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Research Article

An overview of the chemical profile of some aromatic-medicinal plants of the South region (Llogara) in Albania

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Abstract

Albania, located in the Mediterranean region, possesses a climate highly suitable for the growth of numerous plant species (over 3,000), of which more than 300 are aromatic and medicinal. These plants are widely used in culinary applications, traditional medicine, and as ornamental species. Medicinal plants have been utilized since ancient times due to their health-promoting effects, and they continue to play an important role today, both in traditional therapies and in the formulation of pharmaceutical products and dietary supplements. Owing to their natural origin and minimal side effects compared to synthetic drugs, herbal medicines are increasingly incorporated into long-term treatments and clinical applications. The biological properties of these plants are mainly attributed to their phytochemical constituents, particularly essential oil components. This study presents data on the chemical composition of essential oils from three of the most commonly used aromatic plants in Albania, primarily from the southern region: *Salvia officinalis* L. (sage), *Origanum vulgare* L. (oregano), and *Laurus nobilis* L. (laurel). Wild populations of these species were collected from the Llogara Mountain area (southern Albania) in June 2025. Air-dried plant materials were subjected to hydro-distillation using a Clevenger-type apparatus to obtain the essential oils. The chemical composition was analyzed by gas chromatography equipped with a flame ionization detector (GC/FID) using a VF-1ms capillary column for compound separation.

The results showed that α- and β-thujones were the most abundant constituents in *S. officinalis* oils; carvacrol and thymol were predominant in *O. vulgare*; and 1,8-cineole (cineol) was identified as the major component of *L. nobilis* essential oil. The chemical profiles of these Albanian wild populations were consistent with previously reported data for the Balkan and broader Mediterranean regions.

Keywords: *Salvia officinalis*; *Origanum vulgare*; *Laurus nobilis*; essential oil; terpene; hydro-distillation; GC/FID.

1. Introduction

Albania, located on the Balkan Peninsula and forming part of the Mediterranean region, is characterized by exceptional biodiversity. Due to its favorable geographical position, complex topography, and variable climatic conditions, the country supports a remarkably rich flora comprising approximately 3,250 plant species. The diversity of Albania's flora is primarily influenced by the wide range of ecosystems — from coastal plains and hilly landscapes to high mountainous areas — and by the pronounced climatic gradients typical of the Mediterranean basin.

Among this diverse vegetation, more than 300 species are classified as aromatic and medicinal plants, representing a valuable yet underexploited natural resource of significant economic and ecological importance (Asllani, 2012). These species are distributed throughout the country, from the lowland areas along the Adriatic coast to the high-altitude zones of the northern mountains. Albanian aromatic and medicinal plants are notable not only for their taxonomic diversity but also for their high content of essential oils and pharmacologically active compounds.

The use of these plants in Albania has deep historical roots. Since antiquity, they have been employed in traditional medicine, culinary practices, and perfumery. Their essential oils and bioactive constituents have long been recognized for their therapeutic properties and aromatic qualities (Kathe et al., 2014). Today, these species continue to hold scientific, medicinal, and commercial significance, with growing interest in their sustainable utilization and potential for pharmaceutical and nutraceutical development.

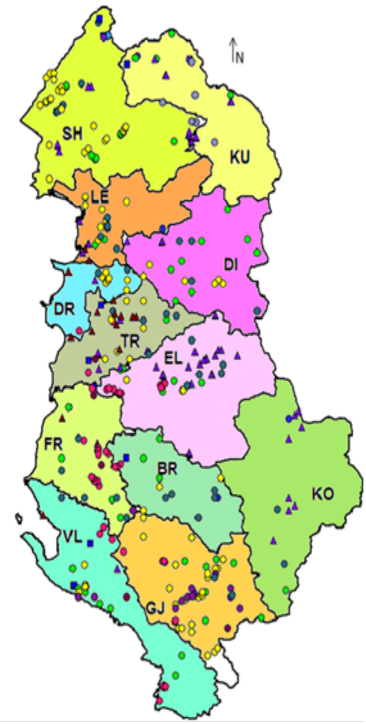


Figure 1. Map of the distribution of medicinal plants in Albania

2. Collection of Medicinal Plants

The collection of aromatic and medicinal plants represents a major source of income for many rural households in Albania, particularly in economically disadvantaged regions. For numerous families, this activity constitutes the primary means of subsistence. In recent years, there has been growing interest among farmers to cultivate medicinal, aromatic, and tannin-producing species on marginal or low-fertility lands. Such cultivation could provide an effective alternative for the sustainable use of abandoned agricultural areas, especially those that are inaccessible to modern agricultural machinery or irrigation systems.

