

Plant-Derived Natural Products in Pharmacognosy: Modern Extraction Technologies, Phytochemical Characterization, and Drug Development Perspectives¹Vishal Garg, ²Lokendra Singh Rathore, ³Dinesh Kumar Jindal, ⁴Shivakshi Shukla¹⁻⁴Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, Rajasthan**Corresponding Author:** Vishal Garg, Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, Rajasthan**Type of Publication:** Original Research Article**Conflicts of Interest:** Nil**Abstract**

Plant-derived natural products remain a cornerstone of pharmacognosy and modern drug discovery due to their immense structural diversity, therapeutic potential, and historical relevance in traditional medicine. Advances in extraction technologies have significantly enhanced the efficiency, selectivity, and sustainability of isolating bioactive compounds from medicinal plants. Modern approaches such as supercritical fluid extraction, microwave-assisted extraction, ultrasound-assisted extraction, and enzyme-assisted extraction offer advantages including reduced solvent consumption, shorter processing time, and preservation of thermolabile constituents. Phytochemical characterization techniques, including chromatographic, spectroscopic, and metabolomic tools, enable accurate identification, quantification, and quality control of plant secondary metabolites. These analytical advancements facilitate standardization, authentication, and safety assessment of herbal medicines. Furthermore, plant-derived compounds continue to contribute substantially to pharmaceutical innovation, serving as lead molecules for anticancer, anti-inflammatory, antimicrobial, antidiabetic, and neuroprotective drugs. Despite promising progress, challenges such as variability in plant material, regulatory constraints, and scalability issues remain. This review highlights contemporary extraction methodologies, analytical strategies for phytochemical characterization, and emerging perspectives in natural product-based drug development, emphasizing their relevance to future pharmacognostic research and pharmaceutical innovation.

Keywords: Pharmacognosy; Plant-Derived Natural Products; Modern Extraction Techniques; Phytochemical Characterization; Herbal Drug Discovery; Supercritical Fluid Extraction; Bioactive Compounds; Natural Product Drug Development.

1. Introduction

Plant-derived natural products have played a foundational role in the evolution of Pharmacognosy, pharmaceutical sciences, and traditional medicine systems worldwide. Since ancient times, humans have relied on medicinal plants for the treatment, prevention, and management of diseases. Early healing traditions across Asia, Africa, Europe, and the Americas developed extensive knowledge of medicinal plants through empirical observation and cultural practices. This traditional knowledge laid the groundwork for modern pharmacognosy, which systematically studies crude drugs derived from natural sources such as plants, animals, and minerals, with particular emphasis on botanical origin, phytochemistry, biological activity, and therapeutic applications.

Medicinal plants are rich reservoirs of structurally diverse secondary metabolites, which are organic compounds not directly involved in primary metabolic processes such as growth and reproduction but essential for plant defense, adaptation, and ecological interactions. These include alkaloids, flavonoids, terpenoids, phenolic compounds, glycosides, tannins, saponins, and essential oils. Such metabolites exhibit a broad spectrum of pharmacological properties including antioxidant, anti-inflammatory, antimicrobial, anticancer, antidiabetic, hepatoprotective, cardioprotective, and neuroprotective activities. Their structural diversity and biological specificity make them valuable leads for drug discovery and development.

Historically, many important pharmaceutical agents have originated from plant sources. Natural products have contributed significantly to therapeutic areas such as oncology, infectious diseases, cardiovascular disorders, and metabolic conditions. Plant-derived molecules often possess complex chemical scaffolds that are difficult to replicate synthetically, providing unique templates for medicinal chemistry optimization. Even today, natural products continue to inspire new drugs either directly as phytopharmaceuticals or indirectly as lead compounds for semi-synthetic and synthetic derivatives.

In addition to their pharmaceutical importance, medicinal plants remain integral to traditional and complementary medicine systems globally. Herbal medicines are widely used due to perceived safety, cultural acceptance, accessibility, and affordability, particularly in developing countries. Increasing global interest in herbal therapies, nutraceuticals, and plant-based health products has further strengthened the relevance of pharmacognostic research. However, ensuring quality, safety, efficacy, and standardization of plant-based medicines remains a critical challenge, highlighting the importance of scientific validation and regulatory oversight.

