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Antimicrobial Activity and Composition of *Rindera lanata* (LAM.) Bunge var. *canescens* (A.D.C.) Kosn. Essential oil Obtained by Hydrodistillation and Microwave Assisted Distillation

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Abstract: The composition of essential oils of *Rindera lanata* (LAM). Bunge var. *canescens* (A.D.C) Kosn. obtained by hydro-distillation (HD) and microwave assisted distillation (MW) by GC, GC/MS. Thirty three and thirty nine compounds were identified in the oils representing 81.20% and 78.57% of the oils obtained by HD and MW respectively. Aldehydes were shown to be the main group of constituents of the MW 40.11% and 15.23%, respectively. However, the major group in the HD was found to be 25.35% alcohols and 23.78% hydrocarbons. 6-Methyl heptan-2-ol (15.97%) was the main compound of the HD. Furthermore, in the MW assisted essential oil, the major compound present was decane (10.50%). Terpenoid class compounds were found in essential oils and oxygenated monoterpenes were determined as major group (13.34% and 7.19%). Antimicrobial activity of the isolated essential oils of the plant was also investigated and they showed moderate antimicrobial activity against the tested microorganisms.

Keywords: Boraginaceae; *Rindera lanata*; hydro-distillation; microwave; essential oil. © 2017 ACG Publications. All rights reserved.

1. Plant Source

The genus *Rindera pallas*. (Boraginaceae) comprises 25 species, mainly in central and western Asia [1]. All species of this genus are widespread in Anatolia, Iran, Iran-Azerbaijan, Iraq and Transcaucasus [2-4]. Rindera genus is represented by 4 species comprising 5 taxa including two endemics in Turkey [5]. One of these is *Rindera dumanii* diagnosed by H. Duman, which only grows in Beyşehir, Ankara, in the village of Akseki [5,6]. *Rindera caespitosa* is also found in Erzurum, Turkey [7,8]. Furthermore, *Rindera gracea* is an endemic plant growing South-East Europe, the Mediterranean Basin and founds a natural habitatoin rocky terrain of Greece [1,9].

Plant material and isolation of the essential oil *Rindera lanata* (Lam.) Bunge var. *canescens* (A.D.C) Kosn. (Boraginaceae) was collected in June 2011 from grassland and meadow areas in

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Aydintepe-Bayburt, Turkey (at altitudes of ~1540 m) in the northeastern part of Turkey. The plant was authenticated by Salih Terzioglu and voucher specimens were deposited at KTU, Herbarium of the Faculty of Forestry, KATO (KATO 8764), Karadeniz Technical University, Turkey.

R. lanata var. *canescens* is a perennial gramineous plant, growing in meadows, on grassland and volcanic slopes (\sim ca.1300-3500m) [7]. In Turkey, when in flower, *R. lanata* (Lam.) var. *canescens* has a white fuzz and purple-pink fruit, the leaves of which are covered with a medium down [10].

2. Previous Studies

Rindera pallas. (Boraginaceae) genus is generally known to be a rich source of pyrrolizidine alkaloids (PAs) group of secondary metabolites [11,13]. In previous work, it has been established that PAs have a neurotoxic, mutagenic, carcinogenic and antitumor activities [14,15]. The Boraginaceae family, which includes 455 genus and 9551 species, has abundant fatty acids [16,18]. Fatty acids, the most important fatty acids of which are Omega 3 and Omega 6, are major sources of energy and they are the initiators of essential substances in the body (structural and functional) [18].

The aim of this study is that whether *R. lanata* var. *canescens* has biological activity or not because of the biological activity results from the PAs in the *Rindera* genus. In this study, essential oils obtained with two different ways (HD and MW) are compared, in order to find the best methods for identifying much more compound from *R. lanata* var. *canescens*. The palynological contribution to the system of *Rindera* genus was performed in previous work [1]. There is a study about FAs values and lipids, lipophilic components in the essential oils of *R. pallas* genus [19]. In previous studies about *Rindera oblongifolia* was worked the acids of triglycerides of the seed oil and lipids from fruit [20,21]. No study has been found concerning the essential oil composition obtained from HD and MW assisted distillation and antimicrobial activity of *R. lanata* var. *canescens*.