Although a wide variety of aromatic and medicinal plants still occur naturally across the country, their abundance has declined significantly in recent decades. Several species have become increasingly rare or endangered, primarily due to habitat loss, environmental degradation, overharvesting, soil erosion, and unsustainable collection practices. In many cases, collectors harvest entire plants—including roots, stems, and leaves—instead of selectively gathering only the necessary parts such as flowers or fruits. This destructive method of harvesting has led to the depletion of natural populations and threatens the extinction of some valuable species.

Particularly affected are the natural populations of mountain tea (*Sideritis raeseri*) in the Lunxheria, Çajup, Sevaster, Gramoz, and Llogara regions, which have been severely degraded by uncontrolled human activity. Other species, such as salep (*Orchis mascula*), gentian (*Gentiana lutea*), red juniper (*Juniperus oxycedrus*), common juniper (*Juniperus communis*), oregano (*Origanum vulgare*), wild rose (*Rosa canina*), and hawthorn (*Crataegus monogyna*), are also experiencing population declines due to excessive exploitation driven by market demand.

The unsustainable collection of these plants highlights the urgent need for conservation measures, improved regulation, and the promotion of cultivated sources to reduce pressure on wild populations.

Figure 2. The act of collecting plants

2.1 Study Area: Llogara National Park

Llogara National Park is located in southwestern Albania, within the Ceraunian Mountain range along the Albanian Riviera. The park covers an area of approximately 1,769 ha and is characterized by highly diverse geomorphological and ecological features, including alpine meadows, steep cliffs, deep ravines, and dense coniferous and mixed forests. Established in 1966, the park was designated as a protected area (IUCN Category II) to conserve ecosystems of national significance and to safeguard the region's rich biodiversity. It is also recognized as an Important Bird and Plant Area (IBA and IPA), supporting a substantial number of endemic and rare species.

The park exhibits remarkable environmental diversity due to its altitudinal gradient and proximity to the Ionian coast. The landscape transitions from the snow-covered alpine peaks of the Ceraunian Mountains during winter to the warm, sunlit coastal areas of the Ionian Sea in summer. The Llogara Pass, situated at an elevation of approximately 1,027 m, provides panoramic views of the Albanian Riviera and nearby islands.

The region experiences a predominantly Mediterranean climate, characterized by hot, dry summers and mild, wet winters. However, due to the park's elevation and exposure, an alpine microclimate prevails at higher altitudes, particularly around Maja e Çikës, the highest peak in the range. Geologically, the area is dominated by carbonate formations, with extensive deposits of limestone and dolomite that shape the park's rugged relief and karstic features.

The combination of diverse climatic, geological, and topographical conditions makes Llogara National Park a hotspot for aromatic and medicinal plant diversity. Numerous species native to this area are traditionally harvested for culinary, therapeutic, and industrial purposes, both within Albania and for export to international markets.

Figure 3. Llogara National Park

2.2 Essential Oils

Essential oils are complex mixtures of volatile organic compounds belonging to various chemical classes, extracted from plants that contain etheric oils. These natural products are typically composed of numerous low-molecular-weight constituents, which collectively contribute to the characteristic aroma and biological activity of the plant.

The components of essential oils generally exhibit boiling points between approximately 120 °C and 150 °C and are only slightly soluble in water. Due to these physicochemical properties, essential oils are most commonly obtained from plant materials by steam distillation, a technique that efficiently separates volatile compounds from non-volatile matrices without causing significant thermal degradation. Other extraction methods, such as hydro distillation, solvent extraction, or supercritical CO_2 extraction, may also be employed depending on the plant source and desired oil quality.

Chemically, essential oils contain a diverse array of terpenoid and non-terpenoid compounds. The terpenoid fraction typically includes aliphatic monoterpenes, monocyclic and bicyclic monoterpenes, tricyclic monoterpenes, aromatic monoterpenoids, oxygenated monoterpenoids, and sesquiterpenes. In addition to terpenoids, essential oils often contain other classes of organic compounds such as alkanes, alkenes, aldehydes, ketones, alcohols, phenols, and esters. The qualitative and quantitative composition of an essential oil varies widely among species and is influenced by genetic, environmental, and technological factors affecting plant growth and processing.

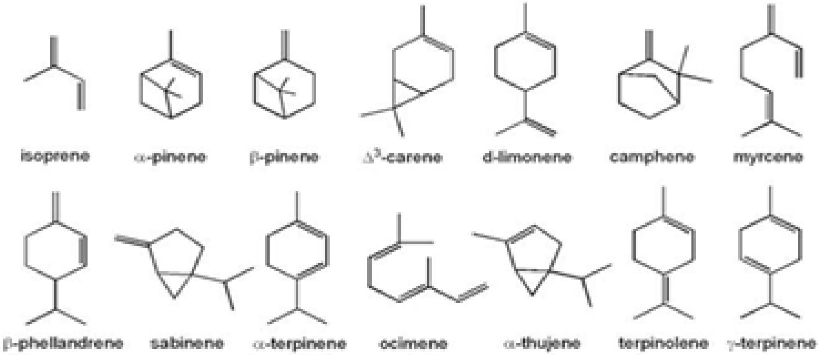
Figure 4. Essential oils of different medicinal plants

2.3 Terpenes

Terpenes represent a large and diverse class of natural products with the general molecular formula $(C_5H_8)_n$, where $n \geq 2$. They serve as fundamental biosynthetic building blocks in numerous organisms, particularly in plants. More than 30,000 terpene compounds have been identified to date, making them one of the most structurally diverse classes of natural metabolites. These unsaturated hydrocarbons are produced predominantly by plants—especially conifers—and, to a lesser extent, by some insects, fungi, and marine organisms.

