



RESEARCH ARTICLE

A REVIEW OF SOLVENT EXTRACTION TECHNIQUES FOR BIOACTIVE COMPOUNDS FROM MEDICINAL PLANTS: CONVENTIONAL METHODS, COMPARISONS, AND APPLICATIONS IN ANTIMICROBIAL ACTIVITY ASSESSMENT

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ABSTRACT

The most common method Solvent extraction, for isolating bioactive phytochemicals from medicinal plants is Solvent extraction, when evaluating potential antimicrobial in the context of antibiotic resistance. This paper compares three conventional solvent-based techniques—maceration, percolation, and Soxhlet extraction in principles, advantages, limitations, and impact on extract yield and bioactivity. Factors such as extraction time, temperature, and plant matrix influence phytochemical recovery and antimicrobial efficacy against common pathogens like *Staphylococcus aureus* and *Escherichia coli*. Literature combined with experimental data from Mahabubnagar district, Telangana, India using roots and leaves of *Boerhaaviadiffusa*, *Azadirachta indica*, *Datura stramonium*, and *Glycyrrhiza glabra* shows that polar solvents applied via Soxhlet or maceration consistently deliver higher yields upwards of 10% and stronger zones of inhibition (i.e 24 mm). There are also challenges like solvent consumption, duration and degradation due to used compounds while being conventional methods which are simple and cost-effective. The paper clarifies need for standardization and highlights opportunities for greener approaches to support development of antimicrobials derived from plants.

INTRODUCTION

The basis for traditional healthcare have always been Medicinal plants for hundreds of years, giving complex mixtures of bioactive secondary metabolites such as alkaloids, flavonoids, tannins, terpenoids, saponins, and phenolic compounds. These compounds exhibit diverse pharmacological effects, including potent antimicrobial activity, making them promising alternatives to synthetic antibiotics amid growing resistance concerns. The fundamental technique for isolating phytochemicals due to its affinity with matching solvent polarity to compounds is Solvent extraction. Here three conventional solvent extraction methods namely maceration, percolation, and Soxhlet extraction comparing their principles, efficiency, advantages, and limitations. The paper explores how method and solvent selection affect phytochemical yield and antimicrobial performance. Insights are drawn from both literature and a practical case study conducted in Mahabubnagar district, Telangana, India, where local medicinal plants were processed using these techniques. Review views such as implications for standardization, quality control, and future development of affordable plant-based antimicrobials, particularly in low, middle income regions.

Principles and Detailed Description of Conventional Solvent Extraction Techniques: Solvent extraction operates on the principle of solubility and diffusion: the solvent penetrates plant cell walls, dissolves compatible phytochemicals, and is later separated from the residual plant material. Maceration involves soaking coarsely powdered plant material in a solvent at room temperature for 3–7 days or shorter periods with occasional shaking. The mixture is filtered and concentrated by evaporation. In the Telangana case study, 200 mg of powdered material was soaked in 2 mL solvent for preliminary screening, while larger batches used 20 g in 200 mL. Percolation is packing powdered plant material in a percolator and allowing solvent to mix with the bed, collecting the results. New solvent can be added as many times as needed repeatedly throughout the process. This is faster than maceration and provides more exhaustive extraction than simple soaking. Soxhlet extraction places powdered material in a porous thimble inside an extractor. Solvent in the round-bottom flask is heated, vapors condense and percolate through the sample repeatedly via siphon action for 6–8 hours until the solvent runs clear. The extract is then concentrated using a rotary evaporator. In the case study, 20 g of material was extracted with 200–250 mL of organic solvents by using methanol, ethanol, chloroform for 6–8 hours. Plant preparation was consistent across methods: fresh specimens collected from

