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Determination of essential oil yield from Eucalyptus globulus, Zingiber officinale, and Allium sativum

Determinación del rendimiento de aceite esencial de Eucalyptus globulus, Zingiber officinale y Allium sativum

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RESUMEN

Los aceites esenciales son combinaciones complejas originadas del metabolismo secundario vegetal, que contienen monoterpenos y sesquiterpenos. La investigación se realizó con la finalidad de contrastar la eficacia de aceites esenciales derivados de las hojas de Eucalyptus globulus, los rizomas de Zingiber officinale y los bulbos de Allium sativum, utilizando el método de extracción por arrastre de vapor. Las muestras fueron secadas, trituradas y sometidas a una destilación mediante arrastre de vapor. Los datos obtenidos se analizaron estadísticamente para determinar diferencias significativas en los rendimientos de los aceites esenciales. Este proceso es crucial para optimizar la producción de aceites esenciales, que tienen aplicaciones en salud, cosmética y alimentación debido a sus propiedades biológicas y terapéuticas. El jengibre mostró el mayor rendimiento de aceites esenciales (2,25%), superando al eucalipto (1,2%) y ajo (0,01%), obtenido por el método de arrastre de vapor. La reducción de humedad en las plantas mejoró el rendimiento de aceites esenciales, como se observó en eucalipto y ajo. El contenido de humedad del jengibre (14%) fue óptimo para la extracción. Estos resultados subrayan la importancia de optimizar las condiciones de extracción para maximizar el rendimiento de aceites esenciales.

Palabras clave: *Hojas de eucalipto, rizomas de jengibre, bulbos de ajos, extracción de aceites..*

ABSTRACT

Essential oils are complex combinations derived from plant secondary metabolism, containing monoterpenes and sesquiterpenes. This research aimed to compare the efficiency of essential oils derived from the leaves of Eucalyptus globulus, the rhizomes of Zingiber officinale, and the bulbs of Allium sativum, using the steam distillation method. The samples were dried, ground, and subjected to steam distillation. The data obtained were statistically analyzed to determine significant differences in essential oil yields. This process is crucial for optimizing the production of essential oils, which have applications in health, cosmetics, and food industries due to their biological and therapeutic properties. Ginger showed the highest essential oil yield (2.25%), surpassing eucalyptus (1.2%) and garlic (0.01%), obtained through the steam distillation method. Reducing moisture content in the plants improved essential oil yields, as observed in eucalyptus and garlic. The moisture content of ginger (14%) was optimal for extraction. These results highlight the importance of optimizing extraction conditions to maximize essential oil yields.

Key words: *Eucalyptus leaves, ginger rhizomes, garlic bulbs, oil extraction.*

INTRODUCTION

According to Reverchon (1997), essential oils are complex combinations of hydrocarbon monoterpenes, oxygenated monoterpenes, hydrocarbon sesquiterpenes, oxygenated sesquiterpenes, and related chemicals that come from the secondary metabolism of plants. Higher yields must be obtained by high-performance extraction methods because of their low concentration in plant material. Since the plant matrix, oil content, and components have a major impact on production kinetics, these methods and distillation settings need to be tailored for each crop (Babu and Singh, 2009).

One popular technique for obtaining essential oils is steam distillation. This procedure uses a condenser, a still (usually composed of stainless steel), and an oil collection container. Polar and non-polar particles separate during steam distillation, allowing the oil to move away from the water for collection (Silveira et al., 2012). The utilization of high temperatures, which may break down thermolabile chemicals, solvent waste, and the presence of leftover solvent in the final product are some disadvantages of this process. However, when compared to more sophisticated extraction methods, it is a less expensive approach. A different option is supercritical fluid extraction, which uses non-toxic solvents like carbon dioxide and permits total solvent and product separation (Barros et al., 2016; Chen et al., 2016).

Eucalyptus leaves contain essential oils and other compounds that have been used as natural remedies since prehistoric times. Of the approximately 2,000 plant species that produce essential oils, about 300 are of industrial importance. These species produce essential oils with remarkable biological properties, such as antifungal, anticancer, antiviral, antimutagenic, antidiabetic, anti-inflammatory, and antibacterial activities (Shankar and Mohan, 2014). By decreasing herbivores' hunger, essential oils help plants defend themselves against them (Bakkali et al., 2008).

The essential oil of Eucalyptus globulus, especially from its leaves, is used in various sectors, including health, flavoring, perfumes, cosmetics, and pharmaceuticals. This oil contains secondary metabolites such as 1,8-cineole (eucalyptol), monoterpenes, sesquiterpenes, aldehydes, and ketones. The cineole content in the essential oil should be less than 70%. The chemical composition of the essential oil varies according to species, geographical location, season, foliage, harvest time, and extraction method (Putra and Maday, 2015).