In plants, terpenes and their oxygenated derivatives, terpenoids, play crucial ecological and physiological roles. They function as chemical mediators in plant–plant and plant–insect interactions, acting as attractants, repellents, or defense compounds. In addition, terpenoids are involved in several vital physiological processes, including modulation of cell growth and elongation, participation in light harvesting and photoprotection, and regulation of membrane permeability and fluidity.

Terpenes are classified based on the number of isoprene (C_5) units or carbon atoms in their structure: monoterpenes (C_{10}), sesquiterpenes (C_{15}), diterpenes (C_{20}), triterpenes (C_{30}), and tetraterpenes (C_{40}). For example, α-pinene, a monoterpene, is the principal constituent of turpentine and a common industrial solvent. Beyond their ecological functions, terpenes possess considerable economic and pharmacological importance. They are key constituents of essential oils used in traditional medicine and aromatherapy, and they serve as active ingredients in natural pesticides, fragrances, and flavoring agents in the food and cosmetic industries.



3. Materials and Methods

3.1 Sampling of Medicinal Plants

The aerial parts of *Salvia officinalis* L. and *Origanum vulgare* L., as well as the leaves of *Laurus nobilis* L., were collected from six different sites within Llogara National Park, near Vlora in southern Albania. The sampling was conducted in June 2025.

Plant materials were air-dried in the shade under ambient laboratory conditions to preserve their morphological and chemical integrity. After complete drying, the samples were manually chopped into small pieces (approximately 0.5–2 cm) to ensure homogeneity prior to essential oil extraction.

Figure 6. Preparing Salvia officinalis samples from the Logara area

Figure 7. Preparing oregano samples from the Logara area

3.2 Materials and Reagents

High-purity n-hexane and toluene, both suitable for gas chromatographic analysis, were obtained from Merck (Darmstadt, Germany). A homologous series of n-alkanes ranging from n-octane (C_8) to n-eicosane (C_{20}) was also purchased from Merck and used to determine Kovats retention indices (KI) for component identification. All reagents were of analytical grade and used without further purification.

3.2.1 Isolation of Essential Oils Using a Clevenger-Type Apparatus

Dried plant materials (50 g each of *Salvia officinalis* L., *Origanum vulgare* L., and *Laurus nobilis* L.) were subjected to hydro-distillation for 4 h using a Clevenger-type apparatus, as recommended by the European Pharmacopeia (2014). The distillation was performed continuously without interruption to ensure complete recovery of volatile compounds.

The obtained distillates were collected in 2 mL of toluene, which served as the extraction solvent for essential oil separation. To remove residual water, the oil extracts were dried over anhydrous sodium sulfate (1 g) and then transferred to amber glass vials to prevent photooxidation. The vials were sealed tightly and stored at +4 °C until chromatographic analysis.

Each essential oil sample was subsequently analyzed by gas chromatography coupled with a flame ionization detector (GC/FID) for compositional characterization.

Figure 8. Clevengar apparatur

Figure 9. Preparing for the gas chromatographic analysis

3.2.2 Apparatus and Gas Chromatography Analysis

Gas chromatographic (GC) analysis of the essential oils from *Salvia officinalis* L., *Origanum vulgare* L., and *Laurus nobilis* L. was performed using a Varian 450 GC system equipped with a programmable temperature vaporization (PTV) injector and a flame ionization detector (FID). The injector temperature was set at 280 °C, and the detector temperature at 300 °C.

A VF-1ms capillary column (30 m × 0.33 mm i.d., film thickness 0.25 μm) was employed for the separation of volatile compounds. The carrier gas was nitrogen at a constant flow rate of 1.0 $mL\cdot min^{-1}$, while nitrogen was also used as make-up gas at 25 $mL\cdot min^{-1}$. Hydrogen and air served as flame gases at flow rates of 30 $mL\cdot min^{-1}$ and 300 $mL\cdot min^{-1}$, respectively.

A 2 μL aliquot of each essential oil sample, previously dissolved in toluene, was injected in split mode (1:50). The identification of individual components was achieved by comparing their retention times (RT) with those of reference compounds and by calculating their Kovats retention indices (KI) relative to a homologous series of n-alkanes (C_8–C_{20}).

