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TERPENOID COMPOUNDS OF *ARTEMISIA TERRAE-ALBAE* GROWING IN THE TURKESTAN REGION OF THE KAZAKHSTAN

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Abstract. This research work was aimed at a comprehensive assessment of the chemical composition and biological activity of the ethanol extract of *Artemisia terrae-albae* Krasch. The obtained extract was studied using IR and GC–MS analysis methods. IR spectroscopic analysis of the extract confirmed the presence of terpenoid compounds in it. Absorption bands characteristic of terpenoid compounds belonging to hydroxyl (–OH) groups, carbonyl (C=O) groups, and unsaturated C=C bonds were observed. As a result of the analysis by GC-MS method, a total of 46 components were identified in the studied extract. From the identified components, 17 compounds were classified as terpenoids, the total amount of which was 36.96% of the total chemical composition of the extract. In the structure of the terpenoid fraction, 8 compounds were identified as monoterpenes (17.39% of the total composition), and another 8 compounds were identified as sesquiterpenes (17.39%). One triterpenoid - ursolic acid - was identified in the amount of 2.17%. In addition, an analysis of the distribution of compounds in the group of terpenoids was carried out. It was established that monoterpenes make up 47%, sesquiterpenes - 47%, and triterpenes - 6% in the terpenoid fraction.

The extract showed moderate activity against gram-positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*), and the effect on gram-negative bacteria was weak. A weak fungistatic effect was recorded against the *Candida albicans* strain. The toxicity level was determined using the *Artemia salina* bioassay, and the LD_{50} value was 90.6 µg/ml, indicating a relatively low toxicity of the extract.

The results obtained indicate that the studied sample is rich in terpene components and can serve as a basis for further studies of their biological activity and pharmacological potential. The relatively high content of terpenes proves the importance of the studied raw material as a source of natural biologically active substances.

Keywords: *Artemisia terrae-albae*, terpenoid compounds, GC-MC, IR-spectroscopy, antimicrobial activity, cytotoxicity

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ҚАЗАҚСТАННЫҢ ТҮРКІСТАН ӨҢІРІНДЕ ӨСЕТІН *ARTEMISIA TERRAE-ALBAE* ТЕРПЕНОИДТЫ ҚОСЫЛЫСТАРЫ

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Аннотация. Бұл зерттеу жұмысы *Artemisia terrae-albae* Krasch. өсімдігінің этанолды сығындысының химиялық құрамын және биологиялық белсенділігін кешенді бағалауға бағытталды. Алынған сығынды ИҚ-спектроскопия және ГХ–

МС талдау тәсілдері арқылы зерттелді. Сығындының ИҚ-спектроскопиялық талдауы оның құрамында терпеноидты қосылыстардың бар екендігін растады. Терпеноидты қосылыстарға тән гидроксил (–OH) топтарына, карбонил (C=O) тобына, қанықпаған C=C байланыстарына тиесілі жұтылу жолақтар байқалды. ГХ-МС талдауы нәтижесінде зерттелген сығындының құрамында барлығы 46 компонент анықталды. Анықталған компоненттердің ішінде 17 қосылыс терпеноидтар ретінде жіктелді, олардың жалпы мөлшері сығындының жалпы химиялық құрамының 36,96%-ын құрады. Терпеноид фракциясының құрылымында 8 қосылыс монотерпендер (жалпы құрамның 17,39%-ы), тағы 8 қосылыс сесквитерпендер (17,39%) ретінде анықталды. Бір тритерпеноид - урсол қышқылы - 2,17% мөлшерінде анықталды. Сонымен қатар, терпеноидтар тобындағы қосылыстардың таралуына талдау жүргізілді. Терпеноидтар фракциясында монотерпендер 47%, сесквитерпендер 47% және тритерпендер 6% құрайтыны анықталды.

Сығынды грамоң бактерияларға қатысты орташа деңгейде белсенділік көрсетті *(Staphylococcus aureus, Bacillus subtilis),* ал грамтеріс бактерияларға әсері әлсіз болды. *Candida albicans* штамына қарсы әлсіз фунгистатикалық әсер тіркелді. Уыттылық деңгейі *Artemia salina* биотесті арқылы анықталып, LD_{50} мәні 90,6 мкг/мл құрады, бұл сығындының салыстырмалы түрде төмен уыттылығын көрсетеді.

Алынған нәтижелер зерттелген үлгінің терпендік компоненттерге бай екенін көрсетеді және олардың биологиялық белсенділігі мен фармакологиялық әлеуетін әрі қарай зерттеуге негіз бола алады. Терпендердің салыстырмалы жоғары үлесі зерттелетін шикізаттың табиғи биологиялық белсенді заттар көзі ретіндегі маңыздылығын дәлелдейді.

