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**Original Research**

# FT-IR and GC–MS analyses and antioxidant activities of extracts of the wild type Saussurea sordida and Saussurea alpina native to Kazakhstan

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**Abstract**

**Objective:** Natural products from medicinal plants, either as pure compounds or as standardized extracts, provide un-limited opportunities for new drug leads because of the unmatched availability of chemical diversity. The objects of the study were the medicinal plant raw materials Saussurea sordida Kar&Kir and Saussurea alpina DC. collected from southern Kazakhstan during the flowering period in the spring-summer months of 2021. experimental and theoretical substantiation of the technology for obtaining phytosubstances S. sordida, S. alpina and their study of antioxidant activity.

**Methods:** Identification of functional groups was performed using Fourier transform infrared spectroscopy (FT-IR). The component composition of extracts of two types of medicinal plant raw materials was studied using gas chromatography with mass spectrometric detection.

**Results:** The present study aimed to analyze the bioactive constituents of the plants S. sordida and S. alpina. The ethanol extracts were subjected to phytochemical screening and Fourier transform infrared (FTIR) spectroscopy. Phytochemical screening of the extract revealed the presence of phenolic compounds. FT-IR spectroscopic analysis revealed various characteristic bands corresponding to various functional groups, such as amines, alcohols, phenols, alkanes, alkenes, and conjugated acids, in the formulation extract. FT-IR analysis of peak values for various functional compounds, such as alcohols, phenols, carboxylic acids, aldehydes, amides, amino acids, anhydrides, esters, ketones, unsaturated aliphatic, aromatics, unsaturated heterocycles, amines, nitro compounds, alkanes, alkenes and sugars. For the first time, the compositions of petroleum ether extracts from medical plants, such as Saussurea sordida and Saussurea alpine, were investigated through GC–MS analysis. The antioxidant activity of the medicinal plants showed that the S. alpine extract had greater activity than the S. sordida extracts according to both methods (the content of antioxidants was measured in terms of quercetin and gallic acid).

**Conclusion:** According to the results of our study, the biologically active substances of this plant relative have an antioxidant effect due to the presence of phenolic compounds in their composition.

**Keywords:** S. sordida, S. alpine, biologically active substances, antioxidant activity

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## INTRODUCTION

Medicinal plants, which are used in traditional medicine or traditional medical practices as medicines, are among the most useful natural resources in the world, as they play an important role in health care in many ancient and modern cultures[1,2]. Therefore, natural products and traditional medicines derived from plant species have incomparable advantages, such as rich clinical experience and unique diversity of chemical structures and biological activities, and can be used in drug development and discovery[3]. *Saussurea* is a large, predominantly East Asian genus belonging to the family *Asteraceae*, and includes approximately 465 species found in the Arctic and temperate zones of the Eurasian and North American continents. Many representatives of the genus are also used in pharmaceuticals, cosmetology, and official and traditional medicine[4,5]. The genus *Saussurea* is well known for its rich chemical composition and wide range of biological activity, therefore, it is necessary to resolve issues related to the conservation of the biological diversity of species of the genus *Saussurea*, which requires a preliminary in-depth study of the composition, morphology and geography of the species[6]. Currently, the scope and boundaries of the genus, as well as the relationships between its constituent substances and pharmacological activities, remain the subject of debate and continue to be revised[7-13]. There are 41 species of *Saussurea* growing on the territory of Kazakhstan[14,15]. The objects of this study are S. sordida, S. alpine, which has a identified as quercetin 5-O-β-D-glucopyranoside. Similarly, flavonoids 6, 7 and 10 were characterized as kaempferol 5-O-glucoside, kaempferol 7-O-glucoside and isorhamnetin 5-O-glucoside. Flavone and flavonol 5-O-glucosides are comparatively rare in the plant kingdom[16].

Medicinal properties of the genus *Saussurea* are gaining popularity in modern traditional medicine systems, including Chinese and Tibetan traditional medicine. According to the literature, the following pharmacological activities of the genus Saussurea were determined: Anticancer/antitumor effect; Hepatoprotective effect; Immunostimulant effect; Anti-angiogenesis effect; Antidiabetic effect; Antimicrobial effect; Anti-inflammatory effect; Activity against coronavirus (COVID-19); Antibacterial and antifungal effect; Antioxidant effect; Antihyperlipidemic and antihyperglycemic effect. See Table 1. Taxonomic Insights into *Saussurea* genus within the *Asteraceae* Family. The genus *Saussurea* belongs to the *Asteraceae* family (Figure 1). In the picture below, a phyllonic tree was created based on the *Saussurea* species that grows in Kazakhstan. As shown in the picture, 39 species grow in Kazakhstan. In our study, we consider two species *S. sordida, S. alpina*. Based on the results of these studies, species of this plant family were found to exhibit multiple types of activity in terms of pharmacological action. It becomes clear that in terms of phytochemical composition, the medicinal plants *S. sordida*, *S. alpina* are closer (similar or identical) to other species of the genus *Saussurea*. Thus, the present work was carried out with the aim of studying the phytochemical composition, as well as biochemical and histological studies of these species of medicinal plants (*S. sordida, S. alpina*) growing in the South Kazakhstan.

## METHODS

### Plant Material

Above-ground parts of medicinal plant raw material *S. sordida*, collected in the South Kazakhstan during the flowering period in the spring-summer months of 2021 in Tolebi district, as well as above-ground parts of medicinal plant raw material *S. alpina* collected from the height of 3050 m of Sayram peak in Tolebi district. Drying of herbs was carried out in South Kazakhstan Medical Academy in a drying oven at room temperature 25±2°C.

### FT-IR Spectroscopic Analysis

All plant material was collected in South Kazakhstan (S.sordida, S. alpina ) 2021 and was identified by Dr. Issayeva E. specimens are kept in the herbarium of the Laboratory of Pharmacognosy, South Kazakhstan Medical Academy, Kazakhstan. Botanical

Table 1. Pharmacological activity of plants of the genus *Saussurea* according to the results of studies presented in different literature reviews

| Authors | Type of plant | Therapeutic effects of Saussurea herbs on the human body |
|---|---|---|
| Jehan S Al-Brahim, et al 2023 | S.costus | The antimicrobial properties of IONPs were evaluated on nine pathogenic microbes, which showed that the nanoparticles have antimicrobial activity against Pseudomonas aeruginosa, Escherichia coli, Shigella sp., Staphylococcus sp. and Aspergillus niger, with potential applications in therapeutic and biomedical fields. |
| Hajo Idriss, et al 2023 | S.costus | The acetic acid extract of Saussurea costus has been shown to possess phytochemical profile, molecular additivity, anti-candida and antiviral activities. Was found to have active properties indicating inhibition of SARS-CoV-2. The extract showed significant antimicrobial activity (in vitro) against Candida albicans. |
| Min Liu, et al 2021 | S.involucrata | A new auronic glycoside was isolated from the extract of the above-ground parts of Saussurea involucrata. All the identified compounds showed in vitro inhibitory activity against α-glucosidase. Among them, compounds 1 and 6 showed significant inhibitory activity against α-glucosidase with IC50 values of 47.1 and 57.7 μM, respectively. |
| Yang Wang, et al 2020 | S.lappa | Pharmacological studies included extracts, essential oils and monomeric components represented by dehydrocostal lactone. It has antitumor, anti-inflammatory and antibacterial effects on the digestive system. |
| Gasha S. Ahmed, et al 2023 | S.costus | The antibacterial and antifungal activities of essential oil, hexane-chloroform, methanol and aqueous extracts of Saussurea costus root was evaluated against Staphylococcus aureus, Pseudomonas aeruginosa, Staphylococcus epidermalis, Enterobacter cloacae, Enterococcus faecalis, Klebsiella pneumoniae, Acinetobacter baumannii, Escherichia coli and Candida albicans. |
| Sana Naseer, et al 2022 | S.lappa | Antioxidant potential refers to the ability of a plant to absorb reactive oxygen species (ROS), which increases the therapeutic potential of the plant. |
| Sana Naseer, et al 2022 | S.lappa | S. lappa extracts have antibacterial potential against six ATCC and three multidrug resistant (MLD) strains were evaluated by agar well method. The research showed antibacterial effect. |