Quantitative composition was determined from relative peak area percentages, calculated automatically by the GC software, excluding the solvent (toluene) peak.

Figure 10. Gas chromatography

4. Gas Chromatography

Gas chromatography (GC) is an analytical technique used to separate and quantify volatile compounds within a mixture. In this method, a gaseous or vaporized liquid sample is introduced into a mobile phase, commonly referred to as the *carrier gas*, which transports the analytes through a stationary phase contained within a separation column. The carrier gas is typically an inert or chemically unreactive gas such as helium, argon, nitrogen, or hydrogen.

The stationary phase may consist of either a solid adsorbent or a nonvolatile liquid immobilized on a solid support; however, modern GC systems predominantly employ polymeric liquid stationary phases coated onto fused-silica capillary columns. These capillary columns generally range from 5 to 60 m in length, with internal diameters between 100 and 320 µm.

The column is housed within a temperature-controlled oven, allowing precise regulation of the thermal environment during analysis. As the sample components migrate through the column, they separate based on differences in volatility and interaction with the stationary phase. The effluent exiting the column is subsequently detected and quantified using an appropriate detector, such as a flame ionization detector (FID) or a mass spectrometer (MS), depending on the analytical objective.

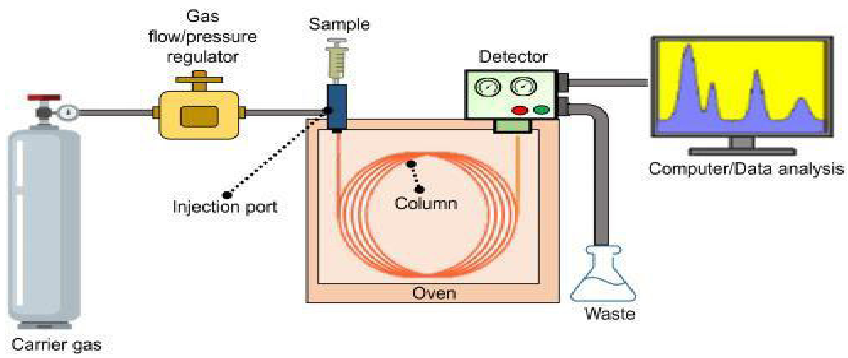


Figure 11. A diagram of the construction of GC/FID

4.1 Salvia officinalis L.

Salvia officinalis L. (sage) is a perennial subshrub native to the Mediterranean region, commonly growing along foothills and rocky slopes. The plant typically reaches a height of 25–80 cm and flowers from May to July, depending on local climatic conditions. Pollination occurs primarily through insects, while seed dispersal is facilitated by birds and rainfall. The species is characterized by quadrangular stems, with annual shoots that are thin, soft, and covered with fine grayish trichomes. Older stems exhibit scaly bark, gray to brown in color.

Leaves are opposite, simple, and elliptic-oblong to lanceolate, with a leathery texture. The adaxial (upper) surface is greenish, while the abaxial (lower) surface is densely pubescent and gray-silver in color. The inflorescences are arranged in verticillasters containing 3–8 flowers, forming a false spike. The corolla is bilabiate and varies in color from purple-blue to pink, and rarely white. The calyx is campanulate, 10–15 mm long, with five small lobes. The fruit is a schizocarp consisting of four dark brown, triangular nutlets, approximately 2 mm in diameter.

Salvia officinalis typically grows on calcareous, well-drained soils developed over limestone and dolomite substrates, with slightly basic to neutral pH. It is widely distributed along the western part of Albania, from the Adriatic to the Ionian coasts, at altitudes ranging from 150 to 1200 m above sea level. The species is heliophilous but can also tolerate partial shade.

The aerial parts of the plant are harvested for both medicinal and industrial use. The first harvest generally occurs from mid-June to mid-July, and the second from mid-September to mid-October. Harvesting is performed when the leaves are fully mature, displaying a silvery hue and a waxy surface. Plant bundles are dried in shaded, well-ventilated areas protected from dust and contamination.

Sage is extensively utilized in the cosmetic, pharmaceutical, and food industries. The essential oil obtained from its leaves is widely used as a fragrance component in perfumes, soaps, and oral hygiene products. In culinary applications, it serves as a flavoring agent in meat-based dishes. Pharmacologically, *S. officinalis* exhibits a broad range of biological activities, including astringent, antiseptic, aromatic, carminative, estrogenic, antisudorific, tonic, stimulant, and antispasmodic properties. It is traditionally used for the treatment of nervous disorders, dizziness, digestive dysfunctions, diarrhea, menstrual irregularities, and menopausal symptoms. The combination of antiseptic and astringent effects also makes sage extracts valuable for treating sore throats, mouth ulcers, and gingival inflammation (GIZ, 2013; Asllani, 2004).