Түйін сөздер: *Artemisia terrae-albae*, терпеноидты қосылыстар, ГХ-МС, ИҚ-спектроскопия, антимикробтық белсенділік, цитоуыттылық

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ТЕРПЕНОИДНЫЕ СОЕДИНЕНИЯ *ARTEMISIA TERRAE-ALBAE*, ПРОИЗРАСТАЮЩЕГО В ТУРКЕСТАНСКОМ РЕГИОНЕ КАЗАХСТАНА

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Аннотация. Настоящая работа посвящена комплексному исследованию химического состава и биологической активности этанольного экстракта *Artemisia terrae-albae* Krasch. Полученный экстракт исследовали с помощью ИК-спектроскопии и ГХ-МС анализа. ИК-спектроскопический анализ экстракта подтвердил наличие в нем терпеноидных соединений. Наблюдались полосы поглощения, характерные для терпеноидных соединений, принадлежащие гидроксильным (–OH) группам, карбонильным (C=O) группам и ненасыщенным связям C=C. В результате анализа методом ГХ-МС в составе исследуемого экстракта было идентифицировано в общей сложности 46 компонентов. Из идентифицированных компонентов 17 соединений были классифицированы как терпеноиды, общее количество которых составило 36,96% от общего химического состава экстракта. В структуре терпеноидной фракции 8 соединений были идентифицированы как монотерпены (17,39% от общего состава), еще 8 соединений - как сесквитерпены (17,39%). Один тритерпеноид - урсоловая кислота — был идентифицирован в количестве 2,17%. Кроме того, был проведен анализ распределения соединений в группе терпеноидов. Было установлено, что монотерпены составляют 47%, сесквитерпены - 47%, а тритерпены - 6% в терпеноидной фракции.

Экстракт показал умеренную активность против грамположительных бактерий (*Staphylococcus aureus*, *Bacillus subtilis*), а эффект на грамотрицательные бактерии был слабым. Слабый фунгистатический эффект был зафиксирован против штамма *Candida albicans*. Уровень токсичности определяли с помощью биотеста на *Artemia salina*, и значение LD_{50} составило 90,6 мкг/мл, что указывает на относительно низкую токсичность экстракта.

Полученные результаты свидетельствуют о том, что исследуемый образец богат терпеновыми компонентами и может служить основой для дальнейших исследований его биологической активности и фармакологического потенциала. Относительно высокое содержание терпенов подтверждает важность исследуемого сырья как источника природных биологически активных веществ.

Ключевые слова: *Artemisia terrae-albae*, терпеноидные соединения, ГХ-МС, ИК- спектроскопия, антимикробная активность, цитотоксичность

Introduction. One of the most widespread medicinal plants in Kazakhstan is the genus *Artemisia* L. a species-rich and taxonomically complex genus of dicotyledonous plants belonging to the family *Asteraceae* L. Plants of the genus *Artemisia* are widely used in various traditional and folk medicine systems and are well known for their medicinal properties in the treatment of fever, malaria, inflammation, ulcers, diabetes, and intestinal parasites. This genus includes more than 500 perennial, biennial, and annual herbaceous plants and small shrubs growing in temperate regions of Europe, Asia, and North America (Nigam et al., 2019). 81 species of this genus grow in Kazakhstan, including 19 described as endemic.

In traditional folk medicine, *Artemisia* species have been used to reduce fever, have antiseptic effects, fight intestinal worms, stimulate the body, induce urination, and relieve abdominal pain (Ksibi et al., 2022). In traditional Central Asian medicine, infusions of *Artemisia* flowers are used to treat various diseases such as ulcerative colitis, appendicitis, hemorrhoids, bad breath, epilepsy, and many others (Koul et al., 2018). The *Artemisia* genus is characterized by a variety of biologically active substances. Studies have shown that the plant species belonging to the *Artemisia* genus contain various biologically active substances, such as lignans, sesquiterpenoids, flavonoids, coumarins, glycosides, acids, and sterols (Jalmakhanbetova et al., 2007, 2021; Trifan et al., 2022). One of the main compounds characteristic of wormwood plants is terpenes, including sesquiterpene lactones, which have a diverse chemical structure and a broad spectrum of pharmacological activities. These compounds have been shown to have anticancer, antimalarial, and anti-inflammatory properties, as well as to accelerate wound healing, and to have antibacterial, antifungal, and antiviral activities (Ivanescu et al., 2015; Wang et al., 2023).

