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ANTIMICROBIAL ACTIVITY OF *SALVIA ROSMARINUS* SPENN. INTRODUCED UNDER ABSHERON CONDITIONS AGAINST THE PRINCIPAL ETIOLOGICAL AGENTS OF SCALP DERMATOSES

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Abstract

This study investigates the antimicrobial activity of *Salvia rosmarinus* Spenn. cultivated under the conditions of the Absheron peninsula against pathogens associated with scalp dermatoses. The relevance of the research is driven by the high prevalence of these conditions and the increasing antimicrobial resistance of pathogens.

The aim of the study was to comparatively evaluate the antimicrobial activity of essential oil and hydroalcoholic extracts obtained from aerial and underground parts of the plant. Clinical isolates from 78 patients, along with reference strains *Staphylococcus aureus* ATCC 29213 and *Candida albicans* ATCC 10231, were used. Antimicrobial activity was assessed using the disk diffusion method and determination of minimum inhibitory concentration (MIC).

The essential oil, rich in 1,8-cineole and α -pinene, demonstrated the highest antimicrobial activity (MIC 0.5–1.25%). Aerial part extracts showed moderate activity, while root extracts exhibited weak effects. Similar patterns were observed against dermatophytes and yeast-like fungi.

The obtained data confirm the potential of using the essential oil of *Salvia rosmarinus* Spenn. in the development of phytotherapeutic agents for the treatment of infectious dermatoses of the scalp.

Keywords: *Salvia rosmarinus* Spenn, rosemary, antimicrobial activity, essential oil, scalp dermatoses, dermatophytes, phytotherapy

INTRODUCTION

Investigations into the phytochemical composition of *Salvia rosmarinus* Spenn. have demonstrated that different plant organs, including the roots, contribute to the formation of a unified phytocomplex with a broad spectrum of biological activity. Moreover, comprehensive processing of the entire rosemary biomass is regarded as a promising strategy for obtaining biologically active compounds.

Salvia rosmarinus Spenn. (synonym: *Rosmarinus officinalis* L.) is an evergreen aromatic shrub of the family *Lamiaceae*, widely recognized as an essential oil-bearing plant. Under the conditions of the Absheron peninsula, it reaches a height of 1.5–2.0 m. Its leaves are linear and leathery, with prominent essential oil glands. Flowering occurs in May–June and lasts approximately 4–6 weeks, corresponding to the period of maximal



accumulation of secondary metabolites; the flowers are light blue and arranged in false whorls [21].

The biological activity of the essential oil of *S. rosmarinus* is largely attributable to its high content of terpene compounds, the predominant constituents being 1,8-cineole, α -pinene, β -pinene, α -terpinene, linalool, sabinene, and other components [19]. These compounds account for the antioxidant, anti-inflammatory, and antimicrobial properties of the plant [1, 2]. Beyond the essential oil, extracts from both the aerial and underground parts of rosemary are of considerable interest. Extracts derived from the aerial organs (leaves and stems) are characterized by a high content of phenolic compounds, such as rosmarinic acid, carnosic acid, and carnosol. These compounds exhibit pronounced antioxidant activity, inhibit lipid peroxidation, and possess anti-inflammatory properties [1,4]. Rosemary leaf extracts have also been shown to display antimicrobial activity against a broad range of bacterial and fungal pathogens. However, the available data remain fragmentary and require further systematization, particularly with regard to the sensitivity of clinically significant microorganisms to these phytocomponents [20].

Extracts from the underground part (roots) have been investigated to a lesser extent; nevertheless, there is evidence indicating the presence of phenolic acids and other secondary metabolites with antioxidant activity [5]. These compounds are believed to participate in plant adaptation mechanisms under stressful conditions, including abiotic environmental factors [6]. A number of studies have pointed to the potential pharmacological significance of root extracts; however, this field still requires further investigation.

Thus, the biological activity of *S. rosmarinus* is determined not only by its essential oil, but also by a complex of biologically active substances present in extracts of both the aerial and underground parts of the plant, thereby broadening its potential applications in medicine and pharmaceuticals.

