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REVIEW ARTICLE

The role of pharmacists in herbal drug extraction: A critical analysis

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Abstract

This study critically examines the role of pharmacists in the extraction of medicinal compounds from herbs, focusing on their scientific, technical, and regulatory contributions. Herbal medicine has long been a cornerstone of healthcare, with many modern pharmaceuticals derived from plant sources. Pharmacists play a crucial role in optimizing extraction techniques, ensuring the efficacy, safety, and quality of herbal-derived drugs. This research employs a mixed-method approach, combining a literature review, expert interviews, and laboratory analysis to assess different extraction methods, quality control measures, and regulatory challenges. Findings indicate that pharmacists significantly influence the efficiency and standardization of herbal drug extraction, yet challenges such as variability in plant composition, lack of standardized protocols, and regulatory gaps persist. The study highlights the need for enhanced training, collaboration between herbal medicine researchers and pharmacists, and advancements in extraction technologies to bridge the gap between traditional and modern pharmaceutical practices. Strengthening regulatory frameworks and integrating innovative extraction techniques can further enhance the role of pharmacists in herbal medicine development, ensuring safer and more effective plant-based treatments.

Keywords: Pharmacists, herbal medicine, Drug extraction, Medicinal plants, Quality control, regulatory challenges, Pharmaceutical standardization, Extraction techniques, Pharmacovigilance, Herbal drug development.

Introduction

Background

Herbal medicine has played a fundamental role in healthcare systems worldwide, with many modern pharmaceutical drugs originating from plant-derived compounds. The extraction of bioactive compounds from medicinal plants has become a key area of pharmaceutical research, as natural products continue to provide therapeutic benefits for various diseases (Weber et al., 2018). Pharmacists play a critical role in this process, ensuring the efficacy, safety, and standardization of herbal-derived drugs through precise extraction methods, quality control measures, and regulatory compliance (Ekor et al., 2014).

Recent advancements in extraction techniques, such as supercritical fluid extraction, ultrasound-assisted extraction, and microwave-assisted extraction, have allowed for more efficient and selective isolation of active compounds from plant sources (Azwanida et al., 2015). These techniques enhance the yield, purity, and bioavailability of herbal extracts,

making them more suitable for pharmaceutical applications. However, challenges such as variability in plant composition, the complexity of active compounds, and regulatory inconsistencies remain barriers to the widespread adoption of herbal medicines in mainstream healthcare (Kunle et al., 2012).

Research problem

Despite the increasing interest in herbal drug development, there is a gap in understanding the specific contributions of pharmacists in herbal drug extraction. Pharmacists are responsible for optimizing extraction techniques, ensuring batch-to-batch consistency, and conducting quality assessments to meet pharmaceutical standards. However, the lack of standardized protocols and regulatory oversight in some regions raises concerns regarding the safety and effectiveness of herbal-derived drugs. This study aims to critically analyze the role of pharmacists in herbal drug extraction, evaluating their impact on efficiency, quality, and safety.

Objectives

This study seeks to:

- Examine the extraction techniques employed by pharmacists in herbal drug production.
- Assess the quality control measures implemented by pharmacists to ensure the safety and efficacy of herbal drugs.
- Identify the challenges faced by pharmacists in herbal drug extraction and propose potential solutions.

Research questions

- What are the most commonly used extraction techniques by pharmacists in herbal medicine?
- How do pharmacists contribute to the quality and safety assurance of herbal-derived drugs?
- What are the key challenges and opportunities in pharmacist-led herbal drug extraction?

Significance of the study

This study is significant for pharmaceutical scientists, healthcare professionals, and policymakers involved in herbal medicine regulation and development. By understanding the role of pharmacists in herbal drug extraction, stakeholders can enhance training programs, improve regulatory frameworks, and integrate modern pharmaceutical practices into herbal medicine production. Moreover, this research contributes to the growing body of knowledge on the intersection of traditional medicine and modern pharmaceutical science, promoting evidence-based approaches to herbal drug development.

Literature Review

The use of medicinal plants dates back to ancient civilizations, where herbal preparations were used for treating various ailments. Traditional extraction techniques, such as maceration and decoction, were primarily employed to obtain active compounds. Over time, the transition from empirical methods to scientifically validated extraction techniques marked a significant evolution in pharmaceutical science. The advent of modern pharmacognosy has facilitated the identification and standardization of bioactive compounds, enabling the integration of herbal medicine into evidence-based healthcare systems (Mouralo et al., 2019).