Plants belonging to the genus *Artemisia* are of great economic and medical importance. This is because the terpenoid compound, terpenoid sesquiterpene lactone artemisinin, isolated from *Artemisia annua L.*, is recognized as the main active ingredient against malaria. This discovery has increased the interest of scientists around the world in finding new biologically active drugs through the study of traditional medicinal plants (Zaman et al., 2021). In traditional Russian medicine, tinctures from the roots and leaves of the *Artemisia* plant are widely used to treat liver, stomach, and spleen diseases. A solution of fresh wormwood juice mixed with diluted ethanol is used for insomnia and kidney stones, as well as as an anti-inflammatory agent (European Scientific Cooperative on Phytotherapy 2003; Abad et al., 2012). In Kazakhstan, tinctures prepared from the aerial parts of this plant have been used in folk medicine to treat stomach ulcers, appendicitis, hemorrhoids, bad breath, and epilepsy. Wormwood is used in the food industry as a spice to give a special taste to fatty foods. It is also used to add flavor to some alcoholic beverages and wines (Krebs et al., 2010). The aerial parts of the plant are also a valuable source of raw materials in the paint industry (Wu et al, 2020).

A. terrae-albae Krasch. is a poorly studied plant, but is of great interest due to its use in folk medicine. *A. terrae-albae* is a semi-shrub plant that grows in the semi-desert and steppe regions of Kazakhstan. In folk medicine of Central Asia and Eastern Europe, *A. terrae-albae* is widely used in the treatment of skin diseases such as dermatitis, eczema, psoriasis, as well as for inflammation, wounds and burns (Turuspekov et al, 2018; Sagyndykova et al., 2024).

The essential oil of *A. terrae-albae*, a plant distributed in Central Asia, is characterized mainly by oxygenated monoterpenes (Sampietro et al, 2016). The dominant component in its composition is camphor (47.3%). In addition, 1,8-cineole (23.9%), camphene (9.8%) and β-thujone (6.0%) were detected. α-Pinene is also present, but its amount is not specified. The chemical composition of the essential oil is characterized by the predominant content of camphor and 1,8-cineole, which determines its biologically active properties.

A number of studies have investigated the chemical composition, biological activity and ecological significance of the plant *A. terrae-albae*. Dyusebaeva and colleagues (Dyusebaeva et al., 2024) determined the macro- and microelement composition, amino acids and fatty acids of the aboveground part of the plant and showed that it is dominated by calcium, magnesium, sodium elements, as well as oleic, linoleic and palmitic acids. These data prove that the plant has nutritional and physiological activity.

In recent years, extracts of the *A. terrae-albae* plant have been used as biogenic reducing agents in the field of nanotechnology. In the conducted studies, silver nanoparticles were obtained by the green synthesis method using the ethanol extract of the plant and their cytogenic toxicity was evaluated. As a result, it was found that the obtained nanoparticles have a pronounced antiproliferative effect, inhibiting cell division (Zhumanova et al., 2023).

In a similar study (Dyusebaeva et al., 2025), the antimicrobial activity of silver nanoparticles stabilized with a lipophilic extract of the plant *A. terrae-albae* was evaluated. The resulting nanoparticles showed activity against microorganisms such as *S. aureus*, *E. coli*, *P. aeruginosa*, and *C. albicans.*

The aim of this research work is to identify terpene compounds in the ethanol extract of *A. terrae-albae,* which grows in the Khantagy Ridge area of Turkestan region, and to characterize their structural features. Determining the chemical composition of terpene compounds of *A. terrae-albae* and studying their relationship with biological activity is an important scientific task for the modern field of phytochemistry and pharmacognosy.

Materials and methods. Plant material. The above-ground part of *Artemisia terrae-albae* Krasch. was collected in July 2024 from the Khantagy Ridge area of Turkestan region. The collected plant material was air-dried in the shade. The dried plant was crushed and stored. Only the above-ground part of the plant was used for research.

Extraction of raw. An ethanol solvent was used to obtain an extract of the crushed and pre-dried aerial part of *A. terrae-albae.* 20 g of dry raw material was extracted twice with ethyl alcohol (ratio 1:10, w/v). Each extraction was carried out with boiling for 2 hours. The resulting extracts were combined and evaporated in a rotary evaporator. As a result, a dark green extract was obtained. Yield – 4.015 g (20 % relative to air-dried raw material).

GC Conditions. Gas chromatography–mass spectrometry was used to determine the composition of the ethanol extract of *A. terrae-albae.* The analysis was carried out on an Agilent 7890A gas chromatograph system and a 5975C Mass Selective Detector

(Agilent Technologies, USA). The analysis was carried out under the following conditions*:* column type – Rtx-100DHA, column length – 30 m; column diameter – 0.25 mm; adsorbent layer thickness in the column – 0.5 μm; evaporator temperature – 280 °C; column temperature – 60–300 °C; column heating rate – 8 °C/min; ion source temperature – 230 °C; quadrupole condenser temperature – 150 °C; EI^- = 70 eV; carrier gas – helium grade A; gas pressure in the column – 2 psi; sample volume – 0.2 μl; injection mode – flow splitting (split 20:1); mass spectrum recording mode – scan; library – NIST 08; analysis time – 32 minutes.