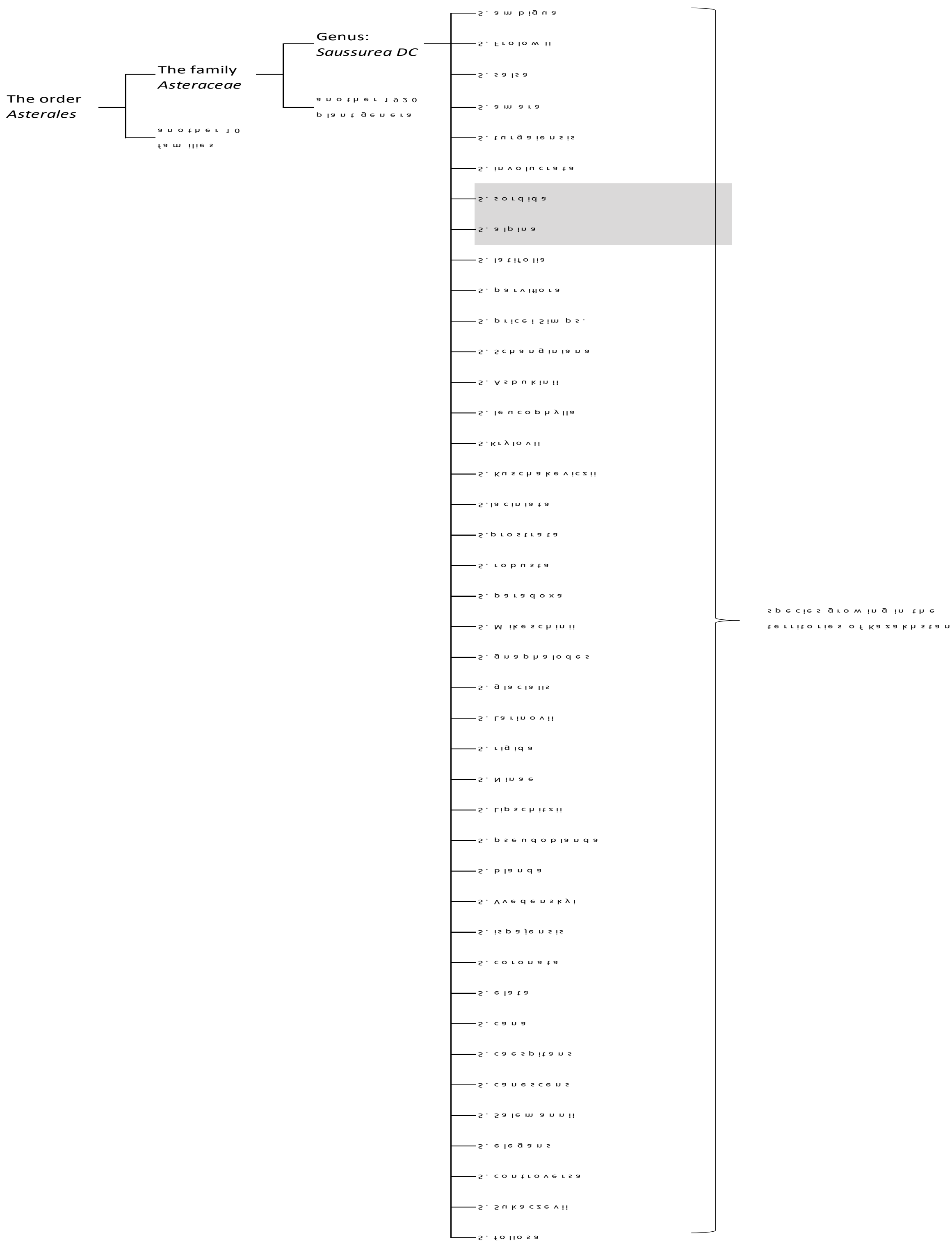


**Figure 1.** Saussurea species growing in Kazakhstan

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name, taxonomic authority, plant part, voucher specimen number, place and date of collection of each plant.

**Determination of organic compounds in plant extract**

A Shimadzu GC–MS chromatograph (Japan) with an ultra inert DB-35 MS capillary column (30 m × 0.25 mm inner diameter × 0.25 μm film thickness; USA) was used for Gas Chromatography–Mass Spectrum Analysis of the metabolites. The oven tempera-ture was set at 40°C for 3 min (isothermal), programmed to 30°C at a rate of 5°C /min, and kept constant at 280°C for 15 min (isothermal); the temperature of the injector was 280°C. Helium was employed as the carrier gas, with a flow rate of 1.40 mL/min. Diluted samples (1% v/v) were injected at a split ratio of 15:1 in a volume of 1 μL. The following were the MS running specifications: 280°C for the interface, 220°C for the ion source, 70 eV for the EI mode, and 35–500 amu for the scan range. Detection was carried out in the SCAN mode m/z 34-750. The Agilent MSD ChemStation software (version 1701EA) was used to control the gas chromatography system, record and process the obtained results and data. Data processing included determination of retention times, peak areas, as well as processing of spectral information obtained with a mass spectrometric detector. To interpret the obtained mass spectra, the Wiley 7th edition and NIST,02 libraries were used (the total number of spectra in the libraries is more than 550 thousand).

**Antioxidant activity of extracts of S.alpina and S. Sordida**

The determination of the total content of antioxidants in extracts from the aerial parts of S. alpine and S. sordida. The concentration of antioxidants (mg/L) was measured using calibration graphs of the dependence of the output signal (NAc) on the concentration (mg/L) of quercetin and/or gallic acid. The method used allows you to convert the current generated during the oxidation of antioxidants contained in the extract on the surface of the working electrode into a digital signal. In this case, the strength of the electric current depends on several factors: the nature and concentration of the analyzed substances, the type of material of the working electrode and the potential applied to the electrode. The antioxidant activity of the extract was studied using the amperometric method. Analysis of each extraction sample was performed in 6 replicates.

Content of antioxidants in terms of quercetin calculations were made using the equation below:

Content of antioxidants in terms of gallic acid calculations were made using the equation below:

Where $X_G$ is the mass concentration of antioxidants found from the calibration curve, mg/l; Vn - volume of extract of the analyzed sample, ml; ma - weight of the analyzed substance, g; N is the dilution factor of the sample being analyzed.

## RESULTS

Aerial parts of S.alpina and S. sordida were grinded by an analytical mill and packed in polyethylene bags. The grinded mass with 50 g of S.alpina and S. sordida from the aerial parts was extracted with 70% ethanol (Figure 2). The vibrational spectrum of a chemical molecule is considered to be a unique physical property. Absorption spectra of dried herbal extracts obtained in the range 4000–400 cm−1 are shown in figure 3. The main vibrational range of the molecules, called “mid-infrared”, lies between wave numbers from 4000 to 400 $cm^{-1}$. All the spectra of the studied samples (70% ethanol extracts from S. sordida and S. alpine) absorption bands reflecting the general chemical composition were detected. In the IR spectra of the studied medicinal plant extracts, characteristic absorption bands of the aromatic part of flavonoids can be identified: The region of 3385 - 2850 cm−1 indicates a symmetric (sym) and asymmetric (asym) stretching of polymeric hydroxyl group (O–H), H-bonded stretching, which is characteristic of phenolic compounds (Table 2), 1680-1615 $cm^{-1}$ (carbonyl group of γ-pyrone), The stretching of the C–H and C=C–C aromatic bond appears in the region of 1620-1470 $cm^{-1}$ (skeletal vibrations of aromatic rings), 2950-2880 $cm^{-1}$. There are absorption bands due to valence vibrations of free groups with phenolic compounds (frequencies 3750-3700 cm-1), intermolecular hydrogen bonds in dimers and polymers (frequencies 3400-3200 $cm^{-1}$) characteristic peaks are observed from 2000 to 1380 cm-1 [17-18]. The results of the obtained spectra are shown in Figures 3-4.