Advancements in extraction technologies have significantly transformed natural product research. Conventional extraction methods such as maceration, percolation, and Soxhlet extraction have long been employed to isolate bioactive compounds from plant materials. Although effective, these methods often require large volumes of solvents, longer extraction times, and may result in degradation of heat-sensitive constituents. Modern extraction approaches emphasize efficiency, selectivity, sustainability, and environmental friendliness. Techniques such as supercritical fluid extraction, microwave-assisted extraction, ultrasound-assisted extraction, pressurized liquid extraction, and enzyme-assisted extraction have improved extraction yields while reducing solvent consumption and processing time. These “green extraction” technologies align with current trends toward environmentally sustainable pharmaceutical practices.

Parallel to extraction advancements, analytical and phytochemical characterization techniques have evolved considerably. Chromatographic methods such as high-performance liquid chromatography, gas chromatography, and thin-layer chromatography enable precise separation, identification, and quantification of plant metabolites. Spectroscopic tools including nuclear magnetic resonance spectroscopy, infrared spectroscopy, ultraviolet–visible spectroscopy, and mass spectrometry facilitate structural elucidation of complex natural compounds. Furthermore, modern approaches such as metabolomics, chemometrics, and high-resolution mass spectrometry provide comprehensive profiling of plant metabolite composition, supporting authentication, quality control, and standardization of herbal products.

The integration of biotechnology and computational tools has further accelerated natural product research. Techniques such as plant tissue culture, metabolic engineering, synthetic biology, and biotransformation enable enhanced production

of valuable phytochemicals while minimizing dependence on wild plant resources. Computational approaches, including molecular docking, quantitative structure–activity relationship modeling, and artificial intelligence-assisted drug discovery, facilitate prediction of biological activity, target identification, and lead optimization. These innovations bridge traditional pharmacognostic knowledge with modern pharmaceutical development strategies.

Despite significant progress, challenges persist in the field of plant-derived natural products. Variability in phytochemical composition due to environmental conditions, seasonal variations, genetic differences, and post-harvest processing can affect therapeutic consistency. Issues of adulteration, substitution, and contamination of herbal raw materials pose safety risks. Additionally, translating promising preclinical findings into clinically approved drugs requires extensive pharmacological evaluation, toxicity studies, clinical trials, and regulatory compliance, which can be resource-intensive.

Nevertheless, growing interest in natural therapeutics, increasing prevalence of chronic diseases, and the search for safer and more effective drugs continue to drive research in plant-derived natural products. Advances in sustainable extraction, analytical chemistry, molecular biology, and computational pharmacology are expected to enhance discovery, characterization, and development of plant-based pharmaceuticals. Interdisciplinary collaboration among pharmacognosists, chemists, pharmacologists, biotechnologists, and clinicians will be essential to fully realize the therapeutic potential of medicinal plants.

2. Modern Extraction Technologies in Pharmacognosy

Extraction is a fundamental step in pharmacognosy and natural product research, as it enables the isolation of biologically active constituents from plant materials for pharmacological evaluation, phytochemical characterization, and drug development. The efficiency, selectivity, and environmental sustainability of extraction processes significantly influence the quality and yield of phytochemicals. Over time, extraction methodologies have evolved from conventional solvent-based techniques to advanced green technologies that aim to improve extraction efficiency while minimizing environmental impact, solvent consumption, and degradation of sensitive bioactive compounds.

2.1 Conventional Extraction Methods

Traditional extraction methods have long served as the backbone of pharmacognostic investigations. Techniques such as maceration, percolation, decoction, infusion, and Soxhlet extraction are widely used because of their simplicity, low cost, and minimal equipment requirements. These methods are still commonly employed in academic laboratories, herbal drug industries, and traditional medicine preparation.

Maceration involves soaking plant material in a suitable solvent at room temperature for a specified duration with occasional agitation. This method allows diffusion of soluble constituents into the solvent and is particularly suitable for thermolabile compounds. However, it generally requires extended extraction periods and relatively large solvent volumes, which may reduce efficiency.