The percentage of component composition was automatically calculated using the GS-MSD Data Analysis program based on the peak areas of the total ion chromatogram, and identification was performed using the NIST 08 library based on mass spectra and retention times.

IR spectroscopy. Infrared spectroscopic analysis was performed to conduct a primary screening of terpene compounds in the ethanol extract of *A. terrae-albae*. The infrared spectrum was recorded on an IRTracer - 100 spectrometer..

IR spectrum (ν, cm^{-1}): 3600–3200 (broadband), 3075, 3030, 2965, 2925, 2855, 1740, 1650, 1605, 1515, 1460, 1375, 1260, 1215, 1170, 1110, 1050, 1020, 970, 920, 875, 820, 760, 700, 650, 600, 520, 470, 430.

The antimicrobial activity. The antimicrobial activity of the ethanolic extract of *A. terrae-albae* was determined by the serial dilution method. The following microorganisms were used as reference test strains for the analysis: gram-positive bacteria: *S. aureus* ATCC 6538, *B. subtilis* ATCC 6633; gram-negative bacteria: *E. coli* ATCC 25922, *P. aeruginosa* ATCC 27853; yeast-like fungus: *C. albicans* ATCC 10231. All strains were obtained from the American Type Culture Collection (ATCC). Daily cultures of microorganisms were grown on nutrient agar at 37 °C (for fungi – 30 °C, 48 h). The antimicrobial activity of the extracts was studied in the concentration range of 1.56–50 μg/ml.

Each sample was incubated with 0.1 ml of microbial suspension (10^6 CFU/ml). The incubation process was carried out in a thermostat at 37 °C for *24–48* hours, depending on the type of microorganism. The minimum inhibitory concentration (MIC) was determined as the lowest concentration at which turbidity was observed. The study was performed in triplicate. Ceftriaxone (antibacterial drug) and nystatin (antifungal drug) were used as controls for comparison.

The cytotoxicity. The cytotoxic activity of ethanolic extract of *A. terrae-albae* was evaluated in vitro by its effect on the larvae of the brine shrimp *A. salina* (Leach). The study was carried out according to the method of B. N. Meyer et al. (Planta Medica, 1982). For the experiment, *A. salina* eggs were placed in artificial seawater and incubated for 48 hours at 37 °C. The 2-day-old larvae (nauplii) obtained in this way were used as samples. A 2 mg sample of the extract under study was dissolved in 2 ml of ethanol and subsequently diluted accordingly to obtain concentrations of 100, 10 and 1 μg/ml. Each concentration was prepared in triplicate. Ten *A. salina* larvae were introduced into each vial. After complete evaporation of the ethanol, 5 ml of artificial seawater was added to each vial. All samples were incubated at room temperature in the light for 24 hours.

After incubation, live and dead larvae were counted and the lethal dose (LD_{50}, μg/ml) was calculated based on the percentage of death. An equivolume solution of dimethyl sulfoxide (DMSO) was used as a control sample, and dactinomycin (actinomycin D) was used as a reference drug. The results were performed in triplicate and statistically processed using the FIN program.

Results. In the IR spectrum of the dry extract of *A. terrae-albae,* a broad absorption band corresponding to the stretching vibrations of hydroxyl groups (–OH) was observed in the region of 3400 cm^{-1}. The peaks in the range of 2920–2850 cm^{-1} indicate the vibrations of the C–H bonds of aliphatic groups. The intense band in the region of 1730–1700 cm^{-1} is characteristic of the C=O bonds of carbonyl compounds (acids, esters). Absorption bands in the range of 1620–1600 cm^{-1} correspond to C=C bonds. In the range of 1250–1050 cm^{-1}, C–O vibrations characteristic of alcohols, ethers, and esters were observed. These spectral data prove the presence of functional groups characteristic of terpenoid compounds in the extract.

GC–MS analysis revealed a multicomponent chemical composition of the ethanol extract of *A. terrae-albae*. Several distinct peaks were observed in the chromatogram, the highest intensity of which was observed at a retention time of 26.411 min, indicating that this compound was present in the majority. Peaks at early retention times correspond to monoterpenes, while peaks at 15–30 min correspond to sesquiterpenes and triterpenoids. A high concentration of terpene compounds was observed between 25–28 min (Figure 1).