Furthermore, the 70% ethyl alcohol extract *S.alpina* and *S. sordida* extracts from South Kazakhstan. The peaks same at 3329, 2927, 1373, 1273, 1045, 879 and 634 cm−1 were identical in two extracts (Figure 3 and Figure 4). These peaks attributed to phenolic and organic compounds. The most prominent signals for the two 70% ethyl alcohol extracts were the major absorption band (Figure 2 and Figure 3) around 3300 cm−1, which can be associated with O–H stretching and C–H stretching vibrations. The peaks between 700 and 1800 cm−1, the fingerprint zone, could be attributed to C=C–C aromatic ring stretching (1580–1615 cm−1, 1450–1510 cm−1) and several aromatic out-of-plane C–H (670–900 cm−1) and in-plane (950–1225 cm−1) bending14–16. In addition, peaks for water were observed in the range 1640 cm−1 and 3300 cm−1 on the basis of functional group H and OH (Table 2. Table 3).

*S.alpina* extract have two different peaks 1772 and 1635 cm-1. This band could be due to stretching vibration of C=C groups, due to aromatic ring deformations, due to flavonoids. Besides the bands previously described, there were other bands encountered. A band at 1772 cm-1, probably related to: stretching vibration of carboxyl groups, stretching of C = O of flavonoids and lipids. A band at 1635 cm-1, related to aromatic ring deformations and to flavonoids and aromatic rings (stretching of aromatic C=C) [19-21]. This study can lead to the production of new herbal medicines from various diseases employing and to creation of new medications.

**Study of the chemical composition of medicinal plant raw materials by GC-MS method**

In this work, extracts of *S. alpine* and *S. sordida* were studied using gas chromatography with mass spectrometric detection (GC-MS) with petroleum ether. Evaluation of the chemical

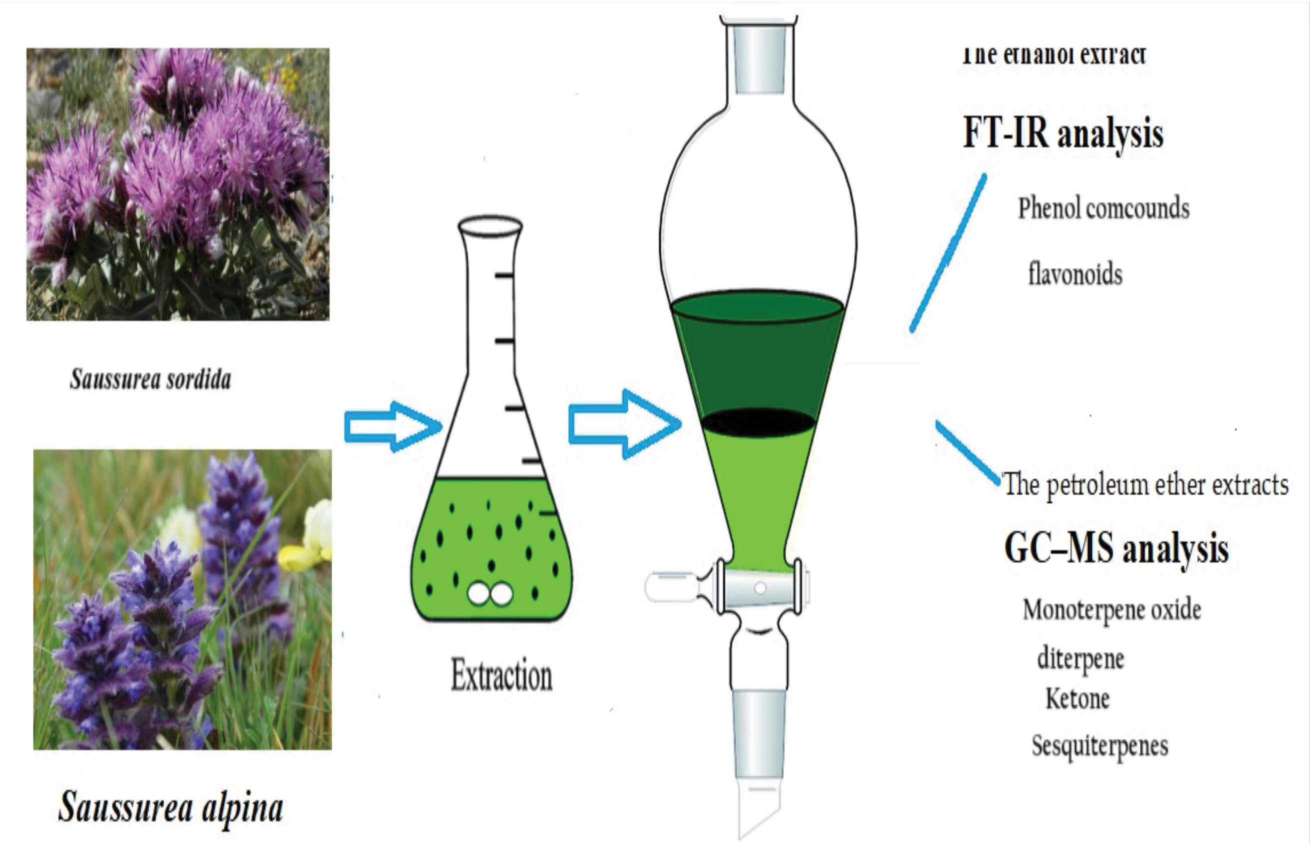


**Figure 2.** Extraction methods to plants

Table 2. FT-IR spectra analysis of dried medical plant extracts.

| Herbs | Absorption spectrum, wave number (cm−1) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3385 - 2850 | 2950-2880 | 1785–1640 | 1680-1615 | 1600–1300 | 1450–1050 | 1080–620 | 935–710 |
| **S. sordida** | 3329 | 2927 | - | - | 1373 | 1273 | 1045 | 879 |
| **S.alpina** | 3329 | 2927 | 1772 | 1635 | 1373 | 1271 | 1045 | 879 |

Table 3. Fundamental IR vibrations of phytochemicals present in fractions of S. Sordida and S.alpina

| **S. sordida** | **Functional Group** | **S.alpina** | **Functional Group** |
|---|---|---|---|
| 3329 | Imino compounds,NH stretch | 3329 | Imino compounds,NH stretch |
| 2927 | Ac-H carbonyl | 2927 | Ac-H carbonyl |
| - | | 1772 | C=C–C aromatic ring stretching |
| - | | 1635 | Alkenyl C=C stretch |
| 1373 | Phenol or tertiary alcohol, OH bend | 1373 | Phenol or tertiary alcohol, OH bend |
| 1273 | Primary or secondary, OH in-plane bend | 1271 | Primary or secondary, OH in-plane bend |
| 1045 | Primary alcohol, C | 1045 | Primary alcohol, C |
| 879 | Alkenyl C=C stretch | 879 | Alkenyl C=C stretch |