Fractures, rheumatism, arthritis, bruises, carbuncles, motion sickness, nausea, hangovers, congestion, cough, sinusitis, skin sores, sore throats, diarrhea, colic, cramps, chills, fever, and colds are all treated with ginger oil. As the main taste in ginger items, ginger oil is also utilized in cookery as a flavoring for cakes, cookies, and biscuits (Khairu, 2006). Ginger's distinctive flavor comes from a volatile oil found in its rhizomes that is made up of monoterpenes (5%), sesquiterpenes (65%), and oxygenated chemicals (30%). The primary sesquiterpene in this oil is α-zingiberene (Mesomo, 2013).

The Liliaceae family includes the garlic bulb (Allium sativum L.), which has Mediterranean and Central Asian origins. In the ninth century, it was brought to South Asia and Japan, and it eventually spread around the world. Since ancient times, this plant has been utilized for both culinary and medicinal purposes, including the prevention and treatment of headaches, tumors, diarrhea, and other illnesses (Nagini, 2008). Major compounds (20–95%), secondary compounds (1–20%), and trace compounds (less than 1%) are the three primary categories of compounds found in garlic essential oil, which is produced by hydrodistillation (Mugao et al., 2020). The hydrothermal breakdown of high-allicin extracts in garlic yields different diallyl mono-, di-, and trisulfides, which are the main constituents of these oils, with a minor amount of terpenes (Abdelrahman et al., 2021). Garlic essential oil is abundant in phenolic compounds, essential amino acids, steroidal saponins, saponin ligands, and other sulfur-free substances in addition to organic sulfides (Amagase, 2006).

Recent studies have indicated that a high moisture content in plant species can reduce the amount of essential oil obtained (Sunanta et al., 2023). The aim of this study is to compare the yield of essential oils from Eucalyptus globulus, Zingiber officinale, and Allium sativum using the steam extraction method.

METHODOLOGY

Sample Selection

Fresh Eucalyptus globulus leaves, Zingiber officinale rhizomes, and Allium sativum bulbs were purchased from the local market in Tarma. In the laboratory, each product was carefully selected, with two kilograms of fresh material taken for each sample. Ginger and garlic were sliced into thin pieces.

Drying of Samples

For natural drying in the shade, Kraft paper was used as a base, on which a uniform layer of each sample was placed. These layers were covered again with Kraft paper to protect them from direct sunlight. After natural drying, the samples were transferred to an industrial dehydrator set at 55°C for 12 hours.

Grinding of Samples

The dried samples were separately ground using a Grindomix GM 300 blade mill fitted with a 60-mesh screen. The ground material was stored in airtight plastic bags to maintain its moisture content. Vacuum packaging was used to extract air and preserve the material's properties.

Steam Distillation Extraction

A 30-gram sample of each product was weighed and combined with 600 ml of distilled water in the boiling flask of the steam distillation apparatus. The material, containing volatile compounds, was heated with steam at 100°C for 4 hours. The volatiles were vaporized along with the steam, condensed using a cooling system, and collected in a container where the essential oil separated from the water due to its lower density.

Statistical Analysis

The data were organized using Microsoft Office 2007 Excel, and their normality was tested using the Shapiro-Wilk statistic (W). Subsequently, the data were analyzed using a one-way analysis of variance (ANOVA) in R software, version 3.6.3, with a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Table 1 shows that the evaluated variables exhibited statistically significant effects ($P \leq 0.05$). Furthermore, ginger proved to be the most efficient in producing essential oils compared to the other analyzed species.

Using the steam distillation method, ginger essential oil yield reached 2.25%. In contrast, water distillation yielded 0.52%, using 100 g of powdered dried ginger and 750 ml of water in a round-bottom flask with an extraction time of 4 hours. The combined method of water and steam distillation produced a yield of 1.77% from 100 g of dried ginger in a two-neck round-bottom flask connected to a 1000 ml flask for steam generation, with an extraction time of 2 hours (Swe and Kyi, 2019). Finally, the Soxhlet extraction method reported a yield of 15.2% using a 30 g sample and 750 ml of methanol over 4 hours (Haidar et al., 2022).

Tabla 1

Averages and p-value of the analysis of variance of the evaluated variables

Variables	E. globulus	Z. officinale	A.sativum	p-valor
Essential oil yield (%)	1,2 ± 0,1b	2,25 ± 0,05a	0,1 ± 0,1c	0,00*
Moisture content (%)	37,0 ± 2,0b	14,0 ± 2,0c	82,67 ± 2,51a	0,00*

(*) Significance at a 95.0% confidence level, LSD (Mean ± SD).