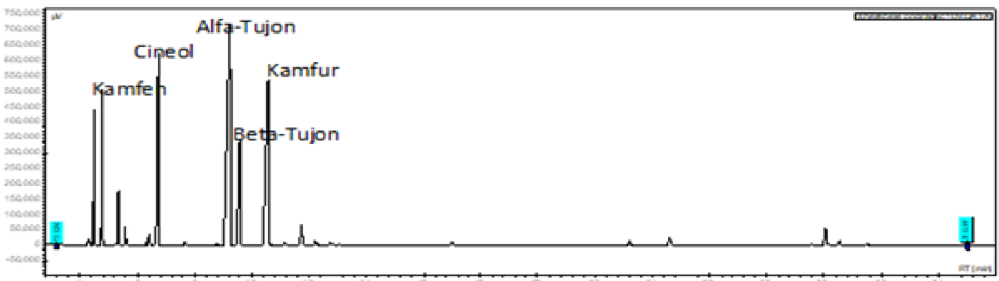
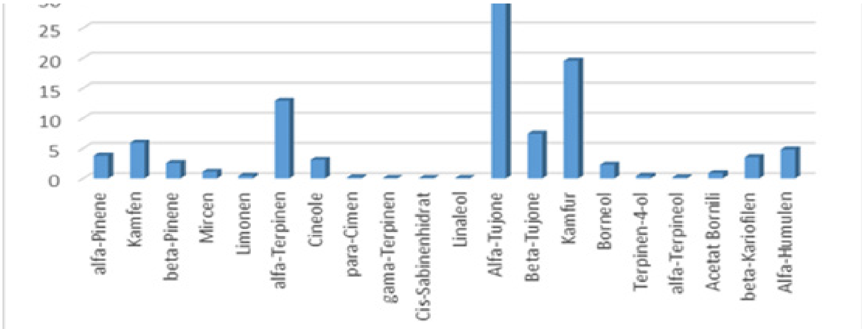


Figure12. Chromatograms of savia officinals from the area of Llogara



4.2 Chemical Composition of Salvia officinalis Essential Oil

The chromatographic profile of *Salvia officinalis* essential oil from the Llogara area is presented in Figure 12, which illustrates the average relative percentages of the identified components. A total of approximately 120 compounds were detected in the analyzed samples, of which the 20 major constituents accounted for more than 95% of the total composition. Compounds with relative abundances below 0.05% were excluded from quantitative evaluation.

The dominant constituents identified in the essential oil were α- and β-thujone, camphor, 1,8-cineole, camphene, α-humulene, β-caryophyllene, and α-pinene. The combined concentration of α- and β-thujone represented 43.2% of the total oil across all four analyzed samples. The distribution pattern of the principal compounds was consistent among samples collected from different sites within the study area, suggesting a relatively homogeneous chemotype of *S. officinalis* in this region.

Minor variations in the quantitative composition of individual constituents are likely attributed to environmental and edaphic factors, including altitude, humidity, temperature, and soil characteristics. These parameters are known to influence the biosynthesis and accumulation of secondary metabolites in aromatic plants.

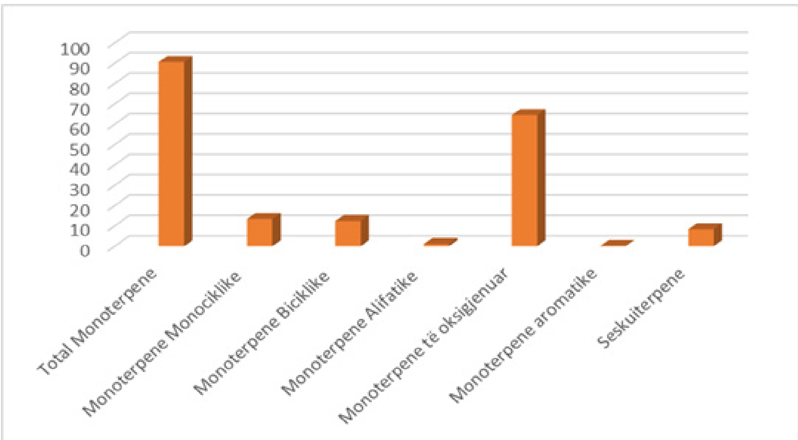


Figure 13. Profile of the main compounds in sage essence

Table 1. Average data for the main compounds analyzed in sage essence obtained in Leskovec, 2020