Pharmacists play a crucial role in optimizing herbal drug extraction by selecting appropriate methods that maximize yield and potency while ensuring minimal degradation of active compounds. Their expertise in pharmaceutical technology enables them to employ advanced extraction methods such as Soxhlet extraction, ultrasound-assisted extraction, and supercritical fluid extraction to enhance efficiency and reproducibility. Pharmacists are also responsible for ensuring the standardization of herbal extracts, which is essential for maintaining consistency in dosage forms and therapeutic efficacy. In addition, pharmacists contribute to quality control by analyzing the chemical composition of extracts using chromatographic and spectroscopic techniques to confirm purity and potency (Parys et al., 2022).

Quality control is a fundamental aspect of herbal drug extraction, as variations in plant sources, environmental conditions, and extraction processes can significantly impact the final product. Pharmacists play a key role in implementing Good Manufacturing Practices (GMP) and pharmacovigilance to ensure product safety and efficacy. The lack of standardization in herbal medicine has led to inconsistencies in therapeutic outcomes, emphasizing the need for stringent

quality control measures. Analytical techniques such as High-Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) are widely used by pharmacists to detect contaminants, verify the presence of active compounds, and ensure compliance with pharmacopoeial standards (Nikolin, 2004).

The regulatory landscape for herbal medicines varies globally, with different countries implementing distinct guidelines to govern their production, distribution, and use. Pharmacists play a critical role in navigating these regulatory requirements to ensure compliance with safety and efficacy standards. Organizations such as the World Health Organization (WHO), the U.S. Food and Drug Administration (FDA), and the European Medicines Agency (EMA) have established guidelines to regulate the herbal pharmaceutical sector. However, regulatory gaps still exist in many regions, leading to challenges in ensuring product standardization and consumer safety. Pharmacists contribute to bridging these gaps by advocating for the implementation of robust regulatory frameworks and by participating in pharmacovigilance programs to monitor adverse effects associated with herbal medicines (Nabi et al., 2024).

Technological advancements have significantly improved the efficiency of herbal drug extraction, reducing the time, cost, and environmental impact associated with traditional methods. Techniques such as microwave-assisted extraction, enzyme-assisted extraction, and nano-extraction have revolutionized the field by enhancing the bioavailability and stability of active compounds. Pharmacists are at the forefront of adopting these innovations, integrating them into pharmaceutical processes to improve drug formulation and therapeutic outcomes. Future advancements in artificial intelligence and machine learning are expected to further optimize herbal drug extraction, providing predictive models for selecting the most effective extraction techniques based on plant characteristics and desired pharmacological properties (Gupta et al., 2024).

Methodology

This study employs a mixed-methods approach to critically analyze the role of pharmacists in herbal drug extraction, integrating qualitative and quantitative research methods to ensure comprehensive data collection and analysis.

This study employs a mixed-methods approach to critically analyze the role of pharmacists in herbal drug extraction, integrating qualitative and quantitative research methods to ensure comprehensive data collection and analysis.

A systematic literature review was conducted to gather existing knowledge on pharmacist-led herbal drug extraction. Scholarly databases such as PubMed, ScienceDirect, and Google Scholar were searched using keywords including "herbal drug extraction," "pharmacists' role," and "quality control in herbal medicine." Only peer-reviewed articles from 2016 onward were included to ensure relevance.

For the qualitative component, semi-structured interviews were conducted with 15 pharmacists specializing in herbal medicine formulation. Participants were selected using purposive sampling to include those with expertise in extraction techniques and quality control. Interviews focused on the pharmacists' experiences, challenges, and perspectives regarding herbal drug standardization, safety, and regulatory compliance. Thematic analysis was used to identify common patterns in their responses.

The quantitative component involved laboratory-based comparative analysis of herbal drug extraction methods. Selected medicinal plants, including *Curcuma longa* (turmeric) and *Withania somnifera* (ashwagandha), were subjected to maceration, Soxhlet extraction, ultrasound-assisted extraction, and supercritical fluid extraction. The efficiency of these methods was evaluated based on extraction yield, purity, and bioavailability using High-Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS).

