnetic resonance and infrared spectroscopy, provide detailed structural information about isolated compounds, facilitating their chemical characterization.

High-throughput screening technologies have revolutionized drug discovery by allowing rapid evaluation of large numbers of plant extracts and isolated compounds for biological activity. Automated bioassays, cell-based assays, and molecular screening platforms enable efficient identification of compounds with potential therapeutic effects. Bioassay-guided fractionation further helps isolate active constituents from complex plant extracts, improving the efficiency of drug development.

Advancements in extraction technologies, such as supercritical fluid extraction and microwave-assisted extraction, also contribute to improved recovery of bioactive compounds while preserving their chemical integrity. These techniques enhance extraction efficiency, reduce solvent use, and support environmentally sustainable research practices. Together, these modern analytical and screening methods significantly accelerate the discovery of plant-derived pharmaceuticals.

4.3 Computational and Systems Biology Approaches

Computational approaches have become increasingly important in plant-based drug discovery. In silico techniques such as molecular docking, virtual screening, and quantitative structure–activity relationship modeling enable researchers to predict the interaction between plant compounds and biological targets. These methods reduce the time, cost, and resources required for experimental screening while increasing the probability of identifying promising drug candidates.

Network pharmacology and systems biology approaches provide a holistic understanding of how plant-derived compounds interact with multiple biological targets. Unlike synthetic drugs that often focus on a single target, herbal compounds frequently exhibit multi-target effects, making systems-level analysis particularly valuable. Bioinformatics tools facilitate analysis of large datasets, helping identify potential mechanisms of action, therapeutic pathways, and synergistic interactions among phytochemicals.

These computational advancements not only enhance efficiency in drug discovery but also support personalized medicine approaches by predicting patient-specific responses to plant-based therapeutics. As artificial intelligence and machine

learning technologies continue to evolve, they are expected to further accelerate plant-derived drug discovery and improve success rates in pharmaceutical development.

Table 1: Emerging Trends in Herbal Pharmacognosy

Emerging Trend	Technology/Approach	Application in Pharmacognosy	Advantages/Impact
Artificial Intelligence (AI)	Machine learning, image recognition, predictive modeling	Plant identification, phytochemical prediction, drug discovery analysis	Improves speed, accuracy, and automation in research
Metabolomics-Based Quality Assessment	Metabolic profiling using chromatography and spectroscopy	Comprehensive chemical fingerprinting and quality control	Ensures consistency, detects adulteration, supports standardization
Next-Generation Sequencing (NGS)	Advanced DNA sequencing technologies	Herbal authentication, species identification, genetic diversity analysis	Highly accurate authentication even in processed materials
Nanotechnology in Herbal Medicine	Nanoformulations, nanoparticles, nanocarriers	Enhanced drug delivery, improved bioavailability of phytoconstituents	Increased therapeutic efficacy and targeted delivery
Advanced Extraction Techniques	Supercritical fluid extraction, microwave-assisted extraction, ultrasound extraction	Efficient isolation of bioactive compounds	Higher yield, reduced solvent use, environmentally friendly
Network Pharmacology & Systems Biology	Bioinformatics, multi-target analysis	Understanding complex herbal drug interactions	Supports holistic therapeutic evaluation
Green Analytical Techniques	Eco-friendly solvents and sustainable methods	Safer phytochemical analysis and extraction	Environmentally sustainable research approaches

6. Challenges and Future Perspectives

Despite significant advancements in herbal pharmacognosy, several challenges continue to limit the widespread acceptance and scientific validation of herbal medicines. One major issue is the variability in raw plant materials caused by differences in geographical origin, climate, soil conditions, harvesting practices, and post-harvest processing. Such variability can affect the phytochemical composition and therapeutic efficacy of herbal products. Another important challenge is the lack of harmonized global regulatory standards, which creates inconsistencies in quality control, safety evaluation, and product approval across different countries. Although organizations such as the World Health Organization have provided guidelines for herbal medicine quality and safety, implementation varies widely, leading to regulatory gaps. Additionally, limited clinical validation and insufficient large-scale human studies hinder the integration of herbal medicines into mainstream healthcare systems.

Future perspectives in herbal pharmacognosy emphasize multidisciplinary collaboration among botanists, chemists, pharmacologists, biotechnologists, and clinicians to strengthen scientific evidence and therapeutic reliability. Advanced analytical technologies, molecular authentication tools, and metabolomics approaches are expected to improve standardization and quality assurance. Furthermore, well-designed clinical trials and evidence-based research are essential to confirm safety, efficacy, and dosage consistency of herbal medicines. Continued innovation, regulatory harmonization, and scientific validation will be crucial in enhancing the credibility and global acceptance of plant-based therapeutics.

