COMPARATIVE ANALYSIS OF PHYSICOCHEMICAL METHODS FOR ISOLATING FRAGRANT ORGANIC COMPOUNDS FROM SURKHANDARYA FLORA

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Annotation: *The growing global demand for natural and eco-friendly raw materials has intensified interest in essential oils and other aromatic compounds derived from regional flora. This article presents a comparative scientific analysis of various physicochemical extraction methods for isolating fragrant organic compounds from endemic and medicinal plants of the Surkhandarya region. Specifically, steam distillation, ultrasonic extraction, and supercritical CO_2 extraction techniques were employed to evaluate the yield, efficiency, safety, and environmental impact of each method. Quantitative and qualitative analyses of the extracted essential oils were performed using gas chromatography (GC) and gas chromatography–mass spectrometry (GC-MS). The study also emphasizes the relevance of applying green chemistry principles in the selection of solvents and energy-saving technologies. Based on the results, ultrasonic and supercritical extraction methods demonstrated superior productivity and chemical purity compared to traditional approaches. The findings have practical implications for industrial-scale essential oil production, particularly in the development of competitive, sustainable, and high-quality aromatic products based on the bioresource potential of Surkhandarya's unique flora.*

Keywords: *Essential oils, Surkhandarya flora, ultrasonic extraction, steam distillation, supercritical CO_2, green chemistry, aromatic plants, terpene compounds, GC-MS analysis, sustainable technologies.*

In recent decades, there has been a growing global demand for natural and environmentally friendly products, particularly in the fields of pharmaceuticals, food technology, cosmetics, and perfumery. As a result, scientific and industrial attention has increasingly shifted toward the exploration and use of natural sources of fragrant organic compounds such as essential oils, terpenoids, aromatic alcohols, esters, aldehydes, and ketones. These volatile organic substances, mainly found in aromatic and medicinal plants, possess not only distinctive sensory properties but also notable biological activity, making them valuable ingredients for health-related and industrial applications.

Surkhandarya region, located in the southern part of Uzbekistan, presents unique climatic and geographical features that support a diverse flora, including a high number

of endemic and aromatic plant species. Despite its biodiversity potential, the aromatic and essential oil content of the region's plant resources remains underexplored. Furthermore, modern, energy-efficient, and environmentally sustainable technologies for extracting these valuable natural compounds from local flora have not yet been widely developed or implemented.

This research focuses on identifying and analyzing the effectiveness of various physicochemical extraction methods to isolate fragrant organic compounds from selected plants native to Surkhandarya. The study compares conventional steam distillation with more advanced approaches such as ultrasonic extraction and supercritical CO_2 extraction, evaluating their yield, chemical purity, ecological impact, and industrial applicability.

The novelty of this research lies in its integrated methodological approach, which combines chemical analysis, technological efficiency, and sustainability criteria. The outcomes are expected to contribute to the scientific understanding of Uzbekistan’s plant-based resources and support the development of value-added natural products for both local and international markets.

During the course of this study, samples of essential oil-bearing plants native to the Surkhandarya region — including *Mentha longifolia*, *Ocimum basilicum*, and *Rosa canina* — were collected and subjected to various extraction technologies. The aim was to evaluate the efficiency of different methods for essential oil isolation, determine their chemical composition, and identify environmentally and economically viable extraction techniques.

In the first phase of the research, three main extraction methods were applied: traditional steam distillation, ultrasound-assisted extraction, and supercritical CO_2 extraction. The oils obtained were evaluated based on their yield, physical-chemical properties, and aromatic quality.

The steam distillation method, while being simple and cost-effective, showed limitations in preserving heat-sensitive components. Essential oil yields using this method were relatively low. For example, *Mentha longifolia* yielded only 0.8%, while *Rosa canina* produced just 0.4%.

The ultrasound-assisted extraction method provided significantly better results in terms of both yield and extraction time. The ultrasonic waves helped break plant cell walls, enabling the rapid and efficient release of essential oils. Using this method, *Ocimum basilicum* yielded up to 1.6% of essential oil, with superior retention of scent and color characteristics.