3. Present Study

The fresh aerial parts (170g and 165g) of *R. lanata* var. *canescens* were subjected to hydro-distillation in a modified Clevenger type apparatus and microwave assisted distillation.

In the hydro-distillation Clevenger type apparatus was used for 4 h to produce oil and in the microwave distillation was carried out at atmospheric pressure using Milestone DryDIST microwave apparatus with a fixed power of 600 W at 110 °C (40 minute). Previously an infrared (IR) sensor had been used to control the temperature [22,24].

Each plant was placed in the bottom of the Clevenger-type apparatus in a cooling bath (-15 °C) and MW resistant flask of Clevenger type apparatus (yields v/w: 0.04 and 0.09%) with 50 mL water, respectively. The oils were extracted with HPLC grade *n*-hexane (0.5 mL) and dried over anhydrous sodium sulfate and stored in sealed vials at 4-6 °C before analysis by GC/FID and GC/MS.

Gas chromotography (GC) and Gas chromotgraphy-mass spectrometry (GC/MS); The capillary GC/FID and GC/MS analyses were performed using Agilent-5973 Network System, equipped with a FID (supplied with air and hydrogen of high purity) and a split inlet. HP-5 capillary column ($30m \times 0.32$ mm i.d., film thickness 0.25μ m). Helium was used as carrier gas, at a flow rate of 1mL/min. The injections were performed in splitless mode at 230 °C. Two µicrolitres of essential oils solutions in hexane (HPLC grade) was injected and analysed with

Table 1. Identified components and the chemical class distribution in the essential oils of *R*. lanata var. canescens.