Percolation is a continuous extraction process in which the solvent passes slowly through powdered plant material packed in a percolator. This technique enhances solvent penetration and extraction efficiency compared to maceration, yet it still involves significant solvent use and processing time.

Decoction and infusion are traditional aqueous extraction methods commonly used in herbal medicine systems. Decoction involves boiling plant material in water to extract water-soluble constituents, while infusion resembles

steeping, often used for delicate plant parts such as leaves and flowers. Although these techniques are simple and culturally significant, they may lead to degradation of heat-sensitive phytochemicals and lack precise standardization.

Soxhlet extraction is a widely recognized laboratory method that allows repeated washing of plant material with heated solvent through reflux cycles. This technique improves extraction efficiency and is particularly useful for exhaustive extraction. However, prolonged heating can degrade thermolabile compounds, and the process consumes considerable energy and solvent.

Despite their widespread use, conventional extraction techniques present several limitations. These include long extraction times, high solvent consumption, potential environmental hazards due to organic solvent disposal, and possible degradation of sensitive compounds due to heat exposure. Such limitations have encouraged the development of modern extraction approaches that are more efficient, selective, and environmentally sustainable.

2.2 Green and Advanced Extraction Techniques

The growing emphasis on sustainability, efficiency, and quality assurance in pharmaceutical and herbal industries has driven the development of green extraction technologies. These modern approaches aim to reduce solvent use, shorten extraction time, enhance yield, and preserve bioactive compounds while minimizing environmental impact. They are increasingly adopted in both research laboratories and industrial-scale production of natural products.

Supercritical Fluid Extraction (SFE) is one of the most significant advancements in modern extraction technology. This technique typically employs supercritical carbon dioxide as a solvent, which exhibits unique properties between those of liquids and gases under high pressure and temperature. Supercritical CO₂ possesses excellent diffusivity, low viscosity, and tunable solvating power, enabling efficient extraction of nonpolar and moderately polar compounds. SFE offers several advantages, including minimal solvent residue, improved selectivity, reduced thermal degradation, and environmental safety. It is widely applied in extracting essential oils, lipids, alkaloids, and other bioactive compounds, especially in pharmaceutical, food, and cosmetic industries.

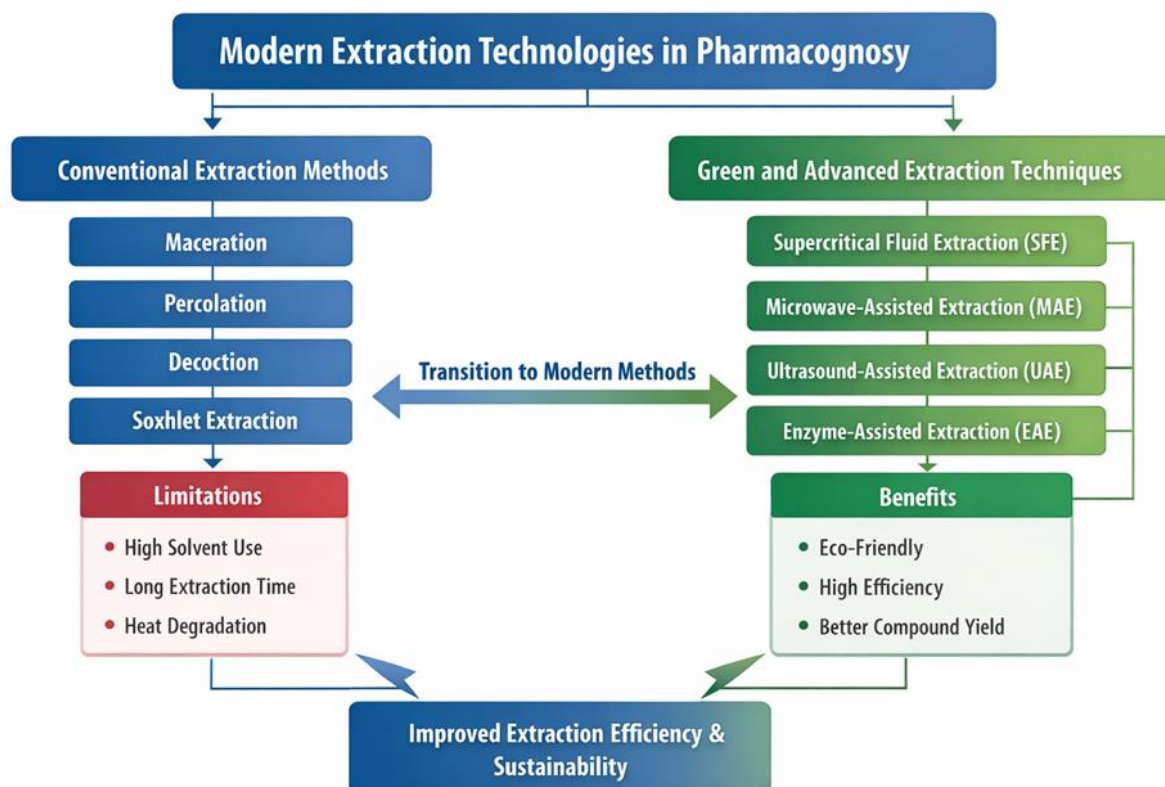
Microwave-Assisted Extraction (MAE) utilizes microwave energy to heat solvents and plant tissues rapidly, facilitating the release of phytochemicals through cell wall disruption. Microwave irradiation enhances solvent penetration and accelerates mass transfer, resulting in significantly reduced extraction time and solvent consumption. MAE is particularly effective for extracting phenolics, flavonoids, alkaloids, and essential oils. Additionally, it allows better preservation of heat-sensitive compounds due to shorter exposure time compared with conventional heating methods.