Table 1. presents a side-by-side comparison of the three techniques

Extraction Method	Principle	Typical Time	Solvent Consumption	Advantages	Disadvantages	Best Suited For
Maceration	Soaking with occasional shaking	3–7 days	High	Simple, inexpensive, no heat, preserves thermolabile compounds	Long duration, incomplete extraction, high solvent use	Heat-sensitive alkaloids & flavonoids
Percolation	Continuous solvent flow through packed material	2-24 Hours	Moderate	More efficient than maceration, good for tinctures	Requires equipment	Moderate-scale exhaustive extraction
Soxhlet	Repeated hot solvent siphoning	6–8 hours	Low	High efficiency, exhaustive	Heat may degrade sensitive compounds	Heat-stable compounds, laboratory scale

Table 2. Extract Yield (%) from Different Solvents and Plants (Mahabubnagar Case Study)

Plant Species	Plant Part	Methanol (%)	Ethanol (%)	Chloroform (%)	Petroleum Ether (%)	Aqueous (%)
Azadirachta indica (Neem)	Leaves	11.4	10	4	3	7.2
Datura stramonium	Seeds	10.6	11.1	Low	Low	Moderate
Glycyrrhiza glabra	Roots	13.4	11.5	–	–	8.2
Boerhaaviadiffusa	Leaves/Roots	9.4	10.1	Low	Low	Low

Yield (%) = (Weight of extract / Weight of dry powder) × 100.

Table 3. Antimicrobial Activity – Zones of Inhibition (mm)

Plant Species	Solvent	Staphylococcus aureus (mm)	Escherichia coli (mm)
Azadirachta indica (Neem)	Methanol	22	16
Azadirachta indica (Neem)	Ethanol	20	14
Glycyrrhiza glabra	Methanol	24	19
Boerhaaviadiffusa	Ethanol	17	15

local habitats in Mahabubnagar were authenticated, washed, shade-dried for 10–15 days to preserve heat-sensitive compounds, and grounded into powder before extraction. Extracts were stored at 4–10°C and reconstituted in 10% DMSO for antimicrobial testing.

Comparative Analysis of Extraction Methods

Comparative Overview of Conventional Solvent Extraction Techniques: Polar solvents generally outperformed non-polar solvents (chloroform) across all methods for broad recovery of antimicrobial phytochemicals such as flavonoids and phenolics. Impact on Phytochemical Yield and Antimicrobial Activity, Solvent polarity and extraction method significantly influence both yield and biological activity. Polar solvents extract higher amounts of water-soluble and semi-polar compounds responsible for antimicrobial effects.

Polar solvents consistently gave higher yields, correlating with greater enrichment of bioactive compounds. Antimicrobial activity was assessed using the agar well diffusion method against Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*) bacteria. Polar extracts produce larger inhibition zones, supporting literature on mechanisms such as membrane disruption, enzyme inhibition (DNA gyrase), DNA intercalation, and oxidative stress induction by flavonoids, alkaloids, and rotenoids.

DISCUSSION

The comparative data confirm that Soxhlet extraction offer superior efficiency and yield due to constant solvent contact, while maceration remains nominal when preserving heat-sensitive compounds.

In the Telangana case study, methanol and ethanol consistently outperformed non-polar solvents in both yield and antimicrobial potency, validating traditional ethnomedicinal uses of these locally abundant plants.

Challenges include high organic solvent consumption, potential thermal degradation in Soxhlet, variability due to seasonal/habitat factors, and lack of standardization. Quality control issues, such as possible adulteration in *Boerhaaviadiffusa* roots, further emphasize the need for proper authentication and reproducible protocols. These conventional methods remain accessible for resource-limited settings and provide a strong foundation for initial screening. However, translation to clinical applications requires rigorous studies, toxicity evaluation (especially for *Datura*), and integration with emerging green techniques such as ultrasound-assisted or microwave-assisted extraction.

CONCLUSION

Conventional solvent extraction techniques maceration for simplicity, Soxhlet for efficiency, and percolation for balanced performance continue to play a vital role in isolating antimicrobial phytochemicals from medicinal plants. The case study demonstrates that polar solvents results in optimal yields and bioactivity, reinforcing the value of traditional knowledge when combined with systematic scientific evaluation.

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