Norane 96 Area ⁴ EX.R ^b EX.R ^b EX.R ^b 1 Norane - 2.92 - 901 900 [26] 2 6-Methyl heptan-2-01 15.97 - 958 - 905 [26] 3 2-Pentyl furan - 2.01 -S 989 991 [26] 5 Decane 1.59 - 0.004 - 1000 [25] 6 (22.4E)-Heptadicnal - 0.80 - 1004 1000 [26] 7 2-Prineylacetaldebyde 1.74 3.26 1046 1043 1042 [26] 9 Linalool 2.03 - 1074 - 1086 1155 [26] 10 Nonanal 3.15 7.20 1105 1103 1102 [26,30] 11 (26,2C)Nonadienal - 2.67 - 1137 1169 [26,30] 14 Dodocane - 0.39		Compounds	А	В	А	В	Lit.	Lit Ref
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$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	22	(2E, 4E)-Decadienal	-	1.34	-	1318	1317	[26,29]
24 (Z)-Jasmone - 0.37 - 1393 1393 [26] 25 Dodecanal - 2.30 - 1405 1409 [26] 26 Geranyl acetone 0.37 0.48 1458 1447 1455 26,27 27 (E)-β-tonone 1.25 2.05 1482 1485 1489 [26] 28 Pentadecane - 0.41 - 1495 1500 [26] 30 Tetradecanal 0.34 1.01 1618 1613 [26] 30 Tetradecane - 0.49 - 1704 1700 [26] 31 Heptadecane - 0.45 - 1798 1800 [26] 32 (2E)-Tetradecen-1-ol 2.84 - 1721 - 1715 [25] 33 Octadecane 0.98 1.57 1895 1847 1848 [25] 34 Hexahydrofarnesyl acetone 0.46 0.71 1910 1911 1915 [27] 35 H	23	(E) - β -Damascenone	0.66	-	1380	-	1385	[26]
25 Dodecanal - 2.30 - 1405 1409 [26] 26 Geranyl acetone 0.37 0.48 1458 1447 1455 26,27 7 (E)-β-Ionone 1.25 2.05 1482 1485 1489 [26] 28 Pentadecane - 0.41 - 1495 1500 [26] 29 Tridecanal 0.39 2.64 1506 1510 [26] 30 Tetradecane - 0.49 - 1704 1700 [26] 31 Heptadecane - 0.49 - 1704 1700 [26] 32 (2E)-Tetradecen-1-ol 2.84 - 1721 - 1715 [25] 33 Octadecane - 0.45 - 1798 1800 [26] 34 Hexabydrofarnesyl acetone 0.72 0.58 1855 1847 1848 [25] 36 Nonadecane 0.78 1.07 1930 1944 1938 [26] 37 Farne	24	(Z)-Jasmone	-	0.37	-	1393	1393	[26]
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27 (<i>E</i>)- <i>F</i> -fonone 1.25 2.05 1482 1485 1489 [26] 28 Pentadecane - 0.41 - 1495 1500 [26] 29 Tridecanal 0.39 2.64 1506 1510 [26] 30 Tetradecane - 0.49 - 1704 1700 [26] 31 Heptadecane - 0.45 - 1798 1800 [26] 32 (2 <i>E</i>)-Tetradecen-1-ol 2.84 - 1721 - 1715 [25] 33 Octadecane - 0.45 - 1798 1800 [26] 34 Hexadecanal - 1.23 - 1815 1814 [27] 35 Hexahydrofarnesyl acetone 0.72 0.58 1855 1847 1848 [26] 36 Nonadecane 0.98 1.57 1895 1897 1900 [26] 37 Farnesyl acetone 0.30 0.56 2002 2000 2001 [26] 40	26	Geranyl acetone	0.37	0.48	1458	1447	1455	26,27
28 Pentadecane - 0.41 - 1495 1500 [26] 29 Tridecanal 0.39 2.64 1506 1506 1510 [26] 30 Tetradecanal 0.34 1.01 1618 1618 1613 [26] 31 Heptadecane - 0.49 - 1704 1700 [26] 32 (2E)-Tetradecen-1-ol 2.84 - 1721 - 1715 [25] 33 Octadecane - 0.45 - 1798 1800 [26] 34 Hexadecanal - 1.23 - 1815 1814 [27] 35 Hexahydrofarnesyl acetone 0.72 0.58 1855 1847 1848 [25] 36 Nonadecane 0.98 1.57 1895 1897 1900 [26] 37 Farnesyl acetone 0.46 0.71 1910 1911 1915 [27] 38 Methyl hexadecanoate 0.30 0.34 2008 2000 193 [26] <	27	(E) - β -lonone	1.25	2.05	1482	1485	1489	[26]
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30 Tetradecanal 0.34 1.01 1618 1618 1613 $[26]$ 31 Heptadecane - 0.49 - 1704 1700 $[26]$ 32 $(2E)$ -Tetradecen-1-ol 2.84 - 1721 - 1715 $[25]$ 33 Octadecane - 0.45 - 1721 - 1715 $[25]$ 34 Hexadecanal - 1.23 - 1815 1814 $[27]$ 35 Hexahydrofarnesyl acetone 0.72 0.58 1855 1847 1848 $[25]$ 36 Nonadecane 0.98 1.57 1895 1897 1900 $[26]$ 37 Farnesyl acetone 0.78 1.07 1930 1944 1938 $[26]$ 40 Ethyl hexadecanoate 0.30 0.34 2008 2000 1933 $[26]$ 41 Methyl hexadecanoate 0.30 0.34 2008 2000 193 $[26]$ 43 Y-Linolenic ac	29	Tridecanal	0.39	2.64	1506	1506	1510	[26]