In Eucalyptus globulus, an average essential oil yield of 1.2% was obtained. This result is similar to that reported in Eucalyptus camaldulensis, where three extraction methods were evaluated: steam distillation, hydrodistillation, and superheated steam distillation. The superheated steam distillation, conducted at 150°C for 60 minutes, achieved the highest essential oil yield at 1.12%, while hydrodistillation yielded the lowest, at 0.59% (Muhammad et al., 2023). The essential oils obtained contained 1.8 cineole as the main component and showed significant antioxidant properties. This remarkable yield can be explained by the combination of the low viscosity of the superheated steam, its higher polarity, better penetration ability, and increased kinetic energy (Ayub et al., 2022). Superheated steam, heated above the boiling point of water, is more volatile and allows for a more efficient release of the essential oil components (Ayub et al., 2023).

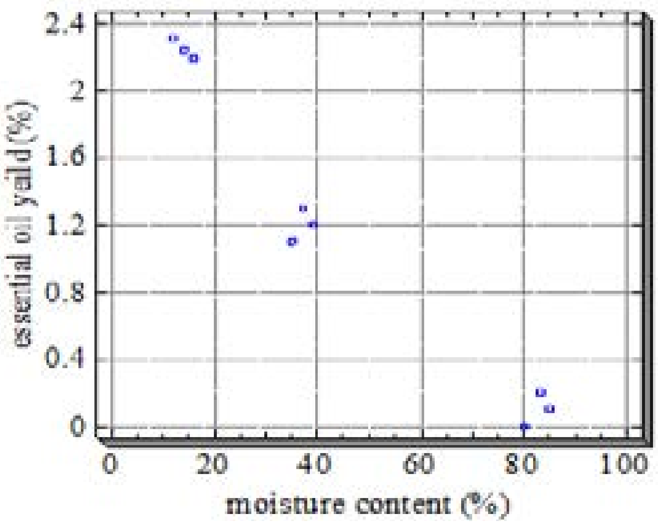
A similar result was reported for Eucalyptus tereticornis, which showed a yield of 2.05% when dried at room temperature for seven days and extracted by steam distillation at 97°C for 105 minutes (Galadima et al., 2012).

For garlic, the essential oil yield was the lowest, at only 0.01% using steam distillation. A study found that the essential oil yield from powdered garlic, extracted with ethanol using the Soxhlet method at 50°C for 4 hours, was 16.55%. The main compounds identified were diallyl disulfide (48.42%), allyl methyl trisulfide (7.27%), di-2-propenyl trisulfide (3.46%), and diallyl sulfide (7.64%) (Nilesh et al., 2021).

Figure 1 illustrates the relationship between the essential oil yield percentage and the moisture content of Eucalyptus globulus, Zingiber officinale, and Allium sativum using the steam distillation method. Ginger, with a moisture content of 14%, showed the highest essential oil yield. It has been observed that a reduction in ginger's moisture content through different dehydration methods increases the essential oil yield. This is because lower moisture content facilitates the release of the volatile compounds in ginger, which are the main constituents of the essential oil. In a study, ginger dried in an oven at 50°C with a moisture content of approximately 45% produced an essential oil yield of 0.60% (Li et al., 2023, Jayashree et al., 2014).

Figure 1

Interaction between the percentage of essential oil yield and moisture content.



The essential oil yield of aromatic plants varies depending on the drying technique, temperature, leaf moisture content, and extraction method. These variations are influenced by differences in species or subspecies, the type of secretory tissue, its location, and the specific components of the plant's essential oil (Rahimmalek and Hossein, 2013). In a study on Eucalyptus globulus, a yield of 3.03% was obtained from freeze-dried leaves with a moisture content of 11.55% using hydrodistillation for 120 minutes. In comparison, fresh leaves with a moisture content of 58.25% produced a yield of 1.89%, indicating that lower moisture content leads to higher essential oil yields (Calderón and Loor, 2023).

Recent studies have shown that a high moisture content in garlic can decrease the essential oil yield, as excess water hinders the release and capture of essential compounds during distillation. According to recent studies, using steam distillation with a moisture content of 75% in the plant material, processed at 100°C for 90 minutes, results in a yield of 0.17% (Sunanta et al. 2023, El-Saadony et al., 2024). In contrast, when the moisture content is reduced to 45%-55%, the yield can increase to between 0.30% and 0.40%, especially when steam distillation is used at a controlled temperature of 95°C for 120 minutes (Sunanta et al. 2023). On the other hand, in dry distillation, garlic with a higher moisture content (75%-80%) produces lower essential oil yields, typically between 0.10% and 0.15%, even when the extraction temperature is raised to 110°C for 80 minutes (El-Saadony et al., 2024). This reduction in efficiency is due to the difficulty in volatilizing the essential compounds when the material is excessively moist.

CONCLUSIONS

The highest essential oil yield was 2.31% for ginger using the steam extraction method at a temperature of 100°C and an extraction time of 240 minutes. The reduction in moisture content of the evaluated species (Eucalyptus globulus, Zingiber officinale, and Allium sativum) improved the essential oil yield, highlighting the importance of optimizing drying conditions. This result underscores the need to optimize both extraction and drying conditions to maximize the essential oil yield from the different species studied.

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