Despite the substantial body of research devoted to the antimicrobial properties of the essential oil of *S. rosmarinus* comparative analyses of the activity of different plant parts (aerial and underground) remain insufficiently explored. Data concerning differences in the phytochemical composition of these parts are limited, and their influence on antimicrobial activity against clinical strains isolated from patients with scalp disorders has likewise been inadequately studied. The lack of such investigations is particularly evident in regions with specific climatic and environmental conditions [10]. The city of Baku, a major industrial center of the Caspian region, is characterized by a combination of unfavorable factors, including a dry subtropical climate, high wind activity, and air pollution. Together with the stress-related effects of the urban environment, these conditions may contribute to impairment of the skin barrier

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and to an increased risk of scalp dermatoses.

Accordingly, it appears warranted to investigate the antimicrobial potential of the essential oil, as well as extracts from the aerial and underground parts of *S. rosmarinus* cultivated in the Absheron region of Azerbaijan, against reference and clinical strains of microorganisms associated with scalp diseases. The results obtained may contribute to the development of novel phytotherapeutic agents for the prevention and treatment of these pathologies.

The aim of the study was to evaluate the antimicrobial activity of the essential oil and extracts from the aerial and underground parts of *S. rosmarinus* against the principal microorganisms responsible for scalp diseases.

To achieve this aim, the following objectives were formulated:

- to perform a comparative analysis of the phytochemical composition of the essential oil and the aerial and underground parts of *S. rosmarinus*;
- to isolate and identify the principal microbial strains from clinical specimens obtained from patients with scalp diseases;
- to assess and compare the antimicrobial activity of the essential oil and extracts of the aerial and underground parts against reference strains and clinical isolates;
- to determine the minimum inhibitory concentrations (MICs) and to conduct a comparative evaluation of the efficacy of the different plant fractions.

MATERIALS AND METHODS

The study used aerial (leaves and shoots) and underground (roots) organs of plants introduced and cultivated on the Absheron peninsula (Azerbaijan). Plant material was collected during the flowering stage in the Baku Dendrological Garden. The harvested

raw material was shade-dried at 25–30°C for 10 days under natural ventilation until an air-dry state was achieved. The dried material was then ground in a laboratory mill to a particle size passing through a 2 mm sieve.

The essential oil was isolated from the aerial parts of the plant by hydrodistillation (steam distillation) according to the Ginzburg method.

Aqueous-alcoholic extracts were prepared separately from the aerial and underground parts of the plant by maceration in 70% ethanol. The use of an aqueous-alcoholic solvent ensured efficient extraction of a broad range of biologically active compounds, including phenolic compounds, flavonoids, and organic acids. The study included clinical specimens obtained from 78 patients with scalp diseases. Samples were collected by sterile scraping of the affected skin areas and by hair epilation using sterile instruments.

Microorganisms were identified using microscopic, cultural, and molecular methods. Microscopic examination was performed with a 10–20% potassium hydroxide (KOH) solution. Fungal isolates, including yeasts of the genus *Malassezia* and dermatophytes of the genera *Trichophyton* and *Microsporum*, were identified on the basis of morphological characteristics and further confirmed by polymerase chain reaction (PCR). *Candida albicans* was identified using the germ tube test and cultivation on chromogenic media. *Malassezia* yeasts were cultured on lipid-dependent media (Dixon agar, Leeming-Notman agar) at 32–34°C. Standard reference strains of *Staphylococcus aureus* ATCC 29213 and *C. albicans* ATCC 10231 were used as control test cultures, thereby ensuring reproducibility of the results and comparability with international data in

accordance with the recommendations of the Clinical and Laboratory Standards Institute and the European Committee on Antimicrobial Susceptibility Testing.

Determination of antimicrobial activity.