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35 Hexahydrofarnesyl acetone 0.72 0.58 1855 1847 1848 [25] 36 Nonadecane 0.98 1.57 1895 1897 1900 [26] 37 Farnesyl acetone 0.46 0.71 1910 1911 1915 [27] 38 Methyl hexadecanoate 0.78 1.07 1930 1944 1938 [26] 39 Eicosane 1.30 0.56 2002 2002 2000 [26] 40 Ethyl hexadecanoate 0.30 0.34 2008 2000 1993 [26] 41 Methyl linoleate 0.44 4.24 2100 2095 [26,30] 42 Heneicosane 0.39 0.71 2106 2101 2100 [26] 43 γ-Linolenic acid methyl ester 2.25 - 2109 - 2101 [30] 44 Ethyl linoleate 0.66 1.42 2170 2172 [30] 45 Docosane 10.62 3.72 2201 2196 2200 [26, 31]	34	Hexadecanal	-	1.23	-	1815	1814	[27]
36 Nonadecane 0.98 1.57 1895 1897 1900 [26] 37 Farnesyl acetone 0.46 0.71 1910 1911 1915 [27] 38 Methyl hexadecanoate 0.78 1.07 1930 1944 1938 [26] 39 Eicosane 1.30 0.56 2002 2000 [26] 40 Ethyl hexadecanoate 0.30 0.34 2008 2000 1993 [26] 41 Methyl linoleate 0.44 4.24 2100 2095 [26,30] 41 Methyl linoleate 0.44 4.24 2100 2095 [26] 43 γ -Linolenic acid methyl ester 2.25 - 2109 - 2101 [30] 44 Ethyl linoleate 0.66 1.42 2170 2172 [30] 45 Docosane 10.62 3.72 2201 2196 2200 [26, 31] 46 Tricosane 1.25 3.98 2502 2502 2500 [26, 31] 47	35	Hexahydrofarnesyl acetone	0.72	0.58	1855	1847	1848	[25]
37 Farnesyl acetone 0.46 0.71 1910 1911 1915 $[27]$ 38Methyl hexadecanoate 0.78 1.07 1930 1944 1938 $[26]$ 39Eicosane 1.30 0.56 2002 2002 2000 $[26]$ 40Ethyl hexadecanoate 0.30 0.34 2008 2000 1993 $[26]$ 41Methyl linoleate 0.44 4.24 2100 2095 2095 $[26,30]$ 42Heneicosane 0.39 0.71 2106 2101 2100 $[26]$ 43 γ -Linolenic acid methyl ester 2.25 - 2109 - 2101 $[30]$ 44Ethyl linoleate 0.66 1.42 2170 2170 2172 $[30]$ 45Docosane 10.62 3.72 2201 2196 2200 $[26, 31]$ 46Tricosane 1.44 3.20 2293 2305 2300 $[26, 31]$ 47Tetracosane 6.22 2.38 2397 2400 2400 $[26, 31]$ 48Pentacosane 1.25 3.98 2502 2502 2500 $[26, 31]$ 48Pentacosane 15.24 40.11 Hydrocarbons 23.78 22.79 Ester 5.12 7.92 79.570 79.570	36	Nonadecane	0.98	1.57	1895	1897	1900	[26]
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40Ethyl hexadecanoate0.300.34200820001993[26]41Methyl linoleate0.444.24210020952095[26,30]42Heneicosane0.390.71210621012100[26]43 γ -Linolenic acid methyl ester2.25-2109-2101[30]44Ethyl linoleate0.661.42217021702172[30]45Docosane10.623.72220121962200[26,31]46Tricosane1.443.20229323052300[26,31]47Tetracosane6.222.38239724002400[26,31]48Pentacosane1.253.98250225022500[26,31]48Pentacosane15.2440.11Hydrocarbons23.7822.7923.7822.79Ester5.127.927.924lcohols25.351.31	39	Elcosane	1.30	0.56	2002	2002	2000	[26]
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$\begin{array}{cccccccccccccccccccccccccccccccccccc$	44	Etnyl linoleate	0.66	1.42	2170	2170	21/2	[30]
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48 Pentacosane 1.25 3.98 2502 2502 2500 [26, 31] Terpenoids 13.34 7.19 Aldehydes 15.24 40.11 Hydrocarbons 23.78 22.79 Ester 5.12 7.92 Alcohols 25.35 1.31	4/	1 etracosane	0.22	2.38	2397	2400	2400	[20, 31]
I erpenoids 13.34 7.19 Aldehydes 15.24 40.11 Hydrocarbons 23.78 22.79 Ester 5.12 7.92 Alcohols 25.35 1.31 Tatal 81.200 78.570	48	Pentacosane	1.25	3.98	2502	2502	2500	[26, 31]
Aidenydes 15.24 40.11 Hydrocarbons 23.78 22.79 Ester 5.12 7.92 Alcohols 25.35 1.31		1 erpenoids	13.34	/.19				
Hydrocarbons 23.78 22.79 Ester 5.12 7.92 Alcohols 25.35 1.31		Aldehydes	15.24	40.11				
Ester 5.12 7.92 Alcohols 25.35 1.31 Tatal 81.200 78.570		Hydrocarbons	23.78	22.79				
Alconois 25.55 1.31		Ester	5.12	1.92				
		Alcohols	25.35	1.51				