	Retention time	**Percentage**
Alfa-Pinene	4.32	3.80 ± 1.22
Kamfen	4.41	5.94 ± 1.78
beta-Pinene	5.22	2.56 ± 0.77
Mircen	5.34	1.13 ± 0.42
Limonen	6.41	0.44 ± 0.10
alfa-Terpinen	6.47	12.89 ± 5.32
Cineole	6.73	3. 1 ± 1.43
para-Cimen	7.33	0.20 ± 0.06
gama-Terpinen	7.98	0.10 ± 0.02
Cis-Sabinenhidrat	8.13	0.10 ± 0.02
Linaleol	8.44	0.10 ± 0.03
Alfa-Tujone	9.12	35.62 ± 7.29
Beta-Tujone	9.21	7.45 ± 1.31
Kamfur	10.52	19.54 ± 5.36
Borneol	11.78	2.27 ± 0.83
Terpinen-4-ol	12.21	0.44 ± 0.09
alfa-Terpineol	14.43	0.20 ± 0.05
Acetat Bornili	16.95	0.88 ± 0.24
beta-Kariofilen	23.14	3.54 ± 1.44
Alfa-Humulen	24.65	4.81 ± 0.96
Total		**98.9**

4.3 Composition and Classification of Terpenes in Salvia officinalis Essential Oil

The analysis revealed that the essential oil of *Salvia officinalis* from the Llogara area is dominated by monoterpenes, which account for 90.6% of the total identified compounds. Sesquiterpenes, represented mainly by β-caryophyllene and α-humulene, constituted 8.4% of the total composition.

Among all samples, the oxygenated monoterpenoids formed the principal group of compounds, representing 64.5% of the total oil. This fraction included 1,8-cineole, linalool, α-thujone, β-thujone, camphor, borneol, terpinen-4-ol, α-terpineol, and bornyl acetate. The bicyclic monoterpenes — α-pinene, camphene, and β-pinene — accounted for 12.4%, followed by monocyclic monoterpenes (α-terpinene, limonene, and γ-terpinene) which made up 13.4%. The aromatic monoterpenes (primarily

p-cymene) contributed only 0.2%, while acyclic monoterpenes such as myrcene were detected in trace amounts (0.1%).
The compositional pattern observed in the Llogara *S. officinalis* samples aligns closely with previous findings reported for sage essential oils from other regions of the Balkans and the broader Mediterranean basin (Khedher et al., 2017; Oniga et al., 2010; Damyanova et al., 2016; Miguel et al., 2011; Bernotienė et al., 2007; Awen et al., 2011; Perry et al., 1999). These similarities suggest a stable chemotype characterized by the predominance of oxygenated monoterpenoids, particularly thujones and camphor, typical of Mediterranean *S. officinalis* populations.

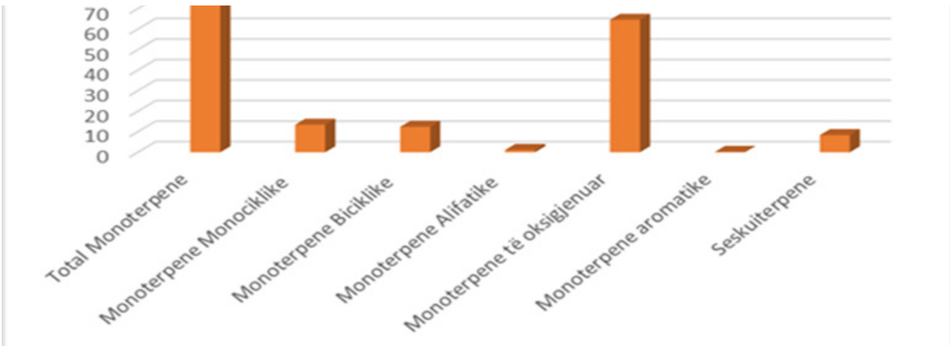


Figure 14. Terpene profile of sage essence

5. Origanum vulgare L. from the Llogara Area

Origanum vulgare L. (oregano) is a perennial aromatic herb belonging to the family Lamiaceae, native to the Mediterranean region and widely distributed throughout Albania. The species typically grows on dry, well-drained soils within a pH range of 6.0–9.0 and thrives in sunny habitats from lowlands to hilly and sub-mountainous zones. Mature plants reach 20–80 cm in height and bear opposite leaves measuring 1–4 cm in length. The inflorescences consist of compact terminal spikes of small purple flowers, approximately 3–4 mm long.
Oregano has been extensively used for centuries in both traditional medicine and as a culinary spice. Its essential oil possesses significant pharmacological and biological properties, which have been widely investigated. Numerous studies have demonstrated its antimicrobial, antifungal, antibacterial, and insecticidal activities, making it valuable for applications in pharmacology, clinical microbiology, phytopathology, and food preservation (Daferera et al., 2000).
The biological activity of *O. vulgare* is primarily attributed to its high content of monoterpenoid phenols, notably carvacrol and p-cymene, as well as other oxygenated and hydrocarbon terpenes. These compounds exhibit strong antimicrobial and antioxidant effects, which contribute to the therapeutic potential of oregano essential oil. Traditionally, preparations of *O. vulgare* herb have been used both internally—as herbal teas—and externally in ointments or infusions for the treatment of

gastrointestinal, respiratory, and nervous system disorders.