Ultrasound-Assisted Extraction (UAE) employs ultrasonic waves to generate cavitation bubbles in the extraction medium. The collapse of these bubbles produces localized high temperatures and pressures that disrupt plant cell walls, enhancing solvent penetration and compound release. UAE offers advantages such as lower extraction temperatures, reduced solvent usage, shorter processing times, and improved extraction efficiency. It is widely used for isolating antioxidants, essential oils, polysaccharides, and other secondary metabolites.

Enzyme-Assisted Extraction (EAE) represents a biotechnological approach that utilizes specific enzymes, such as cellulases, hemicellulases, and pectinases, to degrade plant cell walls. This enzymatic breakdown facilitates the release of intracellular phytochemicals, improving extraction yield and selectivity. EAE operates under mild conditions, making it

suitable for preserving thermolabile compounds. It is particularly useful for extracting polysaccharides, flavonoids, proteins, and other bioactive constituents from plant materials.

These advanced extraction techniques align with the principles of green chemistry by reducing energy consumption, minimizing hazardous solvent use, and enhancing sustainability. Furthermore, they often provide higher extraction efficiency, improved product quality, and better reproducibility compared with traditional methods. Their scalability makes them suitable for industrial applications, including pharmaceutical manufacturing, nutraceutical production, and herbal product standardization.



3. Phytochemical Characterization Techniques

Phytochemical characterization is a crucial component of pharmacognosy and natural product research, as it enables the identification, isolation, quantification, and structural elucidation of bioactive compounds present in medicinal plants. Accurate characterization ensures quality control, authentication, safety assessment, and standardization of herbal drugs and plant-derived pharmaceutical products. With advancements in analytical science, sophisticated chromatographic, spectroscopic, and metabolomic techniques are now routinely employed to study plant metabolites with high precision and sensitivity.

3.1 Chromatographic Methods

Chromatographic techniques are widely used for separating complex mixtures of phytochemicals and analyzing their qualitative and quantitative composition. These methods are essential for identifying active constituents, detecting adulterants, and ensuring batch-to-batch consistency in herbal formulations.

Thin-Layer Chromatography (TLC) is one of the simplest and most cost-effective chromatographic techniques used in pharmacognosy. It involves separation of compounds on a thin stationary phase layer, typically silica gel, followed by visualization using suitable reagents or ultraviolet light. TLC is frequently applied for preliminary phytochemical screening, fingerprint profiling, and detection of adulteration in herbal materials.

High-Performance Liquid Chromatography (HPLC) provides high resolution, sensitivity, and reproducibility for separating and quantifying plant metabolites. It is extensively used for analyzing alkaloids, flavonoids, phenolic acids, glycosides, and other secondary metabolites. HPLC also plays a significant role in quality control of herbal medicines by establishing chemical fingerprints and quantifying marker compounds.