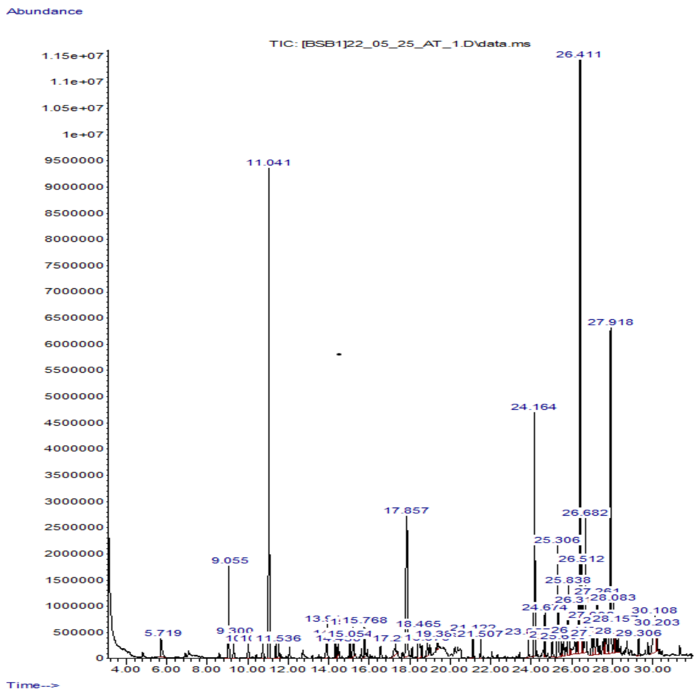
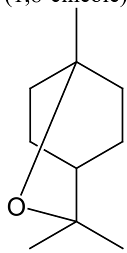
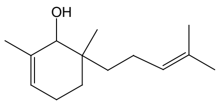
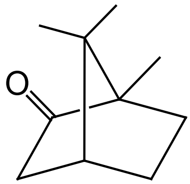
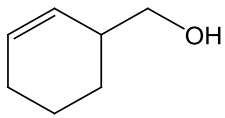
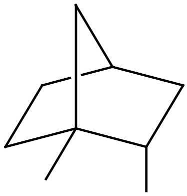
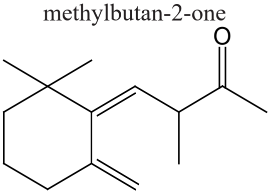
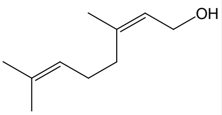
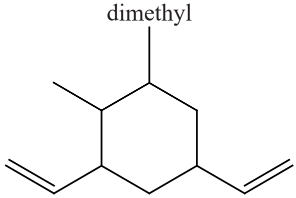
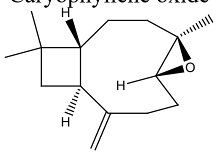
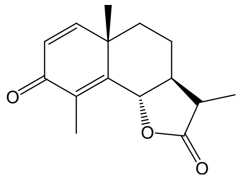
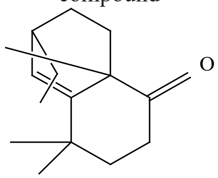
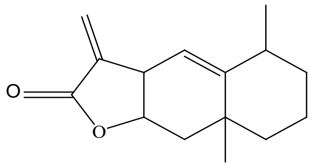
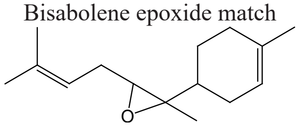
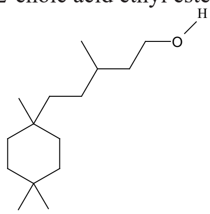
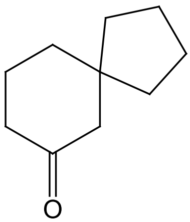
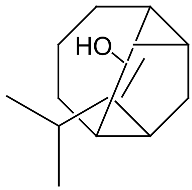
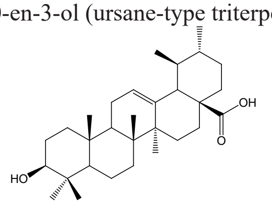


Figure 1. GC/MS chromatogram of *A. terrae-albae* extract collected in the Turkistan region of Kazakhstan.

A total of 46 different organic compounds were identified as a result of gas chromatography–mass spectrometry analysis of the ethanol extract of *A. terrae-albae* (Figure 1). Analysis of the component composition revealed the presence of 17 terpenoid compounds with monoterpene, sesquiterpene and triterpene structures (Table 1).

Table 1. Terpenoids compounds of *A. terrae-albae* extract.