The antimicrobial activity of the essential oil and extracts was evaluated by the disk diffusion method and by determination of the minimum inhibitory concentration (MIC) using both clinical isolates and reference strains. Prior to testing, the samples were dissolved in 1–5% dimethyl sulfoxide (DMSO). For the disk diffusion assay, microbial suspensions were standardized to 0.5 McFarland ($\approx 1.5 \times 10^8$ CFU/mL for bacteria and $\approx 1.0 \times 10^6$ CFU/mL for fungi) and inoculated onto solid nutrient media (Mueller–Hinton agar and Sabouraud Dextrose Agar). Sterile paper disks (6 mm) were impregnated with the test samples and placed on the agar surface. Incubation was carried out at 37°C for 24 h for bacteria and at 28–30°C for 48–72 h for fungi. The results were assessed by measuring the diameters of growth inhibition zones (mm). The minimum inhibitory concentration was determined by two-fold serial dilutions in liquid nutrient media (Mueller–Hinton broth and Sabouraud broth). The essential oil was pre-dissolved in DMSO to obtain a stock solution with a concentration of 10% (v/v). The final concentration range was 5.0–0.312% (v/v). MIC was defined as the lowest concentration at which visible microbial growth was completely inhibited. Statistical analysis was performed using GraphPad Prism software. Differences between groups were assessed using Student's t-test and were considered statistically significant at $p < 0.005$.

RESULTS AND DISCUSSION:

The content of essential oil obtained from the aerial parts of *S. rosmarinus* was 2.06% of the absolute dry weight of the raw

material, which is consistent with published data for plants cultivated under warm climatic conditions [22–25].

The high content of oxygenated monoterpenes, primarily 1,8-cineole, underlies the pronounced antimicrobial activity of the essential oil through disruption of microbial cell membrane integrity and inhibition of enzymatic systems [19, 26, 29]. Water-alcohol extracts of the aerial organs were characterized by a higher content of phenolic compounds (including rosmarinic acid and flavonoids), whereas the underground organs contained these compounds in smaller quantities, which determined differences in biological activity [30–33].

The observed differences in chemical composition may be associated with the ecological and geographical conditions of the Absheron peninsula, including high insolation and an arid climate, which influence the biosynthesis of secondary metabolites [34–37].

The study included 78 patients with scalp diseases (mean age 34.6 ± 12.3 years), among whom fungal infections predominated, in agreement with current epidemiological data [38–42]. The most frequently identified taxa were representatives of the genera *Malassezia* (41.0%), *Trichophyton* (28.2%), and *Microsporum* (12.8%), as well as *C. albicans* (17.9%).

Polymicrobial associations were identified in 50% of patients, most commonly combinations of fungal and bacterial flora, including *S. aureus*, indicating the complex nature of scalp infections and the need for an integrated therapeutic approach [38, 42–45].

The antimicrobial activity of the tested samples was assessed against the reference strains *S. aureus* ATCC 29213

and *C. albicans* ATCC 10231 [46]. The essential oil demonstrated pronounced antimicrobial activity: the diameters of growth inhibition zones were 25 mm for *S. aureus* and 20 mm for *C. albicans*, indicating high susceptibility of these microorganisms, as reported in the literature from 2020 to 2026. These data

are comparable to the findings of other studies, in which inhibition zones ranged from 18 to 30 mm [45,47–49] (Table 1). Extracts of the aerial organs exhibited moderate activity, whereas extracts of the underground organs were characterized by weak antimicrobial effects.

Table 1. Antimicrobial activity of *Salvia rosmarinus* Spenn. against reference strains (disk diffusion method)

Microorganism	Essential oil (mm)	Extracts - Aboveground part (mm)	Extracts - Underground part (mm)	DMSO
<i>S. aureus</i> ATCC 29213	22-25	15–18	10–13	5-6
<i>C. albicans</i> ATCC 10231	18-20	14–17	10–12	5-6

The results obtained indicate higher antimicrobial activity in the aerial organs of the plant, which is associated with increased levels of phenolic compounds and flavonoids possessing pronounced antimicrobial properties [50–53].

Investigation of the clinical strains showed that the essential oil exhibited the highest activity among all samples studied. The diameters of inhibition zones ranged from 16 to 25 mm (Table 2).

Table 2. Antimicrobial activity of *Salvia rosmarinus* Spenn. against clinical strains.