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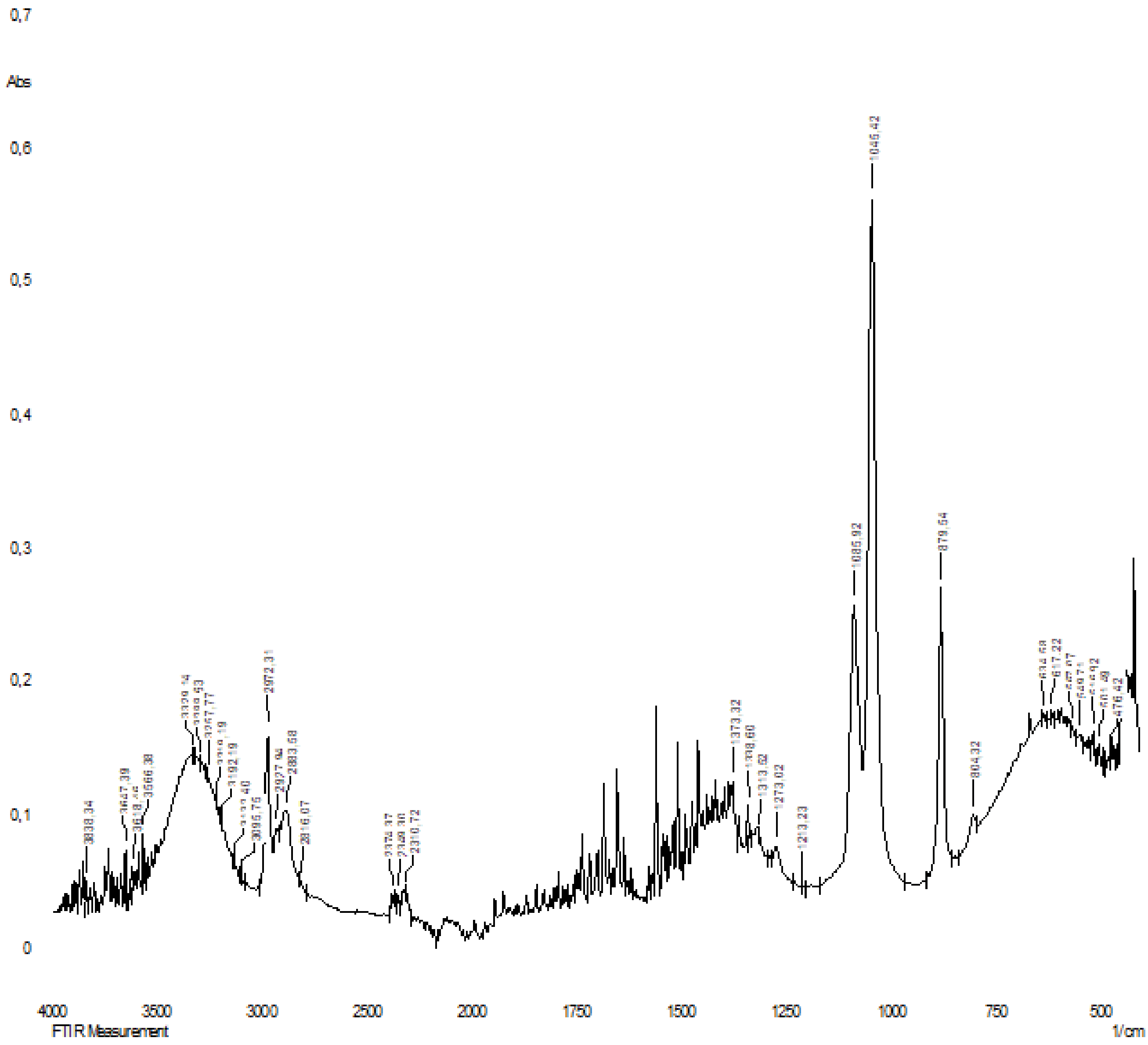


**Figure 3.** IR spectrum of liquid 70% ethanol extract of S. sordida

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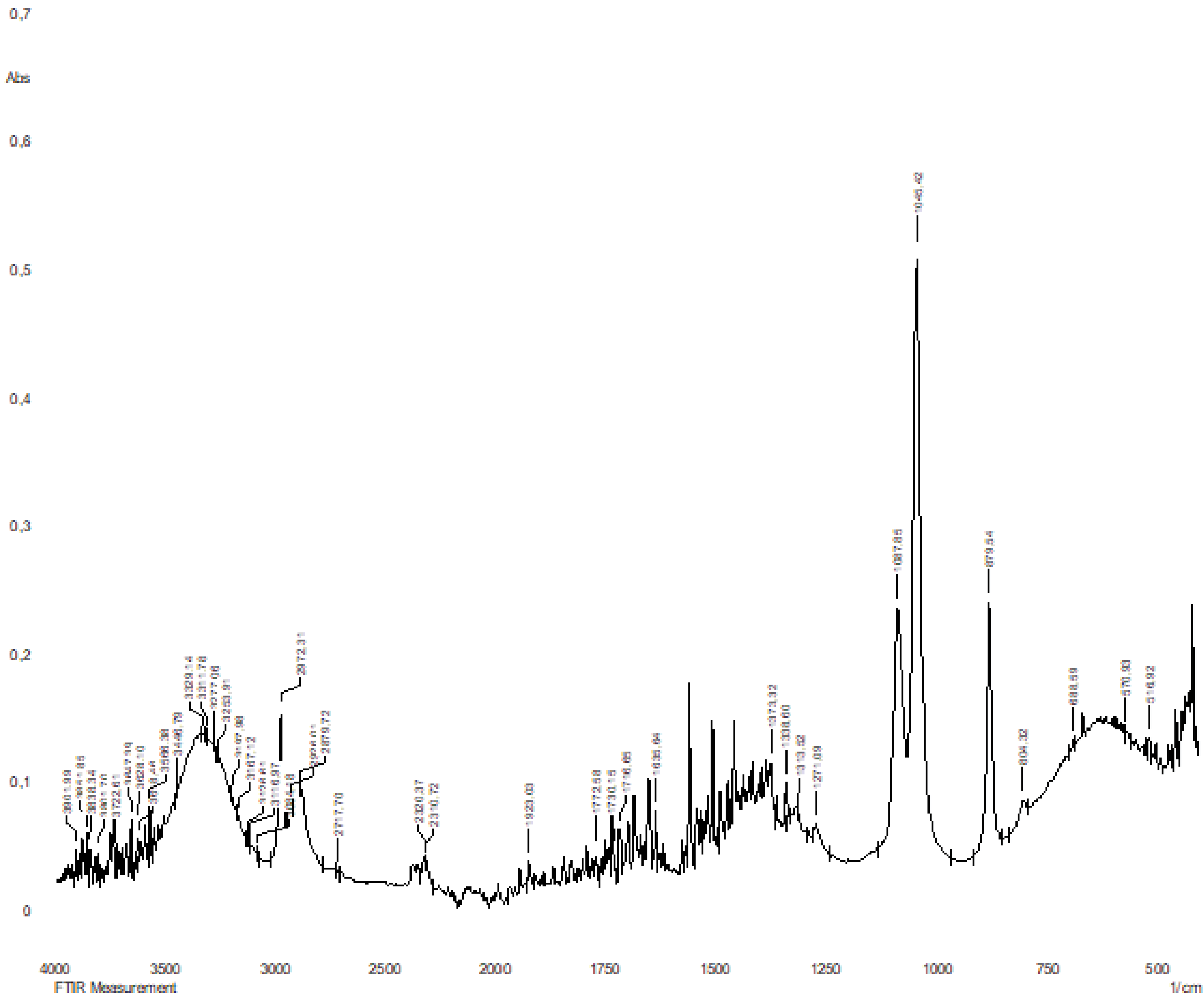


**Figure 4.** IR spectrum of liquid 70% ethanol extract of S.alpina

structure and composition of the extracts can designate various biological potential of different medicinal plant extracts. However, to the best of our knowledge, there is no report on GC–MS based plant metabolic characterization to reveal the presence of various bioactive compounds in petroleum ether extracts. Therefore, the GC–MS analysis was performed in a predetermined study. A total of 37 peaks were observed in all plant parts, each peak designated the bioactive compounds that were recorded by relating their peak retention time, molecular weight, molecular formula to that of the known compounds proposed by the NIST library (Table 4).