A: Hydro-distillation B: Microwave distillation. ^a% Area obtained by FID peak-area normalization.

^bRI calculated from retention times relative to t hat of *n*-alkanes (C_5 - C_{32}) on the non-polar HP-5 column.

Lit.Ref.: Literatur References.

the column held initially at 60 °C for 2 min and then increased to 240 °C with a 3 °C/min heating ramp. The identify of each compound was supported by comparing their indices (RI) with published values [25-31]. The percentage compositions of the oils were computed from GC peak areas without using correction factors. A mass spectrometer with an ion trap detector in full scan mode under electron impact ionization (70 eV) was used. The chromatographic column is same as GC/FID. Helium was used as carrier gas, at a flow rate of 1mL/min. The injections were performed in splitless mode at 230 °C. Two µicrolitres of essential oils solutions in hexane (HPLC grade) was injected and analysed with the column held initially at 60 °C for 2 min and then increased to 240 °C with a 3 °C/min heating ramp.

The constituents of the essential oils were carried out by a comparison of their retention indices (RI) of the using *n*-alkanes (C_5 - C_{32}) as the standards and their mass spectra with those of mass spectral libraries (NIST and WILEY) and literature comparison [25-31]. The GC peak area values from the HP-5 column separation were evaluated to find the ratio of the components of each of essential oils.

Chemical compositions, their percentage and experiment retention indices (RI) and literature retention indices (RI) are presented in Table 1. The main components in the hydrodistillation are 6-methyl heptan-2-ol (15.97%); docosane (10.62%); tetracosane (6.22%); linalool (5.40%) and α -terpineol (2.67%), in the MW assisted distillation decanal (10.50%); nonanal (7.20%); methyl linoleate (4.24%); linalool (2.54%) and (*E*)- β -ionone (2.05%). The hydro-distillation oil identified the presence of 33 compounds, representing 81.20% of the total oil, while 39 components were shown in the MW assisted distillation, accounting 78.57% of the total oil.

The chemical class distributions of the essential components are listed in Table 1. All of compounds were classified into five classes, which are terpenoids, aldehydes, hydrocarbons, esters and alcohols. The major components were alcohols in HD and MW (25.35% and 1.31%), hydrocarbons (23.78% and 22.79%) and aldehydes (15.24% and 40.11%), respectively. Moreover, the value of determined terpenoids (oxygenated monoterpene, oxygenated sesquiterpene) was 13.34% and 7.19%, respectively.

Also, it is known rich in terms of fatty acids of *Rindera* genus, but in this study the ratio of esters is fairly low according to other components classes (5.12% and 7.92%). The major components of esters are γ -linoleic acid methyl ester (2.25% in HD), methyl linoleate (4.24%) and ethyl linoleate (1.42%) in the MW assisted distillation.

As can be seen from the previous data, there are differences in the results regarding esters in the *Rindera* genus. This result is normal because environmental factors affect the chemical composition of the essential composition. According to these data, in terms of the types of components, essential oils are different; however, there is not much difference between the two methods in terms of number of compounds (33 and 39).

The antimicrobial effects of the substances were tested quantitatively in broth media, using double microdilution and the minimal inhibition concentration (MIC) values (μ g/100 mL) were determined, respectively [32]. The essential oils of *R. lanata var. canescens* were tested for antimicrobial activity using the agar-well diffusion method. The microorganism and antimicrobial activities of essential oils are shown in Table 2.

While Boraginaceae family contain PAs group have activities neurotoxic, mutagenic, carcinogenic and antitumor activities, *R. lanata var. canescens* don't showed significant biological activity. But it was established that in high concentrations they have a strong antimicotic effect only against *C. albicans* bacteria.

Hexane with a dilution of 1:10 was used as solvent control, by using ampicillin and fluconazole as standard antibacterial and antifungal agents [33]. All test microorganisms were

obtained from the Hifzissihha Institute of Refik Saydam (Ankara, Turkey). All the newly extracted compounds were weighed and dissolved in hexane to prepare an extract stock solution of between 489-107200 microgram/milliliter (μ g/100mL).