Gas Chromatography–Mass Spectrometry (GC-MS) combines the separation capability of gas chromatography with the identification power of mass spectrometry. This technique is particularly useful for volatile and semi-volatile compounds such as essential oils, fatty acids, and terpenoids. GC-MS enables precise identification of phytochemicals based on their mass spectral fragmentation patterns and is widely used in phytochemical profiling and natural product research.

3.2 Spectroscopic and Molecular Approaches

Spectroscopic techniques complement chromatographic methods by providing detailed structural information about phytochemicals. These tools are essential for confirming molecular identity, elucidating chemical structures, and studying functional groups in natural compounds.

Nuclear Magnetic Resonance (NMR) spectroscopy is a powerful technique for determining the molecular structure, stereochemistry, and purity of organic compounds. It provides detailed information about atomic connectivity and molecular conformation, making it indispensable for structural elucidation of complex natural products.

Fourier Transform Infrared (FTIR) spectroscopy is commonly used to identify functional groups present in phytochemicals by measuring molecular vibrations. FTIR is particularly valuable for rapid qualitative analysis, authentication of herbal materials, and detection of chemical interactions in plant extracts.

Liquid Chromatography–Mass Spectrometry (LC-MS/MS) combines chromatographic separation with highly sensitive mass detection, allowing identification and quantification of phytochemicals even at trace levels. It is extensively used in metabolite profiling, pharmacokinetic studies, and biomarker identification.

Additionally, **metabolomics and chemometric analysis** have emerged as advanced approaches for comprehensive profiling of plant metabolites. Metabolomics enables large-scale analysis of biochemical compounds in plants, while chemometric tools assist in interpreting complex datasets, facilitating classification, authentication, and quality assessment of herbal drugs.

4. Drug Development Perspectives from Plant Natural Products

Plant-derived natural products have played a crucial role in pharmaceutical innovation and continue to serve as valuable sources of new therapeutic agents. Numerous modern drugs used in the treatment of cancer, cardiovascular disorders, infectious diseases, metabolic conditions, and inflammatory disorders originate directly or indirectly from plant secondary metabolites. These bioactive compounds possess remarkable chemical diversity, structural complexity, and biological specificity, which often make them ideal templates for drug discovery. Natural molecules frequently provide unique

chemical scaffolds that inspire the design of semi-synthetic or synthetic analogues with enhanced efficacy, stability, and safety profiles.

In recent years, advances in interdisciplinary scientific approaches have significantly accelerated natural product-based drug development. Computational pharmacology, including molecular docking, pharmacophore modeling, and artificial intelligence-assisted screening, enables rapid identification of potential bioactive compounds and prediction of their biological targets. These techniques reduce time, cost, and experimental effort associated with conventional drug discovery processes.

Furthermore, metabolomics has emerged as a powerful tool for comprehensive profiling of plant metabolites, facilitating identification of novel lead compounds and understanding their biosynthetic pathways. Biotechnological approaches such as plant tissue culture, metabolic engineering, and synthetic biology also allow sustainable production of valuable phytochemicals without overexploitation of natural plant resources.

The integration of pharmacognosy with modern drug discovery platforms, including high-throughput screening, systems biology, and precision medicine approaches, has enhanced the therapeutic potential of plant-derived compounds. Such integration not only supports the development of novel pharmaceuticals but also contributes to improved standardization, safety assessment, and clinical validation of herbal medicines. As interest in natural therapeutics continues to grow, plant-based drug discovery is expected to remain a promising and dynamic field in pharmaceutical research.

5. Challenges in Natural Product Research

Despite significant advances in pharmacognosy and natural product drug discovery, several challenges continue to limit the full therapeutic and commercial potential of plant-derived medicines. One major issue is the **variability in plant raw materials**, which can arise due to environmental conditions such as climate, soil composition, altitude, seasonal variation, and cultivation practices. Genetic diversity among plant species and differences in harvesting, storage, and processing methods can also influence phytochemical composition, ultimately affecting the efficacy, safety, and reproducibility of herbal products.