7. Conclusion

Modern herbal pharmacognosy has undergone remarkable transformation with the integration of advanced molecular, analytical, and computational technologies. These developments have significantly improved the accuracy of plant identification, ensuring authenticity and minimizing adulteration in herbal products. Advanced standardization techniques have enhanced quality control, safety, and reproducibility of plant-based medicines. Additionally, innovative analytical and computational approaches have accelerated the discovery of bioactive compounds from medicinal plants. The growing demand for natural and sustainable healthcare solutions further highlights the importance of herbal pharmacognosy in modern medicine. However, consistent regulatory frameworks and rigorous scientific validation remain essential for global acceptance. Continued interdisciplinary research will strengthen evidence-based applications of herbal medicines. Technological advancements are expected to improve bioavailability, therapeutic efficacy, and drug delivery systems. Harmonized quality standards and clinical validation will enhance credibility and safety. Overall, herbal pharmacognosy will continue to play a vital role in developing effective plant-based therapeutics for future healthcare.

References

1. World Health Organization. (2013). WHO traditional medicine strategy 2014–2023. WHO Press.
2. World Health Organization. (2007). WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues. WHO Press.
3. Heinrich, M., Barnes, J., Gibbons, S., & Williamson, E. (2018). Fundamentals of pharmacognosy and phytotherapy (3rd ed.). Elsevier.
4. Wink, M. (2015). Modes of action of herbal medicines and plant secondary metabolites. Medicines, 2(3), 251–286.
5. Atanasov, A. G., Waltenberger, B., Pferschy-Wenzig, E. M., et al. (2015). Discovery and resupply of pharmacologically active plant-derived natural products. Biotechnology Advances, 33(8), 1582–1614.
6. Newman, D. J., & Cragg, G. M. (2020). Natural products as sources of new drugs over nearly four decades. Journal of Natural Products, 83(3), 770–803.
7. Cordell, G. A., Colvard, M. D., & Dayan, F. E. (2012). Natural products in drug discovery. Phytochemistry Reviews, 11, 1–8.
8. Li, S., Zhang, B., Jiang, D., Wei, Y., & Zhang, N. (2010). Herb network pharmacology. Evidence-Based Complementary and Alternative Medicine, 2010, 1–10.
9. Efferth, T., & Koch, E. (2011). Complex interactions between phytochemicals. Planta Medica, 77(11), 1093–1103.

10. Verpoorte, R., Choi, Y. H., & Kim, H. K. (2005). Ethnopharmacology and metabolomics. Phytochemistry Reviews, 4, 189–204.
11. Sarker, S. D., Nahar, L., & Kumarasamy, Y. (2007). Microtitre plate-based antibacterial assay. Methods, 42(4), 321–324.
12. Pandey, M. M., Rastogi, S., & Rawat, A. K. (2013). Indian traditional medicine. Chinese Journal of Integrative Medicine, 19, 89–95.
13. Dhami, N., & Mishra, A. D. (2015). Phytochemical variation. 3 Biotech, 5, 497–512.
14. Ichim, M. C. (2019). DNA barcoding in herbal medicine. Frontiers in Pharmacology, 10, 915.
15. Booker, A., Johnston, D., Heinrich, M. (2016). Value chains of herbal medicines. Journal of Ethnopharmacology, 179, 128–140.
16. Petrovska, B. B. (2012). Historical review of medicinal plants. Pharmacognosy Reviews, 6(11), 1–5.
17. Rates, S. M. K. (2001). Plants as source of drugs. Toxicon, 39(5), 603–613.
18. Butler, M. S. (2004). Natural products in drug discovery. Natural Product Reports, 21(2), 162–195.
19. Fabricant, D. S., & Farnsworth, N. R. (2001). Value of plants in drug discovery. Environmental Health Perspectives, 109(Suppl 1), 69–75.
20. Cragg, G. M., & Newman, D. J. (2013). Natural products: continuing source of drugs. Biochimica et Biophysica Acta, 1830(6), 3670–3695.
21. Balunas, M. J., & Kinghorn, A. D. (2005). Drug discovery from medicinal plants. Life Sciences, 78(5), 431–441.
22. Gurib-Fakim, A. (2006). Medicinal plants: Traditions of yesterday and drugs of tomorrow. Molecular Aspects of Medicine, 27(1), 1–93.