Based on the results of the study of *S. sordida*, 37 compounds were identified. These compounds belong to different chemical classes, including hydrocarbons, esters of fatty acids, triterpenes, aldehydes, vitamins. Of these, substances with a high proportion were identified: (+)-2-Bornanone -20,45%, phytol – 11,57%, 2-pentadecanone,6,10,14-trimethyl – 9,14%, 2,4-dimethyl-2,4-pentandiol – 6,87%, eudesm-4(14)-en-11-ol – 5,47%, 5-eocosene,(E)- - 4,09%, hexacosane – 3,29 %. According to the results of the study of *Saussurea alpine*, 29 compounds were identified (Table 5). Of these, substances with high proportion were identified: (+)-2-Bornanone -26,79%, phytol – 14,78%, 2-pentadecanone,6,10,14-trimethyl – 9,58%, 2,4-dimethyl-2,4-pentandiol – 6,68%, eudesm-4(14)-en-11-ol – 7,45%, hexacosane – 3,25% and Pulegone -1,75% *Saussurea alpine* DC extract have Pulegone bioactive compound. According to GC-MS results, Saussurea alpina DC contains the biologically active substance Pulegone. Pulegone is used in flavorings, perfumery, aromatherapy (as a component of essential oils), and also to produce menthol. The GC-MS analysis of the petroleum ether extracts of *S.sordida* and *S. alpina*, showed promising biological activities, which has resulted in the identification of 37 and 29 compounds (Figure 5 and Figure 6). These constituents belong to 9 classes of compounds including hydrocarbons, fatty acids, esters, alcohols, aromatics,

Table 4. Identified phytochemicals in petroleum ether extract of S. sordida through the GC–MS technique

| № | Retention time, min | Compounds | Molecular formula | MW, g/mol | Identification probability,% | Percentage content, % |
|---|---|---|---|---|---|---|
| 1 | 10,56 | Cyclohexanone,5-methyl-2-(1-methylethyl)-,trans- | $C_{10}H_{18}O$ | 154.2 | 82 | 0,94 |
| 2 | 10,90 | (+)-2-Bornanone | $C_{10}H_{16}O$ | 152.2 | 98 | 20,45 |
| 3 | 11,56 | Pentadecane | $C_{15}H_{32}$ | 212.4 | 94 | 0,82 |
| 4 | 12,15 | 1-Decanol,2-Hexyl | $C_{16}H_{34}O$ | 242.4 | 79 | 1,17 |
| 5 | 12,53 | Acetic acid, 1,7,7-trimethyl-bicyclo[2,2,1]hept -2-yl ester | $C_{16}H_{34}O$ | 242.4 | 80 | 1,58 |
| 6 | 13,51 | 2,4-Dimethyl-2,4-pentanediol | $C_7H_{16}O_2$ | 132.2 | 85 | 6,87 |
| 7 | 13,86 | Hexadecane | $C_{16}H_{34}$ | 226.4 | 92 | 1,04 |
| 8 | 13,99 | Cyclohexanone,5-methyl-2-(1-methylethylidene)- | $C_{10}H_{18}O$ | 154.2 | 91 | 1,67 |
| 9 | 14,12 | Bicyclo[3,1,1]heptan -3-ol,6,6-dimethyl -2-methylene- | $C_9H_{14}O$ | 138.2 | 87 | 0,34 |
| 10 | 15,18 | Endo-Borneol | $C_{10}H_{18}O$ | 154.2 | 89 | 1,10 |
| 11 | 15,83 | 7-Oxybiclo [4,1,0] heptan -2-one, 6-methuyl – 3-(1-methylethyl)- | $C_9H_{14}O_2$ | 154.2 | 80 | 2,03 |
| 12 | 16,66 | 1-Dodecanol, 2-octyl- | $C_{20}H_{42}O$ | 298.5 | 85 | 1,13 |
| 13 | 17,31 | 1-Decanol,2-hexyl- | $C_{16}H_{34}O$ | 242.4 | 81 | 1,31 |
| 14 | 18,23 | Octadecane | $C_{18}H_{38}$ | 254.5 | 92 | 0,97 |
| 15 | 18,97 | 1,4 –Methanobenzocyclodecene, 1,2,3,4,4a,5,8,9,12,12a-decahydro- | $C_{15}H_{22}$ | 202.3 | 70 | 0,56 |
| 16 | 19,10 | 5-eicosene, (E)- | $C_{20}H_{40}$ | 280.5 | 83 | 4,09 |
| 17 | 19,78 | Butylated Hydroxytoluene | | | 86 | 0,78 |
| 18 | 20,67 | 3,7,11,15-Tetramethyl-2-hexadecen-1-ol | $C_{20}H_{40}O$ | 296.5 | 87 | 2,33 |
| 19 | 20,92 | Caryophyllene oxide | $C_{15}H_{24}O$ | 220.3 | 91 | 1,53 |
| 20 | 21,24 | Phytol | $C_{20}H_{40}O$ | 296.5 | 78 | 0,98 |
| 21 | 23,80 | Spathulenol | $C_{15}H_{24}O$ | 220.3 | 86 | 1,36 |
| 22 | 24,16 | Heneicosane | $C_{21}H_{44}$ | 296.6 | 92 | 2,27 |
| 23 | 24,30 | 2-pentadecanone, 6,10,14-trimethyl- | $C_{18}H_{36}O$ | 268.5 | 94 | 9,14 |
| 24 | 25,60 | Eudesm-4(14)-en-11-ol | $C_{15}H_{26}O$ | 222.3 | 90 | 5,47 |
| 25 | 27,35 | 2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-,(R)- | $C_{11}H_{16}O_2$ | 180.2 | 87 | 1,61 |
| 26 | 28,33 | 5,9,13-Pentadecatrien-2-one,6,10,14-trimethyl- (E,E)- | $C_{18}H_{30}O$ | 262.4 | 81 | 0,92 |
| 27 | 28,59 | 1-hexadecanol | $C_{16}H_{34}O$ | 242.4 | 80 | 0,96 |
| 28 | 29,66 | Hexadecanoic acid, butyl ester | $C_{20}H_{40}O_2$ | 312.5 | 81 | 1,29 |
| 29 | 30,93 | 1,2- Benzenedicarboxylic acid, bis (2-methylpropyl) ester | $C_{16}H_{22}O_4$ | 278.3 | 90 | 0,54 |
| 30 | 31,06 | Hexacosane | $C_{26}H_{54}$ | 366.7 | 92 | 3,29 |
| 31 | 32,42 | Phytol | $C_{20}H_{40}O$ | 296.5 | 94 | 11,57 |
| 32 | 33,28 | Dibutyl phthalate | | | 94 | 1,36 |
| 33 | 33,40 | 9,12,15 – Octadecatrienoic acid, (Z,Z,Z)- | $C_{19}H_{32}O_2$ | 292.5 | 83 | 1,22 |
| 34 | 36,52 | Hexadecanoic acid | $C_{16}H_{32}O_2$ | 256.4 | 82 | 2,32 |
| 35 | 37,53 | 4,8,12,16-Tetramethylheptadecan-4-olide | $C_{21}H_{40}O_2$ | 324.5 | 90 | 2,12 |
| 36 | 38,99 | Squalane | $C_{30}H_{62}$ | 422,8 | 93 | 1,06 |
| 37 | 43,55 | 9-Octadecenamide,(Z)- | $C_{18}H_{35}NO$ | 281.5 | 83 | 1,79 |