Microorganism	Essential oil (mm)	Extracts - aboveground part (mm)	Extracts - belowground part (mm)
<i>S. aureus</i>	22–25	15–18	10–13
<i>C. albicans</i>	18–20	14–17	10–12
<i>Malassezia</i> spp.	18	15	11
<i>Trichophyton</i> spp.	16–17	13–15	10–12
<i>Microsporum</i> spp.	17–18	14–16	11–13

The obtained data demonstrate that antimicrobial activity depends on the type of plant material in the following order: essential oil > aerial parts > underground parts. This pattern is attributable to differences in the accumulation of secondary metabolites in various plant organs and is consistent with contemporary research [54–57].

To quantify antimicrobial activity, the minimum inhibitory concentration (MIC) method was employed.

The essential oil demonstrated the most pronounced activity: the MIC was 0.5% for *S. aureus* and 1.0% for *C. albicans*. For dermatophytes, MIC values ranged from 0.5 to 1.25%, whereas for yeasts they were approximately 1.25%. Extracts obtained from the aerial parts showed moderate

antimicrobial activity (MIC 1.0–2.5%), whereas extracts from the underground parts exhibited weak activity (MIC ≥ 2.0 –2.5%), which may be related to the lower

content of biologically active compounds and the organ-specific features of their distribution [58–61] (Figure 1).

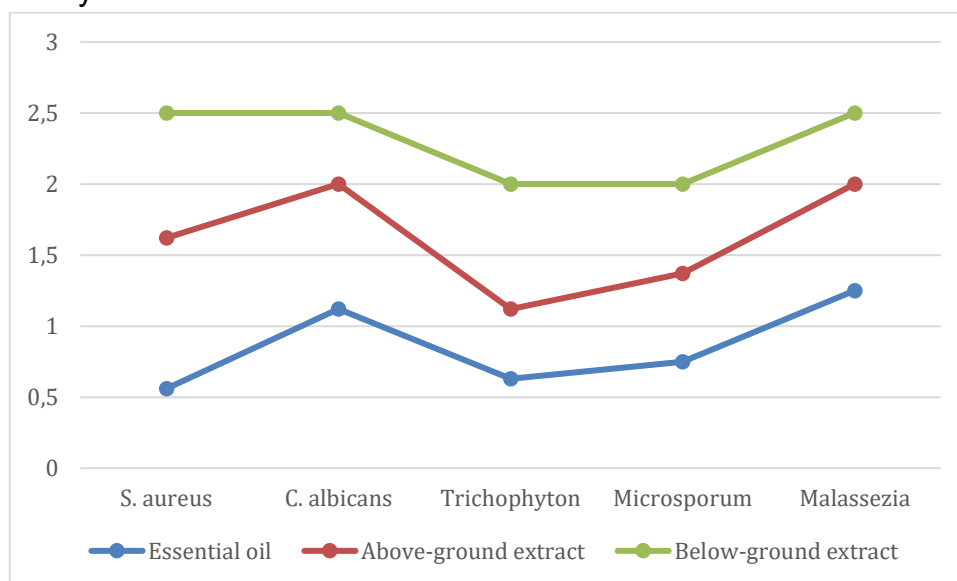


Figure 1. Minimum inhibitory concentrations of *Salvia rosmarinus* Spenn. (MIC)

The high antimicrobial activity of the essential oil is attributable to the presence of monoterpenes (1,8-cineole, α -pinene), which are capable of disrupting cell membrane permeability and inhibiting microbial metabolic processes [62–64].

CONCLUSION.

Thus, the findings of the present study demonstrate that the essential oil of *S. rosmarinus* cultivated in the Absheron region exhibits pronounced antimicrobial activity against both reference and clinical microbial strains, whereas extracts of the aerial parts exert a moderate effect and those of the underground parts only a weak effect. These data confirm the potential applicability of the essential oil in phytotherapeutic and dermatocosmetic formulations intended for the treatment of infectious and inflammatory diseases of the scalp.