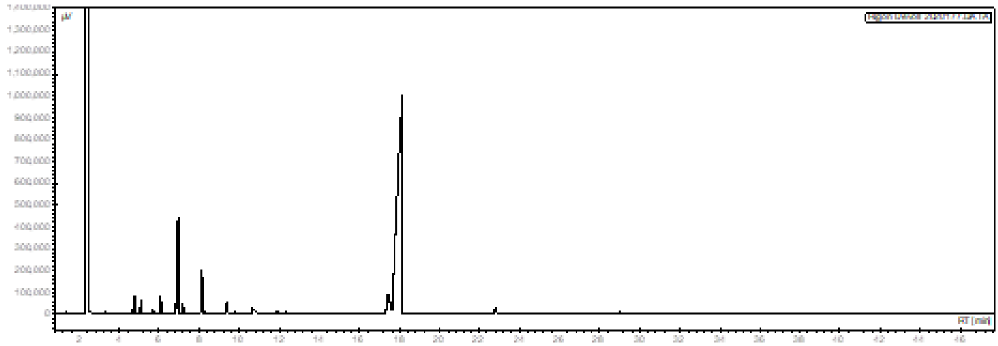


Figure 15. Chromatograms of the oregano essential oil for Pogradeci sample

5.1 Chemical Composition of Origanum vulgare Essential Oil

Oregano (*Origanum vulgare* L.) is one of the most widely used aromatic and medicinal plants in traditional medicine and Albanian cuisine. It is also among the most broadly distributed species in the Mediterranean region, which represents the primary global source of oregano essential oil. Several *Origanum* species grow naturally in Albania, but *O. vulgare* is the most prevalent and economically significant.

In this study, 15 samples of *O. vulgare* were collected from southern Albania, specifically from the regions of Devoll, Ersekë, Leskovik, Përmet, Tepelenë, and Gjirokastër, during June 2021. The essential oils obtained from these samples were analyzed using gas chromatography with flame ionization detection (GC/FID). Chromatographic analysis revealed the presence of 45–60 individual compounds per sample.

Quantitative evaluation identified 19 major constituents, which collectively accounted for 95.8–98.9% of the total detected components. Peak areas were expressed as relative percentages of the total chromatogram, excluding the solvent peak (toluene) used for sample dilution. Compounds with relative abundances below 0.05% were excluded from the statistical analysis.

The compositional pattern of the oregano essential oils was consistent with previous findings reported for Mediterranean and Balkan populations of *O. vulgare* (Daferera et al., 2000; Dadalioglu & Evrendilek, 2004; Teixeira et al., 2013; Kula et al., 2013; Russo et al., 1999).

Table 2. Essential oil data on Origanum vulgare samples from Llogara area

Terpene's\Stations	Mean	Min	Max	STDEV
alpha-Pinene	0.669	0.470	1.200	0.250
Camphene	0.537	0.240	0.780	0.207
beta-Pinene	1.329	0.220	3.090	0.923
Myrcene	0.647	0.420	0.870	0.186

Limonene	0.971	0.000	2.560	0.892
alpha-Terpinene	1.156	0.140	2.170	0.701
para-Cymene	9.490	6.760	13.070	2.118
gamma-Terpinene	1.963	0.970	3.880	1.030
Linalool	1.414	0.150	4.120	1.432
Camphour	0.211	0.020	0.770	0.264
Borneol	0.416	0.000	0.940	0.362
Terpinen-4-ol	0.374	0.000	0.790	0.320
alpha-Terpineol	0.113	0.000	0.320	0.126
Bornil Acetate	0.211	0.000	0.450	0.206
Carvone/Pulegone / Citroneol	1.224	0.520	2.560	0.723
Thymol	3.166	2.050	4.230	0.994
Carvacrol	72.109	61.590	76.580	5.002
beta-Cariophyllene	1.379	0.910	2.070	0.493
alpha-Humulene	0.267	0.120	0.480	0.124
Total 97.644		95.810	98.870	1.214

5.2 Chemical Composition of Origanum vulgare Essential Oil

The relative composition of *Origanum vulgare* essential oils collected from the Llogara area is summarized in Table 2. The reported values represent the mean percentages of the compounds identified in replicate samples from the same collection sites. The essential oil compositions of all analyzed samples exhibited similar qualitative profiles, indicating a consistent chemotype likely influenced by comparable environmental and genetic factors.

The principal constituents identified across all samples were carvacrol, thymol, p-cymene, γ-terpinene, and β-caryophyllene. The predominant compound was carvacrol (72.1%), followed by p-cymene (9.5%), thymol (3.2%), γ-terpinene (2.0%), linalool (1.4%), β-caryophyllene (1.4%), β-pinene (1.3%), and α-terpinene (1.2%). All remaining components were present in amounts below 1%. Among the major constituents, p-cymene reached up to 13.1%, while thymol was found up to 4.2%. Minor variations in composition among sampling locations are attributed to microclimatic and edaphic factors such as relative humidity, temperature, solar radiation, altitude, and soil characteristics.