Another important challenge involves **standardization and quality control** of plant-based medicines. Natural products often contain complex mixtures of bioactive compounds, making it difficult to establish consistent quality standards. Issues such as adulteration, substitution, contamination with pesticides or heavy metals, and lack of validated analytical protocols can compromise product safety and therapeutic reliability.

Additionally, **limited clinical validation** remains a major barrier. Although many medicinal plants demonstrate promising pharmacological activities in laboratory and preclinical studies, well-designed clinical trials are often lacking. Insufficient clinical evidence can restrict acceptance of herbal medicines in mainstream healthcare systems and delay regulatory approval.

Finally, **regulatory and commercialization barriers** pose significant obstacles. Variations in international regulatory frameworks, intellectual property concerns, and high costs associated with drug development and clinical testing can hinder commercialization of plant-derived therapeutics. Addressing these challenges through multidisciplinary research, improved analytical methods, standardized cultivation practices, and harmonized regulations will be essential for advancing natural product research and ensuring safe, effective herbal medicines.

6. Future Perspectives

Future pharmacognostic research is expected to advance significantly through the integration of innovative technologies, sustainability-focused practices, and personalized therapeutic approaches. One major area of focus is the development of **sustainable and green extraction technologies** that minimize environmental impact while improving extraction efficiency. Techniques such as supercritical fluid extraction, microwave-assisted extraction, and ultrasound-assisted extraction are gaining prominence due to reduced solvent usage, lower energy consumption, and improved preservation of bioactive compounds. These environmentally friendly approaches align with global efforts toward sustainable pharmaceutical manufacturing and responsible utilization of natural resources.

Another promising direction involves the **integration of artificial intelligence (AI) and metabolomics** in natural product research. AI-driven computational tools enable rapid screening of large phytochemical databases, prediction of biological activity, identification of potential drug targets, and optimization of lead compounds. Metabolomics, combined with advanced analytical platforms, facilitates comprehensive profiling of plant metabolites, enhancing understanding of biosynthetic pathways, chemical diversity, and therapeutic potential. Together, these technologies can accelerate drug discovery and improve accuracy in phytochemical characterization.

Biotechnological production of plant metabolites also represents an emerging frontier in pharmacognosy. Approaches such as plant tissue culture, metabolic engineering, synthetic biology, and microbial biosynthesis allow sustainable production of valuable phytochemicals without overharvesting natural plant populations. These strategies help ensure consistent quality, scalability, and conservation of medicinal plant biodiversity.

Additionally, the concept of **personalized herbal medicine and precision phytotherapy** is gaining attention. Advances in pharmacogenomics, systems biology, and individualized healthcare may enable tailoring of herbal treatments based on genetic makeup, metabolic profiles, and disease characteristics. Such personalized approaches could enhance therapeutic efficacy, minimize adverse effects, and bridge traditional herbal medicine with modern precision healthcare. Overall, these future perspectives highlight the evolving role of pharmacognosy in developing innovative, sustainable, and patient-centered natural product therapeutics.

7. Conclusion

Plant-derived natural products continue to play a vital role in pharmacognosy, pharmaceutical sciences, and modern drug discovery due to their rich chemical diversity and therapeutic potential. Medicinal plants have historically provided numerous bioactive compounds that serve either directly as therapeutic agents or as templates for synthetic drug development. Recent advancements in extraction technologies have significantly improved the efficiency, selectivity, and environmental sustainability of isolating phytochemicals. Modern green extraction methods help preserve thermolabile compounds while reducing solvent consumption and processing time. Simultaneously, sophisticated analytical and phytochemical characterization techniques have enhanced the accuracy of identification, quantification, and standardization of plant metabolites. These advancements ensure better quality control, safety assessment, and consistency of herbal medicines. The integration of traditional knowledge with modern scientific tools, including biotechnology, computational pharmacology, and metabolomics, has further accelerated natural product research. However, challenges such as variability in plant materials, regulatory issues, and limited clinical validation still need to be addressed.

Continued interdisciplinary research and technological innovation are essential to overcome these limitations. Overall, plant-based natural products remain indispensable resources for future drug discovery and therapeutic development. Their sustainable utilization, scientific validation, and proper standardization will contribute significantly to global healthcare advancement.