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Table 5. Results of chromatographic analysis of the extract S. alpine

| № | Retention time, min | Compounds | Molecular formula | MW, g/mol | Identification probability,% | Percentage content, % |
|---|---|---|---|---|---|---|
| 1 | 10,48 | Dodecane,4,6-dimethyl- | $C_{14}H_{30}$ | 198.39 | 77 | 0,47 |
| 2 | 10,56 | Cyclohexanone,5-methyl-2-(1-methylethyl)-,trans- | $C_{10}H_{18}O$ | 154.2 | 85 | 0,71 |
| 3 | 10,91 | (+)-2-Bornanone | $C_{10}H_{16}O$ | 152.2 | 98 | 26,79 |
| 4 | 11,58 | Pentadecane | $C_{15}H_{32}$ | 212.4 | 92 | 0,86 |
| 5 | 12,17 | 1-Dodecanol,2-octyl- | $C_{20}H_{42}O$ | 298.5 | 78 | 1,57 |
| 6 | 12,55 | 1-Decanol,2-Hexyl | $C_{16}H_{34}O$ | 242.4 | 74 | 1,73 |
| 7 | 13,52 | 2,4-Dimethyl-2,4-pentanediol | $C_{7}H_{16}O_{2}$ | 132.2 | 89 | 6,68 |
| 8 | 13,88 | Hexadecane | $C_{16}H_{34}$ | 226.4 | 92 | 0,92 |
| 9 | 14,00 | Pulegone | $C_{10}H_{16}O$ | 152.2 | 90 | 1,71 |
| 10 | 14,12 | Bicyclo[3,1,1]heptan -3-ol,6,6-dimethyl -2-methylene-,[1S-(1α,3α,5α)]- | $C_{10}H_{18}$ | 138.2 | 77 | 0,35 |
| 11 | 15,19 | Endo-Borneol | $C_{10}H_{18}O$ | 154.2 | 91 | 1,27 |
| 12 | 15,83 | 7-Oxybiclo [4,1,0] heptan -2-one, 6-methuyl – 3-(1-methylethyl)- | $C_{9}H_{14}O_{2}$ | 154.2 | 85 | 2,19 |
| 13 | 16,10 | Heptadecane | $C_{17}H_{36}$ | 240.5 | 87 | 1,78 |
| 14 | 17,91 | 2,4-Dimethyl- 2,4- pentanediol | $C_{7}H_{16}O_{2}$ | 132.2 | 73 | 1,72 |
| 15 | 18,24 | Octadecane | $C_{18}H_{38}$ | 254.5 | 91 | 1,01 |
| 16 | 19,57 | Heptacosane | $C_{27}H_{56}$ | 380.7 | 78 | 0,59 |
| 17 | 19,79 | Butylated Hydroxytoluene | $C_{15}H_{24}O$ | 220.3 | 89 | 1,20 |
| 18 | 20,68 | 3,7,11,15-Tetramethyl-2-hexadecen-1-ol | $C_{20}H_{40}O$ | 296.5 | 89 | 1,34 |
| 19 | 20,93 | Caryophyllene oxide | $C_{15}H_{24}O$ | 220.3 | 87 | 1,47 |
| 20 | 21,25 | Phytol | $C_{20}H_{40}O$ | 296.5 | 80 | 1,02 |
| 21 | 24,30 | 2-pentadecanone, 6,10,14-trimethyl- | $C_{18}H_{36}O$ | 268.5 | 94 | 9,58 |
| 22 | 25,61 | Eudesm-4(14)-en-11-ol | $C_{15}H_{26}O$ | 222.3 | 90 | 7,45 |
| 23 | 29,43 | Tetracosane | $C_{24}H_{50}$ | 338.7 | 81 | 0,79 |
| 24 | 29,67 | Hexadecanoic acid, butyl ester | $C_{20}H_{40}O_{2}$ | 312.5 | 86 | 1,54 |
| 25 | 31,07 | Heneicosane | $C_{21}H_{44}$ | 296.6 | 92 | 3,25 |
| 26 | 31,33 | 1-Hexadecyn-3-ol, 3,7,11,15- tetramethyl- | $C_{20}H_{40}O$ | 296.5 | 77 | 2,82 |
| 27 | 32,42 | Phytol | $C_{20}H_{40}O$ | 296.5 | 94 | 14,78 |
| 28 | 33,29 | Dibutyl phthalate | $C_{16}H_{22}O_{4}$ | 278.3 | 94 | 2,66 |
| 29 | 38,99 | Squalane | $C_{30}H_{62}$ | 422,8 | 89 | 1,75 |