The sum of phenolic monoterpenes (carvacrol and thymol) ranged between 64.3% and 79.8%, confirming that *O. vulgare* essential oil from this region belongs to the phenolic chemotype, characterized by high concentrations of phenolic monoterpenoids and relatively lower proportions of ketones and sesquiterpenes.

The monocyclic monoterpenes (α-terpinene, limonene, and γ-terpinene) constituted

2.8–6.4% of the total oil, while the bicyclic monoterpenes (α-pinene, camphene, and β-pinene) ranged from 1.5–4.0%. Oxygenated monoterpenes (linalool, camphor, borneol, terpinen-4-ol, α-terpineol, pulegone, carvone, citronellol, and bornyl acetate) represented 1.6–7.7%. The aliphatic monoterpene myrcene was present in trace quantities (0.4–0.9%). Sesquiterpenes, primarily β-caryophyllene and α-humulene, were detected in low concentrations ranging from 1.3–2.2%.

Overall, the high percentage of phenolic constituents and the relatively stable distribution of other terpene groups indicate that the chemical composition of *O. vulgare* essential oil from Llogara is characteristic of Mediterranean oregano, consistent with findings from other regions of southern Albania and the wider Balkan Peninsula. Environmental parameters, particularly altitude, soil composition, and climatic variation, appear to play a significant role in modulating the biosynthesis and accumulation of these secondary metabolites.

6. Conclusion

The present study investigated the chemical composition of essential oils obtained from *Salvia officinalis* L. and *Origanum vulgare* L. collected in the Llogara region of southern Albania, an area characterized by rich biodiversity and favorable climatic conditions for aromatic and medicinal plants.

Salvia officinalis

S. officinalis is one of the most economically important medicinal plants in Albania, both naturally distributed and cultivated across the country. GC/FID analyzed four representative samples of sage collected from Llogara Mountain in June 2025. The dominant components identified were α- and β-thujone, camphor, 1,8-cineole, camphene, α-humulene, and β-caryophyllene, with α- and β-thujones collectively accounting for 43.2% of the total composition. The essential oil was dominated by monoterpenes, particularly oxygenated terpenoids, which represented the largest chemical group.

Minor quantitative variations between samples were attributed to environmental factors, including altitude, humidity, temperature, and soil composition. The overall chemical profile of *S. officinalis* essential oil from the Llogara region was consistent with previously reported data for sage populations from other parts of the Balkan and Mediterranean regions, indicating a stable chemotype typical of Mediterranean sage.

Origanum vulgare

Fifteen samples of *O. vulgare* collected from several sites within the Llogara area were analyzed using gas chromatography with flame ionization detection (GC/FID). A total of 19 major constituents, representing 95.8–98.9% of the total composition, were identified. The essential oils were rich in phenolic monoterpenes, with carvacrol (72.1%), p-cymene (9.5%), thymol (3.2%), and β-caryophyllene (1.4%) as the predominant components.

The compositional uniformity observed among samples indicates a single dominant chemotype across the studied sites. Variations in compound abundance were minor and primarily related to microclimatic and edaphic factors, particularly altitude, soil geology, and temperature gradients. The chemical profiles of the *O. vulgare* essential oils from southern Albania closely matched those reported for oregano from other Mediterranean and Balkan regions, confirming the regional consistency of this phenolic chemotype.

Overall, the findings demonstrate that both *Salvia officinalis* and *Origanum vulgare* from southern Albania exhibit chemical compositions typical of Mediterranean populations. The essential oils are characterized by high concentrations of bioactive monoterpenoids, particularly oxygenated and phenolic constituents such as thujones, camphor, carvacrol, and thymol. These results highlight the significant potential of Albania's native flora as a source of pharmacologically valuable essential oils, supporting their continued economic and therapeutic importance in both domestic and international markets.

7. Significance of the Findings

The present findings highlight the rich chemical composition of *Salvia officinalis* and *Origanum vulgare* grown in the Llogara region of southern Albania and confirm their close similarity to typical Mediterranean chemotypes. In sage, the major constituents were α- and β-thujone, camphor, and 1,8-cineole, while the essential oil of oregano was dominated by carvacrol, p-cymene, and thymol. These compounds are primarily responsible for the plants' characteristic aroma and their documented antimicrobial, antiseptic, and antioxidant activities.

From a scientific perspective, this study contributes valuable data on the natural chemical variability of essential oils in Mediterranean flora. The results provide a reference framework for future pharmacological, biochemical, and biotechnological investigations focused on bioactive terpenoid compounds.

From a practical standpoint, the findings emphasize the economic and industrial potential of Llogara's aromatic and medicinal plants. The demonstrated chemical consistency and high-quality essential oil profiles support their cultivation, standardization, and commercial exploitation, particularly for Albania's export market in medicinal and aromatic plant products.

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