Monoterpenes			
Compound	**Structural features**	**Compound**	**Structural features**
1	2	3	4
Eucalyptol (1,8-cineole) 	Monoterpene oxide -Bicyclic ether, Contains an internal oxygen bridge (ether linkage), Fully saturated carbon skeleton.	2-Cyclohexene-1-methanol, 2,6-dimethyl-6-(4-methyl-3-pentenyl) 	Monoterpene oxide -Composed of two isoprene units Monocyclic hydrocarbon structure Contains two vinyl (ethenyl) groups (C=C)
Camphor-type bicyclic monoterpene 	Monoterpene ketone -Bicyclic bornane skeleton, Contains a ketone group, Rigid, saturated structure.	2-Cyclohexene-1-methanol 	Monoterpene oxide -Monocyclic Structure, One double bond, One hydroxyl group.
Borneol (Bicyclo[2.2.1] heptan-2-ol, 1,7,7-trimethyl-) 	Monoterpene alcohol -Bicyclic bornane skeleton, Saturated carbon framework.	4-(2,2-Dimethyl-6-methylenecyclohexylidene)-3-methylbutan-2-one 	Monoterpene oxide -Built from two isoprene units Monocyclic structure Contains a ketone group
Linalool / Geraniol family (2,6-Octadien-1-ol, 3,7-dimethyl-) 	Monoterpene alcohol -Acyclic monoterpene alcohol, Contains two double bonds, One hydroxyl group, Built from two isoprene units	Cyclohexane, 1,5-diethenyl-2,3-dimethyl 	Monoterpene alcohol -Derived from three isoprene units

1	2	3	4
Sesquiterpenes			
Caryophyllene oxide 	Sesquiterpene oxide -Derived from three isoprene units Bicyclic structure Contains an epoxide ring (three-membered cyclic ether)	α-Santonin 	Sesquiterpene lactone -Bicyclic structure Contains a lactone ring, Multiple double bonds
Neoisolongifolene-8-oxo-type compound 	Sesquiterpene oxide -Tricyclic frame-work Ketone functionality Longifolene-type sesquiterpene structure.	Eudesma-5,11(13)-dien-8,12-olide 	Sesquiterpene lactone Eudesmane-type skeleton Lactone functional group
Bisabolene epoxide match 	Sesquiterpene oxide -Mono- or acyclic framework, Contains an epoxide ring	3-Methyl-5-(1,4,4-trimethylcyclohex-2-enyl)-pent 2-enoic acid ethyl ester 	Sesquiterpene oxide -Built from three isoprene units Contains a cyclohexene ring
Spiro[4.5]decan-7-one, epoxy-derivative 	Sesquiterpene oxide Spiro structure (two rings sharing one carbon atom).	3-Isopropyl-tricyclo[4.3.1.1(2,5)]undec-3-en-10-one 	Sesquiterpene oxide -It contains a 15-carbon skeleton (C_{15}). Sesquiterpenes are composed of three isoprene units ($C_5 \times 3$).
Triterpenes (C_{30})			
Urs-20-en-3-ol (ursane-type triterpenoid) 		Triterpenes (C_{30}) -Pentacyclic (five-ring) structure Ursane-type triterpenoid skeleton One hydroxyl group at C-3 One double bond at C-20.	

Among them, the main components were 2-Cyclohexene-1-methanol, 2,6-dimethyl-6-(4-methyl-3-pentenyl)- (17.33%), Bicyclo[2.2.1]heptan-2-one, 1,7,7-trimethyl-

(camphor) (13.19%), Cyclohexane, 1,5-diethenyl-2,3-dimethyl- (9.71%) and Butanoic acid, octyl ester (8.29%). Thus, as a result of gas chromatography-mass spectrometry studies, it was determined that the extract contains monoterpene, sesquiterpene, and triterpene compounds belonging to terpenoid compounds.

According to the results of the study, the ethanolic extract of *A. terrae-albae* showed pronounced antimicrobial activity. The inhibitory effect of the extract against *B. subtilis* ATCC 6633, *E. coli* ATCC 25922 and *C. albicans* ATCC 10231 strains was observed at a concentration of 50 mg/ml. In addition, moderate activity was determined against the *S. aureus* ATCC 6538 strain, the effective concentration was 25 mg/ml. However, the antimicrobial activity of the extract against the *P. aeruginosa* ATCC 27853 strain was not recorded (Table 2).

Thus, the results obtained indicate that the *A. terrae-albae* extract has a pronounced antimicrobial potential against gram-positive bacteria and yeast-like fungi, but its effect on the gram-negative *P. aeruginosa* strain is limited. Overall, these results provide evidence for the antimicrobial properties of biologically active compounds in the extract, including potential terpenoid components.

Table 2. Antimicrobial activity of *A. terrae-albae* extract.