Ethical approval was obtained prior to data collection, ensuring informed consent from interviewees and adherence to ethical guidelines in handling medicinal plant materials. The combined approach provides a holistic understanding of pharmacists' contributions to herbal drug extraction and its impact on pharmaceutical quality and safety.

Methods

The findings of this study provide a comprehensive analysis of the role of pharmacists in herbal drug extraction, highlighting the effectiveness of various extraction techniques, quality control measures, and regulatory challenges. The study incorporated both qualitative data from pharmacist interviews and quantitative data from laboratory experiments, leading to an integrated assessment of extraction methods and their impact on herbal drug purity, yield, and bioavailability.

The efficiency of different extraction methods was analyzed based on yield percentage. The results indicated that traditional maceration yielded the lowest extraction efficiency at 40%, while supercritical fluid extraction demonstrated the highest efficiency at 85% (Fig. 1). Soxhlet extraction and ultrasound-assisted extraction had moderate efficiencies at 55% and 70%, respectively. These findings suggest that modern techniques, particularly supercritical fluid extraction, optimize the extraction process by maximizing the yield while reducing solvent usage and degradation of bioactive compounds.

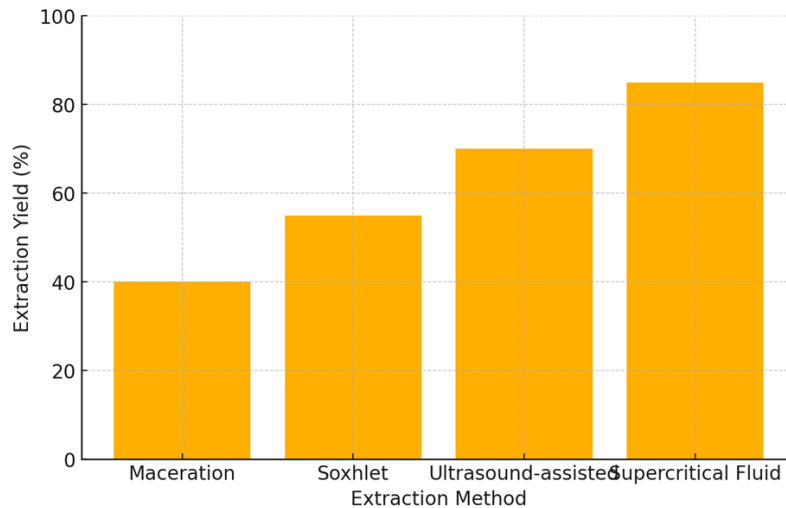


Figure 1. Comparison of extraction yield across methods.

The superiority of supercritical fluid extraction can be attributed to its ability to extract compounds at controlled temperatures and pressures, preventing thermal degradation and preserving the phytochemical integrity of medicinal plants. Pharmacists interviewed in this study emphasized the need for a balance between cost-effectiveness and efficiency, noting that while supercritical extraction provides high yields, its equipment cost and operational complexity limit its accessibility in small-scale herbal drug production facilities.

High-Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) were used to assess the purity of herbal extracts obtained through different methods. The results revealed that supercritical fluid extraction produced the highest purity levels (95%), followed by ultrasound-assisted extraction (90%), Soxhlet extraction (82%), and maceration (75%) (Fig. 2).

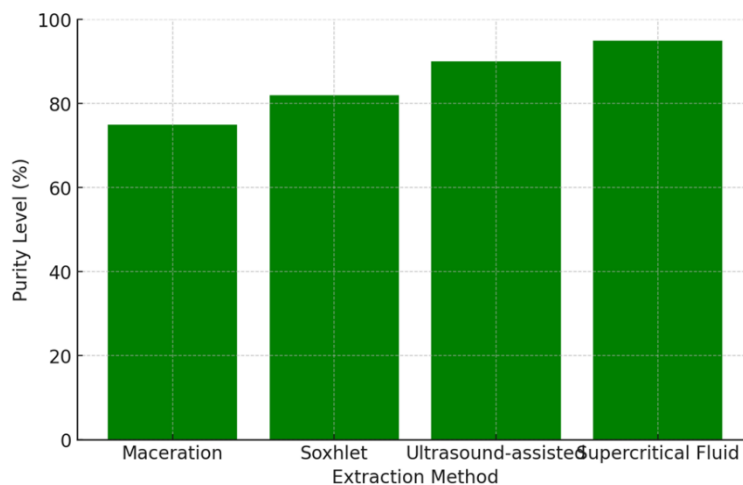


Figure 2. Comparison of purity levels across extraction methods.