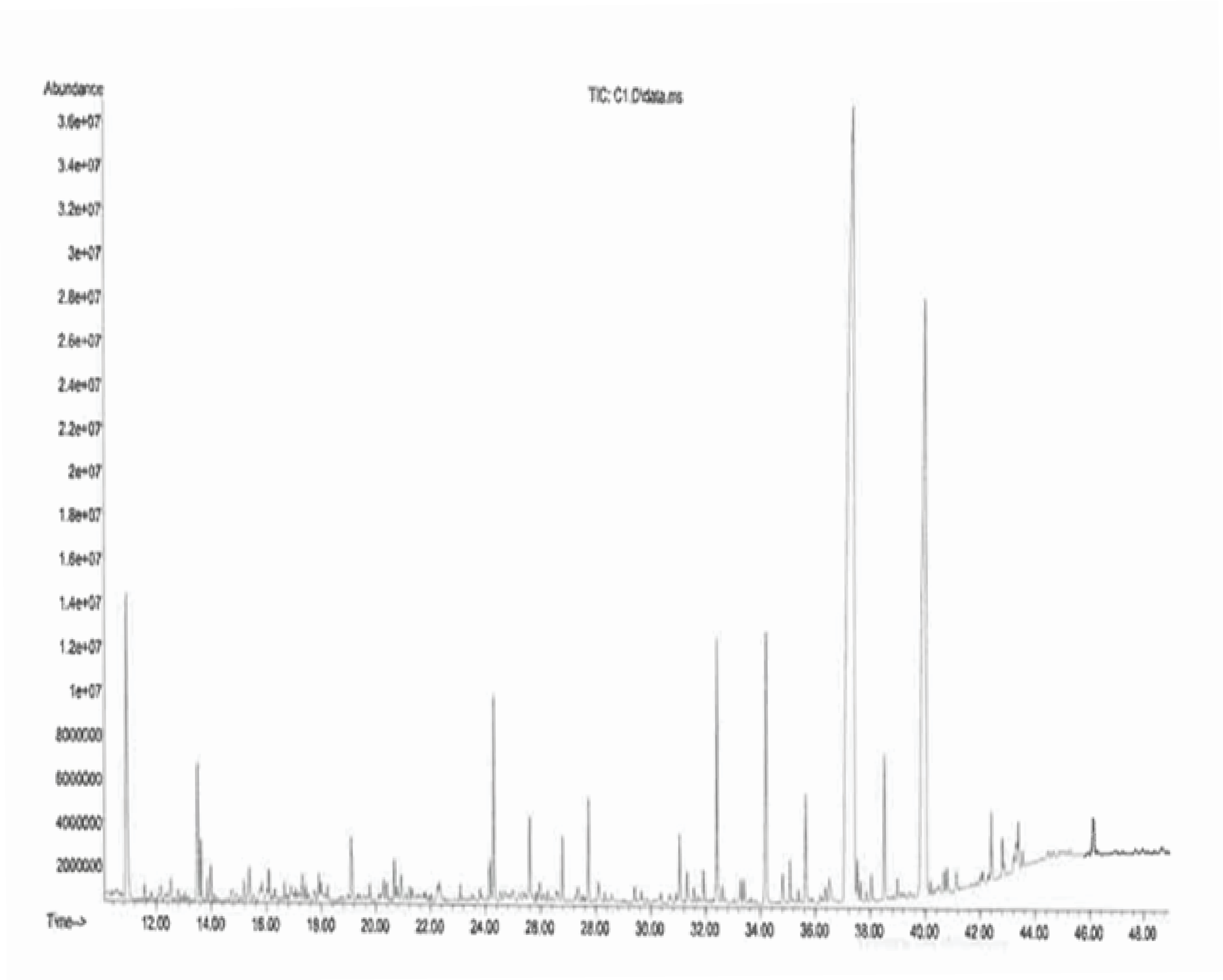


**Figure 5.** Chromatogram of the extract S. sordida

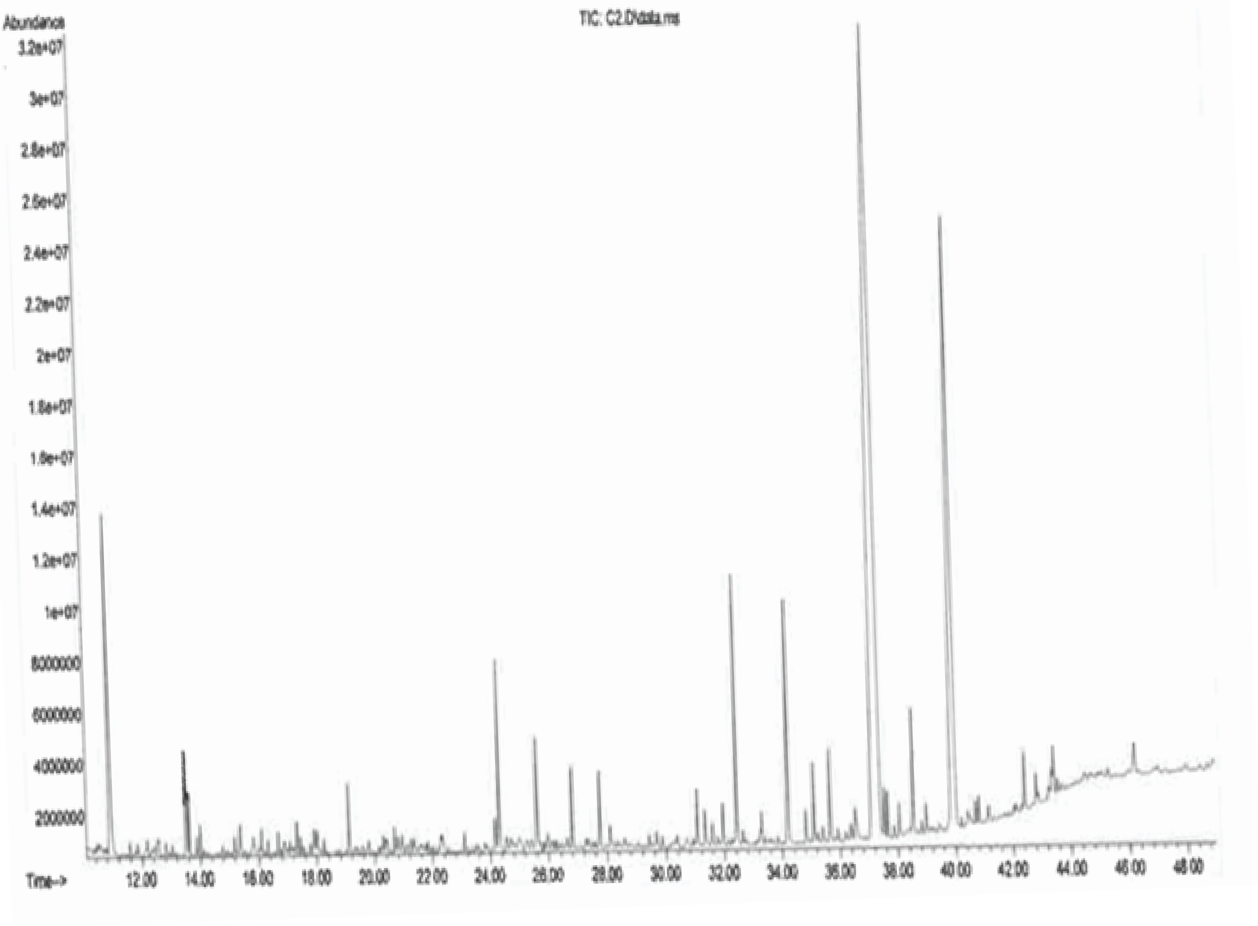


**Figure 6.** Chromatogram of the extract S. alpina

alkamides, steroids, unsaturated alkenamides and alkyne.

**Antioxidant activity of extracts of *S.alpina* and *S. Sordida***

Since preliminary studies showed that the largest amount of phenolic compounds from the aerial parts of *S. alpine* and *S. sordida* was extracted with 70% ethyl alcohol, these extracts were used to study the antioxidant activity. Extracts were obtained using the following method: 1 g of dried and crushed raw material (exactly weighed) - the above-ground part was placed in a 100 ml conical flask, 30 ml of 70% ethyl alcohol was added, a reflux condenser was connected and heated in a boiling water bath for 30 minutes. Then the extract was separated from the meal using a paper filter. The procedure was repeated thrice. The resulting total extraction was transferred to a 100 ml volumetric flask and adjusted to the mark with 70% ethyl alcohol. The presence of antioxidants was determined using an in vitro calculation method. Their total content in the analyzed extracts was determined using the peak areas of differential curves, which reflected the dependence of the output signal on the concentration of the sum of phenolic compounds in terms of quercetin or gallic acid.

The figures show graphs of the output signals of quercetin Figure 7 and gallic acid in NAc versus concentration in mg/ml, Figure 8. Data on the total concentration of antioxidants in the studied extracts from the aerial parts of S. alpine and S. sordida are presented in Table 6.

## DISCUSSION

Some frequencies are absorbed when infrared radiation passes through a sample of an organic compound; however, some frequencies are transmitted through the sample without any absorption. Absorption of infrared radiation is associated with. vibrational changes occurring within the molecule caused by infrared radiation. Therefore, infrared spectroscopy can be characterized as vibrational spectroscopy. Different bonds (C–C, C=C, C–C, C–O, C=O, O–H, and N–H) have different vibrational frequencies. If such bonds are present in an organic molecule, they can be detected by determining the characteristic frequency absorption band in the infrared spectrum[22]. Fourier transform infrared spectroscopy (FTIR) is a high-resolution analytical tool for detecting chemical components and