Test substances	*Staphylococcus aureus* ATCC 6538	*Bacillus subtilis* ATCC 6633	*Escherichia coli* ATCC 25922	*Pseudomonas aeruginosa* ATCC 27853	*Candida albicans* ATCC 10231
Extract of *A. terrae-albae*	25	50	50	-	50
Control (ceftriaxone)	6.3	12,5	6,3	12,5	-
Control (nystatin)	-	-	-	-	12,5

According to the results of the study, the cytotoxic activity of the extract of the *A. terrae-albae* plant was determined. The half-lethal dose (LD_{50}) of the studied sample was 90.6 µg/ml.

Dactinomycin (actinomycin D), used as a reference drug, showed a significantly higher cytotoxicity, its LD_{50} value was recorded at the level of 45.8 µg/ml. This indicator is approximately two times lower than that of the studied plant extract, which indicates that the cytotoxic effect of dactinomycin is stronger (Table 3).

Thus, the results obtained indicate that the extract of *A. terrae-albae* has cytotoxic activity, but its effect is weaker than that of a standard antitumor drug. This indicates the prospect of further pharmacological studies of the plant extract.

Table 3. Cytotoxic activity of *A rtemisia terrae-albae* extract.

Test substances	LD_{50}, µg/ml
Extract of *A. terrae-albae*	90.6
Comparison drug: dactinomycin (actinomycin D)	45.8

Discussions. During the general analysis, 17 terpene compounds (mono-, sesquiterpenes and one triterpenoid) were identified in the extract. The quantitative ratio and group classification of these terpenes are shown in the diagram presented in the work (Figure 2). Terpenes constitute the majority of the identified compounds and are the main biologically active components of the extract.

Camphor and cyclic monoterpenes are known natural compounds characteristic of the *Artemisia* genus and exhibit antiseptic, anti-inflammatory and antimicrobial activity. In addition, the identified triterpenoid Urs-20-en-3-ol indicates the presence of high molecular weight terpenes in the extract and may be associated with its antioxidant and cytoprotective properties.

Among the 17 terpene compounds identified in the extract of *A. terrae-albae* by GC–MS analysis, monoterpenes (47%) and sesquiterpenes (47%) accounted for the majority, while triterpenes accounted for only 6%. These results indicate a clear dominance of low-molecular, volatile terpenes in the secondary metabolite profile of the studied species (Figure 2).

The presence of equal amounts of monoterpenes and sesquiterpenes indicates a relatively balanced activity of the plant's biosynthetic pathways (mevalonate and methylerythritol phosphate pathways). The high proportion of monoterpenes may be related to their volatility and protective function, as these compounds play an important role in plant defense against phytopathogens, insects, and abiotic stress factors.

The high percentage of sesquiterpenes (47%) is also a chemical marker characteristic of the *Artemisia* genus. Literature data indicate that biologically active sesquiterpenes (especially lactones) are common in *Artemisia* species, which are associated with their anti-inflammatory, antimicrobial and antioxidant properties.

The relatively low content of triterpenes (6%) may indicate that they are mainly structural or late metabolic products. Triterpenes are often described as storage or stabilizing compounds and may be less detectable by GC–MS analysis than volatile terpenes.

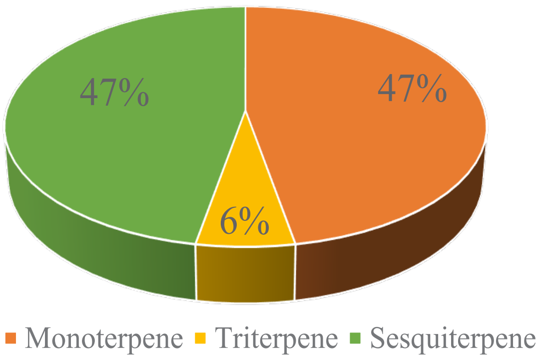


Figure 2. Relative percentage composition of terpenoid compounds identified in *A. terrae-albae* extract by GC–MS analysis.

In general, the terpene profile determined indicates that *A. terrae-albae* has a high pharmacological potential and that its biological activity is likely to be mainly associated with mono- and sesquiterpene components. This ratio of terpenes also provides important information for the chemotaxonomic characterization of the species.

It was observed that the chemical nature of the compounds is diverse: monoterpenes, sesquiterpenes, sesquiterpene lactones, as well as triterpenoids were identified.

GC–MS analysis revealed a high concentration of terpene compounds in the ethanol extract of *A. terrae-albae*. Among them, the highest concentration was 2-Cyclohexene-1-methanol, 2,6-dimethyl-6-(4-methyl-3-pentenyl)- (17.33%). This compound is structurally related to terpene alcohols and is considered a mono- or sesquiterpene derivative. Terpene alcohols are generally characterized by antimicrobial and anti-inflammatory activity.