The most advanced and efficient method was supercritical CO_2 extraction, which operates under high pressure and moderate temperature. This technique allowed for the isolation of high-purity, fractionated oils resistant to oxidation. Yields of 1.7% for *Mentha longifolia* and 1.2% for *Rosa canina* were achieved using this approach.

A comparative summary of essential oil yields by extraction method is presented below in Table 1:

TABLE 1

ESSENTIAL OIL YIELDS (%) BASED ON EXTRACTION METHODS

Plant species	Steam distillation (%)	Ultrasound extraction (%)	Supercritical CO_2 (%)
Mentha longifolia	0.8	1.4	1.7
Ocimum basilicum	0.9	1.6	1.9
Rosa canina	0.4	0.9	1.2

Source: Author's laboratory analysis

Chemical analysis using gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) revealed key volatile constituents in the essential oils. *Mentha longifolia* samples were rich in menthol (45%), menthone (18%), and isomenthone (12%). *Ocimum basilicum* samples predominantly contained linalool, eugenol, and methyl chavicol, compounds known for their strong aromatic and antimicrobial properties.

The graphical representation in Figure 1 demonstrates the yield variation across different extraction methods:

FIGURE 1. Relationship between extraction methods and essential oil yield [4] *(Placeholder for figure with source citation beneath)*

These findings clearly indicate that modern extraction technologies — particularly supercritical CO_2 and ultrasound-assisted methods — offer considerable advantages over traditional techniques in terms of oil quality and efficiency. This has significant implications for the industrial-scale production of natural aromatic compounds, enhancing competitiveness, sustainability, and compliance with international standards.

The conducted research highlights the importance of selecting an appropriate extraction method for obtaining high-quality essential oils from plant species native to Surkhandarya. Each method examined—steam distillation, ultrasound-assisted extraction, and supercritical CO_2 extraction—offered distinct advantages and limitations depending on plant type, oil yield, energy consumption, and chemical integrity of the final product.

Steam distillation, being the most conventional and widely used technique, is often employed for its simplicity and low cost. However, the process requires prolonged heating, which can lead to the degradation of heat-sensitive volatile compounds such as monoterpenes and aromatic aldehydes. As a result, while the method remains suitable for basic applications, its effectiveness in preserving the full spectrum of active constituents

is limited. This was evident in the relatively lower oil yields and reduced aromatic profiles observed in all three plant species analyzed.

In contrast, ultrasound-assisted extraction demonstrated increased efficiency in terms of both time and output. The application of ultrasonic waves enhanced cell wall disruption and solvent penetration, leading to a more complete extraction of essential oils. The method also proved to be energy-efficient and less damaging to thermolabile compounds, thereby maintaining higher concentrations of bioactive molecules such as linalool, eugenol, and limonene. This technique offers a promising alternative for small- to medium-scale operations aiming to maximize productivity while adhering to sustainable practices.

The most advanced approach explored in this study, supercritical CO_2 extraction, yielded the highest quality oils with superior aromatic and chemical characteristics. The non-polar nature of supercritical carbon dioxide allowed for selective extraction, minimizing contamination and oxidation. This method produced the purest oils, with minimal residue and waste. Although the initial investment and operational costs of supercritical CO_2 systems are relatively high, the benefits—such as increased yield, reduced environmental impact, and scalability—make it a viable long-term solution for industrial essential oil production.

Moreover, the chemical composition of the oils extracted using modern methods was more consistent and concentrated in key compounds. This has significant implications not only for the perfumery and cosmetics industry but also for pharmaceuticals and food preservation, where consistent quality and biological activity are critical.

Another important aspect of this study was its alignment with green chemistry principles. Both ultrasound and supercritical CO_2 extraction methods meet sustainability criteria by reducing the need for toxic solvents, minimizing energy usage, and lowering greenhouse gas emissions. These features are particularly relevant for the growing demand in global markets for eco-friendly and organic products.

In conclusion, the study clearly shows that transitioning from traditional to modern extraction methods can substantially enhance the efficiency, quality, and environmental compatibility of essential oil production. The adoption of such technologies in Surkhandarya and similar bioresource-rich regions could contribute to economic development while preserving ecological balance.

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