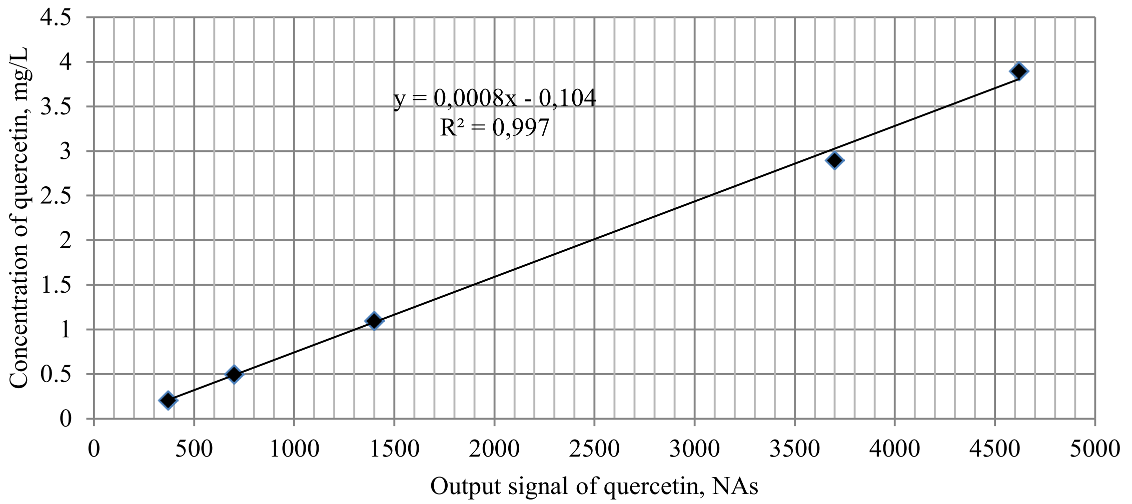


**Figure 7.** Dependence of quercetin output signal on concentration

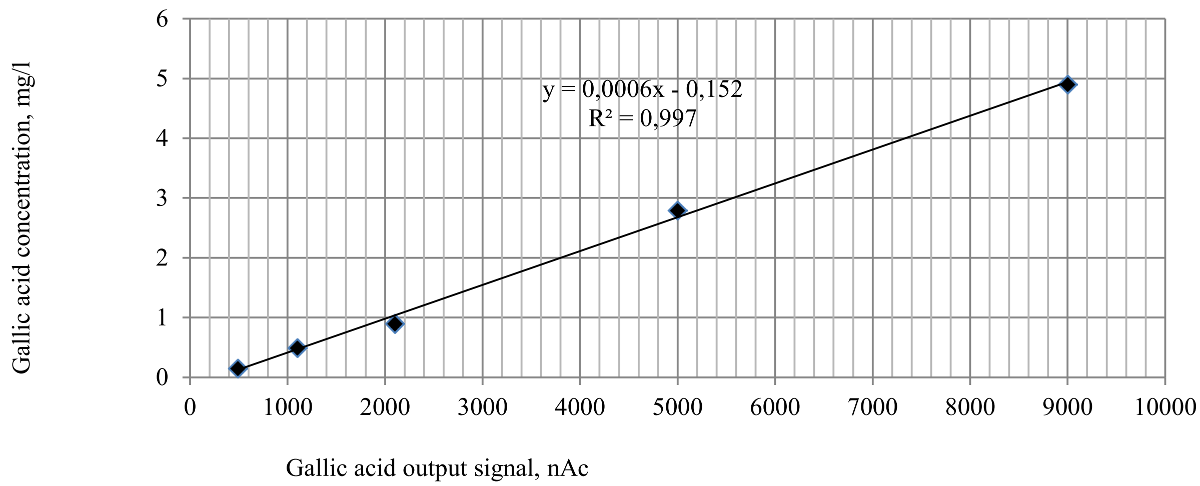


**Figure 8.** Dependence of the output signal of Gallic acid on concentration

**Table 6.** Total content of antioxidants in 70% ethanol extracts of C. sordida and **S. alpina**

| Subject of research | Antioxidant content, calculated as quercetin (mg/g) | Antioxidant content, calculated as gallic acid (mg/g) |
|---|---|---|
| 70% ethanol extract of S. alpina | 0,125 ± 0,005 | 0,088 ± 0,006 |
| 70% ethanol extract of C. sordida | 0,056 ± 0,007 | 0,043 ± 0,008 |

Table 7 Identified bioactive compounds from S. sordida and S. alpina aerial part through the GC–MS technique

| Name of the Compound | Sature of the Compound | Activity | Reference |
|---|---|---|---|
| (+)-2-Bornanone | Monoterpene oxide | Antitumor, Analgesic Antibacterial, Anti-inflammatory Sedative, Fungicide, Anticancer. | [24] |
| phytol | diterpene | Antimicrobial, Antibacterial, Anticancer, Anti-inflammatory, antioxidant, | [25] |
| 2-pentadecanone | Ketone | Anti-Inflammatory, Antioxidant And Antiulcer Activities | [26] |
| 2,4-dimethyl-2,4-pentanediol | chiral diol | Antimicrobial, | [27] |
| eudesm-4(14)-en-11 | Sesquiterpenes | Antioxidant, Antimicrobial, and Cytotoxic | [28] |
| 5-eocosene,(E)- | Alken | Enzyme inhibition antioxidant | [29] |
| hexacosane | Alkane | Antimicrobial | [30] |

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detecting structural compounds. FTIR offers rapid and non-destructive testing of herbal extracts or powders[23-24].

The ethanol extracts from S.sordida and S. alpina was shown to have several bioactive components that were confirmed by FTIR spectroscopy, including alcohol, carboxylic acid, phenolic acids, and aromatic compounds. the functional groups identified from the ethanoic extract are shown in Table 2, 3 and Figure 3, 4. The powerful instance peak is located at peak number 3329, which assigns the NH stretch. The biologically active substances and their derivatives important constituents of plants and are commonly known to possess various medicinal properties. Especially they are known to have antimicrobial and antibacterial activities and the next generation of medications that can be used to treat different illnesses caused by pathogens could be replaced with terpens and their derivatives.

In the present study, (+)-2-Bornanone, phytol, 2-pentadecanone,6,10,14-trimethyl, 2,4-dimethyl-2,4-pentandiol, eudesm-4(14)-en-11-ol, hexacosane are the lead compounds showing among the subjected bioactive compounds. The biologically active substances of this extracts, have antibacterial, antimicrobial, antioxidant and anti-inflammatory activity (Table 7). Thus, we want to draw attention to the fact that this circumstance indicates that this plants speciese is a potential raw material for drug development.

Thus, the proposed schemes for determination of the above organic substances in various objects by GC-MS methods provide high accuracy and reliability of determination of the determined substances and can be used for determination of some products of plant origin. The possibility of practical application of the identified marker compounds for authentication and quality control of dietary supplements is shown. On the basis of the obtained data it is established, one hundred of two plant species (S. sordida, S. alpine) contain a number of specific markers that allow their unambiguous identification.

In recent years, a connection has been established between the growth of free radicals (superoxide anion radical, hydro-peroxide radical, hydrogen peroxide, hydroxyl radical, etc.) in human biological fluids with the occurrence of dangerous diseases, in particular cardiovascular, cancer, diabetes, etc. Premature aging is also associated with an increase in the number of free radicals. To reduce the level of free radicals in human biological fluids, it is recommended to consume daily foods, medications, dietary supplements and drinks containing natural antioxidants, in particular fruits, berries, vegetables, vegetable oils, tea, honey, etc. Regular preventive consumption of the appropriate level of antioxidants will restore the body's antioxidant status to normal and maintain health and a full life expectancy.

The amperometric method is based on measuring the electric current that arises during the oxidation of the substance under study (or a mixture of substances) on the surface of the working electrode, which is under a certain potential. It is known that the amperometric method of analysis has a number of advantages: a low detection limit, high selectivity (only compounds whose molecules can be oxidized are determined; other compounds present even in high concentrations are not determined), small cell volume (0.1-5 µl) , simplicity of maintenance. The presence of antioxidants was determined using an in vitro calculation method. Their total content in the analyzed extracts was determined using the peak areas of differential curves, which reflected the dependence of the output signal on the concentration of the sum of phenolic compounds in terms of quercetin or gallic acid.

The plant objects studied in this work contain significant amounts of biologically active substances, including phenolic compounds, which have antioxidant properties. As can be seen from Table 6, the antioxidant activity results of medical plants showed that S. alpine extract has more activity than S. sordida extracts in results of both methods (content of antioxidants in terms of quercetin and gallic acid). The 70% ethanol extract of S. alpina: quercetin - 0,125 ± 0,005 mg/g; gallic acid - 0,088 ± 0,006 mg/g.

## CONCLUSION

The main range of vibrations of molecules, called "mid-infrared", lies between wave numbers from 4000 to 400 cm-1. Absorption bands reflecting the general chemical composition were found in all spectra of the studied samples. Through the use of FT-IR and GC–MS techniques in this investigation, it was shown that the observed biological ac-tivities came at the expense of the plant's rich phytochemical content. Further studies are necessary to isolate pure biologically active compounds responsible for the noticed biological potentials. The antioxidant activity results of medical plants showed that S. alpine extract has more activity than S. sordida extracts in results of both methods (content of antioxidants in terms of quercetin and gallic acid).

## AUTHOR CONTRIBUTIONS

Conceptualization, Zh.K.; writing—original draft preparation, A.T.; methodology, A.K., K.R.; Formal analysis K.O., S.O., .investigation Zh.S., F.K., supervision, R.O.; project administration, R.K, S.O.; funding acquisition, A.K., validation S.O. K.R. All authors have read and agreed to the published version of the manuscript.

## CONFLICTS OF INTEREST

The authors declare no competing interests.

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