The second highest-abundant compound is Bicyclo[2.2.1]heptan-2-one, 1,7,7-trimethyl- (13.19%), a camphor-like monoterpene. Camphor-like compounds are characteristic of the *Artemisia* genus and are the main components of the essential oil fraction of the plant. These substances are known for their antimicrobial, fungicidal, and insecticidal properties.

In addition, the compound Cyclohexane, 1,5-diethenyl-2,3-dimethyl- (9.71%) was also detected in significant amounts. Based on its structural features, it also belongs to the terpene hydrocarbons. Terpene hydrocarbons are protective metabolites of plants and play an important role in environmental adaptation.

Among the sesquiterpenes, the pharmacologically important α-santonin (1.04%) and Eudesma-5,11(13)-dien-8,12-olide (1.38%) were identified. These compounds belong to sesquiterpene lactones and are known as chemotaxonomic markers of the *Artemisia* genus. Their anthelmintic, anti-inflammatory and cytotoxic activities have been reported in the literature.

Of particular interest is the ursane-type triterpenoid (Urs-20-en-3-ol, 3.21%). Triterpenes with the ursane structure are characterized in the literature by anti-inflammatory, hepatoprotective and antitumor activity. Its detection confirms the pharmacological potential of the studied plant. In general, terpenes with a high percentage are the main components that determine the biological activity of the plant. Their predominance indicates a high pharmacological potential of the *A. terrae-albae* species.

The results of this work show that the ethanol extract of *A. terrae-albae* is rich in biologically active compounds, with a predominantly terpene nature. The high content of identified mono- and sesquiterpenes confirms the specificity of the essential oil and secondary metabolite profile of the species and allows it to be considered as a promising source of raw materials for pharmacological studies.

Thus, the GC–MS results showed that the composition of *A. terrae-albae* is rich in terpenes, and the 17 terpene compounds identified determine the phytochemical and pharmacological potential of the plant. The relative distribution and structural features of terpenes are presented in a diagram, and the obtained data allow us to consider the plant as a promising source of biologically active natural compounds.

As a result of GC–MS analysis, a total of 46 compounds were identified from the extract. Of these, 17 compounds are of terpene nature, which accounts for 36.96% of the total composition. In particular, 8 monoterpenes (17.39%), 8 sesquiterpenes (17.39%) and 1 triterpenoid – Ursolic acid (2.17%) were identified. The results obtained indicate that the studied extract is rich in terpenes and its biological activity may be associated with these compounds.

Conclusion. The study conducted comprehensively analyzed the chemical composition and biological activity of the ethanol extract of *A. terrae-albae*. The results showed that this plant is rich in biologically active compounds, including terpene compounds.

Initial IR spectroscopic screening revealed absorption bands characteristic of functional groups commonly found in plant terpenoid compounds, namely hydroxyl (–OH), carbonyl (C=O), as well as C=C and C–O bonds.

As a result of GC–MS analysis, a total of 46 organic compounds were identified, 17 of which were attributed to the terpene nature. In particular, monoterpenes, sesquiterpenes and one triterpenoid were identified.

The main components were 2-cyclohexene-1-methanol derivative (17.33%), camphor (13.19%), cyclohexane derivative (9.71%) and octyl butanoate (8.29%). It was found that the terpene profile consists mainly of oxygenated monoterpenes, which is a chemotaxonomic characteristic of the *Artemisia* genus. In addition, the discovery of the urs-20-en-3-ol triterpenoid, which belongs to the ursane family, indicated the presence of high molecular weight terpenes.

The antimicrobial activity evaluation revealed that the extract exhibited moderate activity against Gram-positive bacteria. The minimum inhibitory concentration (MIC) against *S. aureus* ATCC 6538 and *B. subtilis* ATCC 6633 strains ranged from 12.5–50 μg/ml. A weak effect was observed against the fungus *C. albicans* ATCC 10231 (MIC = 50 μg/ml). Gram-negative bacteria (*E. coli* ATCC 25922 and *P. aeruginosa* ATCC 27853) showed relative resistance. This antimicrobial effect may be due to the combined action of oxygenated monoterpenes, sesquiterpene lactones and phenolic compounds.

The *A. salina* test system was used to determine the toxicity level. As a result, the half-lethal dose (LD_{50}) of the extract was 90.6 μg/ml, which indicates a lower toxicity compared to the standard drug dactinomycin (LD_{50} = 45.8 μg/ml).

Overall, the results obtained demonstrate that *A. terrae-albae* is rich in terpenes and is a promising source of natural raw materials with antimicrobial activity. In the future, the isolation of individual active components, the study of their mechanisms of action, and testing in in vivo models will allow us to further explore the pharmacological potential of this plant.

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