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SAÇ DƏRİSİNİN DERMATOZLARININ ƏSAS ETIOLOJİ TÖRƏDİCİLƏRİNƏ QARŞI, ABŞERON ŞƏRAİTİNDƏ İNTRODUKSIYA OLUNMUŞ *SALVIA ROSMARINUS* SPENN. BITKİSİNİN ANTİMİKROB AKTİVLİYİ

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Xülasə

Tədqiqat Abşeron yarımadası şəraitində introduksiya olunmuş *Salvia rosmarinus* Spenn. bitkisinin saç dərisinin dermatozlarının törədicilərinə qarşı antimikrob aktivliyinin öyrənilməsinə həsr edilmişdir. İşin aktuallığı bu xəstəliklərin geniş yayılması və mikroorqanizmlərin ənənəvi antimikrob preparatlara qarşı artan davamlılığı ilə bağlıdır.

Tədqiqatın məqsədi *Salvia rosmarinus* Spenn. bitkisinin efir yağı, həmçinin yerüstü və yeraltı hissələrindən alınmış su-spirit ekstraktlarının antimikrob aktivliyinin müqayisəli qiymətləndirilməsi olmuşdur. Tədqiqat obyektlərini 78 pasiyentdən ayrılmış klinik mikroorqanizm ştammları, eləcə də *Staphylococcus aureus* və *Candida albicans* referent kulturaları təşkil etmişdir, maddələrin aktivliyi isə disk-diffuziya üsulu və minimal inhibəedici konsentrasiyanın (MIC) təyini metodu ilə qiymətləndirilmişdir.

Müəyyən edilmişdir ki, tədqiq olunan efir yağı ən yüksək antimikrob aktivlik göstərmişdir (MIC 0,5–1,25%). Yerüstü hissələrin ekstraktları orta dərəcədə təsir göstərdiyi halda, yeraltı hissələr zəif aktivlik nümayiş etdirmişdir. Oxşar nəticələr dermatofitlər və mayayabənzər göbələklər üçün də müşahidə edilmişdir.

Əldə edilmiş nəticələr *Salvia rosmarinus* Spenn. efir yağının saç dərisinin infeksiya dermatozlarının müalicəsi üçün fitoterapevtik vasitələrin hazırlanmasında perspektivli olduğunu təsdiqləyir.

Açar sözlər: *Salvia rosmarinus* Spenn., rozmarin, antimikrob aktivlik, efir yağı, saç dərisinin dermatozları, dermatofitlər, fitoterapiya

АНТИМИКРОБНАЯ АКТИВНОСТЬ SALVIA ROSMARINUS SPENN. ИНТРОДУЦИРОВАННОГО В УСЛОВИЯХ АПШЕРОНА, ПРОТИВ ОСНОВНЫХ ЭТИОЛОГИЧЕСКИХ ВОЗБУДИТЕЛЕЙ ДЕРМАТОЗОВ КОЖИ ГОЛОВЫ

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Резюме

Исследование посвящено изучению антимикробной активности *Salvia rosmarinus* Spenn., культивируемого в условиях Апшеронского полуострова, в отношении возбудителей дерматозов волосистой части головы. Актуальность работы обусловлена высокой распространённостью данных заболеваний и ростом устойчивости микроорганизмов к традиционным противомикробным препаратам.

Целью исследования являлась сравнительная оценка антимикробной активности эфирного масла и водно-спиртовых экстрактов надземной и подземной частей растения. Объектами исследования служили клинические штаммы микроорганизмов, выделенные у 78 пациентов, а также референтные культуры *Staphylococcus aureus* и *Candida albicans*. Активность оценивали диско-диффузионным методом и методом определения минимальной ингибирующей концентрации (MIC).

Установлено, что эфирное масло проявляет наиболее выраженную антимикробную активность (MIC 0,5–1,25%). Экстракты надземной части характеризуются умеренным эффектом, тогда как подземные органы демонстрируют слабую активность. Аналогичные результаты получены для дерматофитов и дрожжеподобных грибов.

Полученные данные подтверждают перспективность использования эфирного масла *Salvia rosmarinus* Spenn., в разработке фитотерапевтических средств для лечения инфекционных дерматозов волосистой части головы.

Ключевые слова: *Salvia rosmarinus* Spenn., розмарин лекарственный, антимикробная активность, эфирное масло, дерматозы волосистой части головы, дерматофиты, фитотерапия