References

1. Barthwal, R., & Mahar, R. (2024). Exploring the significance, extraction, and characterization of plant-derived secondary metabolites in complex mixtures. *Metabolites*, 14(2), 119. <https://doi.org/10.3390/metabo14020119>
2. El-Saadony, M. T., Saad, A. M., Mohammed, D. M., Alkafaas, S. S., Abd El-Mageed, T. A., Fahmy, M. A., et al. (2025). Plant bioactive compounds: Extraction, biological activities, and human health benefits—A comprehensive review. *Frontiers in Nutrition*, 12, 1659743. <https://doi.org/10.3389/fnut.2025.1659743>
3. Soni, V., & Mangal, R. (2023). Innovative approaches in phytochemical extraction: A comprehensive review. *Pexacy International Journal of Pharmaceutical Science*, 2(12), 1–18.
4. Microchemical Journal Review Authors. (2024). Metabolic profiling of plant and natural products: Platforms, applications, and quality evaluation. *Microchemical Journal*, 207, 111779.
5. Recent Chemistry Review Authors. (2025). Current development in spectroscopic and chromatographic techniques for natural product analysis. *Results in Chemistry*.
6. Atanasov, A. G., Zotchev, S. B., Dirsch, V. M., & Supuran, C. T. (2021). Natural products in drug discovery: Advances and opportunities. *Nature Reviews Drug Discovery*, 20(3), 200–216.
7. Chemat, F., Abert-Vian, M., & Cravotto, G. (2020). Green extraction of natural products: Concept and principles. *International Journal of Molecular Sciences*, 21(3), 1236.
8. Dai, J., & Mumper, R. J. (2010). Plant phenolics: Extraction, analysis, and biological activities. *Molecules*, 15(10), 7313–7352.
9. 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.
10. Mukherjee, P. K. (2019). *Quality control and evaluation of herbal drugs*. Elsevier.
11. Sarker, S. D., & Nahar, L. (2018). *Natural products isolation* (3rd ed.). Humana Press.
12. Chemat, F., Rombaut, N., Sicaire, A. G., Meullemiestre, A., Fabiano-Tixier, A. S., & Abert-Vian, M. (2017). Ultrasound-assisted extraction of food and natural products. *Ultrasonics Sonochemistry*, 34, 540–560.
13. Herrero, M., Cifuentes, A., & Ibáñez, E. (2010). Sub- and supercritical fluid extraction of functional ingredients. *Food Chemistry*, 98, 136–148.
14. Azmir, J., et al. (2013). Techniques for extraction of bioactive compounds from plant materials: A review. *Journal of Food Engineering*, 117, 426–436.
15. Ignat, I., Volf, I., & Popa, V. I. (2011). Critical review of methods for characterization of polyphenolic compounds. *Food Chemistry*, 126, 1821–1835.
16. Wolfender, J.-L., Marti, G., Thomas, A., & Bertrand, S. (2015). Current approaches and challenges in metabolite profiling. *Journal of Chromatography A*, 1382, 136–164.

17. Verpoorte, R., Choi, Y. H., & Kim, H. K. (2007). NMR-based metabolomics in medicinal plant research. *Phytochemistry Reviews*, 6, 3–14.
18. Dewick, P. M. (2009). *Medicinal natural products: A biosynthetic approach* (3rd ed.). Wiley.
19. Cos, P., Vlietinck, A. J., Berghe, D. V., & Maes, L. (2006). Anti-infective potential of natural products. *Journal of Ethnopharmacology*, 106, 290–302.
20. Cragg, G. M., & Newman, D. J. (2013). Natural products: A continuing source of novel drug leads. *Biochimica et Biophysica Acta*, 1830, 3670–3695.
21. Rates, S. M. K. (2001). Plants as source of drugs. *Toxicon*, 39, 603–613.
22. Harvey, A. L., Edrada-Ebel, R., & Quinn, R. J. (2015). The re-emergence of natural products in drug discovery. *Nature Reviews Drug Discovery*, 14, 111–129.
23. Li, Y., Kong, D., Wu, H. (2020). Comprehensive review of extraction and isolation of natural products. *Fitoterapia*, 143, 104-558.