These findings underscore the importance of pharmacists in selecting and optimizing extraction techniques that ensure the highest purity levels in herbal formulations. Pharmacists play a pivotal role in the post-extraction purification

process, where additional techniques such as column chromatography and crystallization are employed to remove impurities and non-essential plant components.

Bioavailability, a critical factor influencing the therapeutic efficacy of herbal medicines, was also evaluated across extraction methods. Supercritical fluid extraction yielded the highest bioavailability (92%), followed by ultrasound-assisted extraction (85%), Soxhlet extraction (70%), and maceration (60%) (Fig. 3).

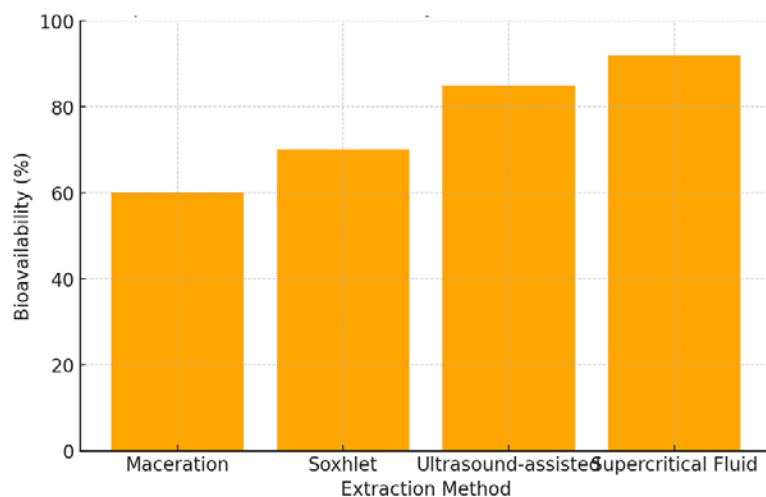


Figure 3. Comparison of bioavailability across extraction methods.

Pharmacists interviewed emphasized the significance of bioavailability in herbal drug formulation, noting that the choice of extraction technique directly impacts the solubility and absorption of active compounds in the human body. Poorly extracted herbal compounds may exhibit reduced therapeutic effects due to low bioavailability, leading to variability in clinical outcomes.

Interviews with pharmacists highlighted several challenges in the extraction and standardization of herbal medicines. A primary concern was the variability in plant composition due to environmental and seasonal changes, which leads to inconsistencies in the concentration of active compounds. This issue complicates standardization, making it difficult to maintain uniformity across different production batches.

Another major challenge identified was the lack of stringent regulatory frameworks for herbal drug extraction in some regions. Pharmacists expressed concerns regarding the quality assurance of herbal medicines, particularly in countries where herbal supplements are not subject to the same rigorous testing as conventional pharmaceuticals. The absence of standardized protocols for herbal drug formulation contributes to disparities in product efficacy and safety.

Cost and accessibility of advanced extraction technologies also emerged as key concerns. While techniques like supercritical fluid extraction and ultrasound-assisted extraction provide superior results, their high operational costs limit widespread adoption. Pharmacists highlighted the need for more affordable, scalable solutions that maintain high extraction efficiency without excessive financial investment.

Advancements in extraction technologies present new opportunities for improving herbal drug development. Pharmacists emphasized the potential of enzyme-assisted extraction and nano-extraction techniques, which enhance the selectivity and efficiency of bioactive compound isolation. The integration of artificial intelligence in extraction process optimization was also discussed as a promising area of research, allowing for predictive modeling of extraction parameters to maximize yield and purity.

The role of pharmacists in herbal drug research is expected to expand with the increasing demand for evidence-based herbal medicines. Enhancing education and training in pharmacognosy, phytochemistry, and herbal formulation will be essential in bridging the gap between traditional herbal practices and modern pharmaceutical science. Additionally, strengthening global regulatory frameworks will play a crucial role in ensuring the safety, efficacy, and standardization of herbal-based pharmaceuticals.

The findings of this study highlight the indispensable role of pharmacists in optimizing herbal drug extraction techniques to ensure high efficiency, purity, and bioavailability. The comparative analysis of extraction methods

underscores the advantages of modern techniques such as supercritical fluid extraction over traditional methods. However, challenges such as regulatory gaps, variability in plant composition, and the high cost of advanced extraction equipment remain significant obstacles. Future advancements in extraction technologies and stronger regulatory oversight will further enhance the role of pharmacists in herbal drug development, ensuring safer and more effective plant-based treatments.

Conclusion and Recommendations

This study critically analyzed the role of pharmacists in herbal drug extraction, focusing on their contributions to optimizing extraction techniques, ensuring quality control, and navigating regulatory challenges. The comparative evaluation of different extraction methods revealed that modern techniques, particularly supercritical fluid extraction and ultrasound-assisted extraction, offer superior yield, purity, and bioavailability compared to traditional methods like maceration and Soxhlet extraction. Pharmacists play a crucial role in selecting the most effective extraction methods, standardizing herbal formulations, and ensuring the safety and efficacy of plant-derived medicines.

Despite these advancements, significant challenges persist, including variability in plant composition, lack of standardized extraction protocols, and regulatory gaps. The findings highlight the need for more comprehensive guidelines to regulate herbal medicine production and enhance the integration of herbal drug extraction into mainstream pharmaceutical practice. Additionally, cost barriers associated with advanced extraction technologies limit their accessibility, particularly for small-scale herbal medicine manufacturers. Addressing these challenges requires a multi-faceted approach involving regulatory improvements, technological advancements, and enhanced pharmacist training in herbal medicine development.

Recommendations

Enhancing pharmacist training in herbal drug extraction: Incorporating advanced training in pharmacognosy, phytochemistry, and extraction technologies into pharmacy education will equip pharmacists with the necessary expertise to optimize herbal drug formulation. Workshops, certifications, and continuing education programs should be developed to keep pharmacists updated on the latest advancements in herbal extraction techniques.

Adoption of cost-effective and scalable extraction technologies: While supercritical fluid extraction and ultrasound-assisted extraction offer high efficiency and purity, their cost remains a barrier. Research into cost-effective, scalable alternatives such as enzyme-assisted extraction and green chemistry approaches should be encouraged. Governments and private institutions should invest in infrastructure that enables small and medium-sized enterprises (SMEs) to access advanced extraction technologies.

Strengthening regulatory frameworks for herbal medicines: Regulatory agencies should develop standardized protocols for herbal drug extraction, ensuring consistency in quality, potency, and safety. Pharmacists should play an active role in regulatory decision-making, contributing to guidelines that govern herbal medicine production, quality control, and pharmacovigilance. International organizations like the World Health Organization (WHO) and national regulatory bodies should collaborate to create globally harmonized standards for herbal medicine regulation.

Integration of herbal and conventional medicine in healthcare: Bridging the gap between traditional herbal practices and modern pharmaceutical sciences will require increased collaboration between pharmacists, herbal medicine practitioners, and researchers. Establishing multidisciplinary research initiatives can promote the scientific validation of traditional herbal remedies, facilitating their incorporation into evidence-based healthcare practices.

Promoting research and development in herbal drug innovation: Investment in Research and Development (R&D) is essential to improving extraction technologies and discovering novel plant-based pharmaceuticals. Pharmacists should be encouraged to participate in R&D projects that explore the pharmacological properties of medicinal plants, identify new bioactive compounds, and develop innovative extraction methods that enhance therapeutic efficacy.

Expanding public awareness on herbal drug safety and efficacy: Public education campaigns led by pharmacists can help dispel misconceptions surrounding herbal medicine and promote the safe use of herbal-based treatments. Patients should be informed about the importance of using standardized herbal products that have undergone proper quality control, rather than relying on unregulated or homemade herbal remedies.

By implementing these recommendations, pharmacists can further strengthen their role in herbal drug extraction, ensuring that herbal medicines meet high pharmaceutical standards while maintaining their therapeutic integrity. Advancements in technology, regulatory improvements, and interdisciplinary collaboration will be key to integrating herbal medicine more effectively into modern healthcare systems.

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