Table 2. Screening for antimicrobial activity of essential oil in *R. lanata* (Lam.) Bunge var. canescens Kosn. (μg/ 100mL)

Sample	Stock sol.	Microorganisms and Minimal Inhibition Concentration							
	$(\mu g/mL)$	Ec	Yp	Pa	Sa	Ef	Bc	Ms	Ca
R.lanata MW	4890	-	-	-	-	-	-	-	611.2
R.lanata HD	11690	-	-	-	-	-	-	-	584.5
Ampicilin	10	2	32	>128	2	2	<1		
Streptomisin	10							4	
Fluconazole	5								<8

Escherichia coli (E. coli) ATCC35218, Yersinia pseudotuberculosis (Y. pseudotuberculosis) ATCC911, Pseudomonas aeruginosa (P. aeruginosa) ATCC43288, Enterococcus faecalis (E. faecalis) ATCC29212, Staphylococcus aureus (S. aureus) ATCC25923, Bacillus cereus (B.cereus) 709 Roma, Mycobacterium smegmatis (M. smegmatis) ATCC607 and Candida albicans (C. albicans) ATCC60193.

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References

- [1] M. Bigazzi, E. Nardi and F. Selvi (2006). Palynological contribution to the systematics of *Rindera* and the allied genera *Paracaryum* and *Soleanthus* (Boraginaceae Cynoglosseae), *Willdenowia* **36**, 37-46.
- [2] R.R. Mill (1977). Materials for a flora of Turkey XXXIV: *Boraginaceae, Gentianaceae, Solanaceae,* In: Notes Roy. Bot. Gard., *ed*: P. H. Davis, Edinburgh **35**, pp.303-308.
- [3] R.R. Mill (1979). *Rindera pallas*, In: Flora of Turkey and the East Aegean islands, *ed:* P.H. Davis, Edinburgh **6**, 282-305.
- [4] H. Riedl (1967). Boraginaceae, In: Flora Iranica Lieferung, *ed:* K.H. Rechinger, Akademische Druck-u. Verlagsanstalt, Graz, pp.48.
- [5] S.T. Körüklü (2012). Rindera Pallas, In: Türkiye Bitkileri Listesi (Damarlı Bitkiler), Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmalar Derneği Yayını, *ed:* A. Güner, S. Aslan, T. Ekin, M. Vural, M.T. Babaç, İstanbul, pp.243.
- [6] Z. Aytaç and R.R. Mill (2005). Two new species of *Boraginaceae* (Tribe *Cynoglosseae*) from Turkey, *Edinburgh J. Bot.* **61** (**2&3**), 109–118.
- [7] Bge., (1851), Mém. Acad. Imp. Sci. St. Petersb. 7, 415.
- [8] [cited 28/06/2016]. Netherlands Species 2000 & ITIS Catalogue of Life [Web Page] 2016; Available from: http://www.catalogueoflife.org/col/search/all/key/rindera+/fossil/0/match/1.
- [9] A. Strid and K. Tan (1991). Mountain Flora of Greece, Edinburgh University Press 2, 64-65.
- [10] M. T. Babac (2004). Possibility of an information system on plants of South-West Asia with particular reference to the Turkish Plants Data Service (TÜBİVES), *Turk J. Bot*. **28**, 119-127.
- [11] L.W. Smith, C.J. Culvenor (1981). Plant sources of hepatoxic pyrrolizidine alkaloids, *J. Nat. Prod*. 44, 129–152.
- [12] M. Dreger, M. Stanisławska, M. Krajewska-Patan, S. Mielcarek, P. Łukasz Mikołajczak and W. Buchwald (2009). Pyrrolizidine alkaloids-Chemistry, biosynthesis, pathway, toxicity, safety and perspectives of medicinal usage, *Herba Pol*. 55, 127–147.
- [13] M.M. Boris, R.S. Milena, M.V. Ivan, V.V. Ljubodrag, M.N. Miroslav, S.T. Snežana, D.N.M Snežana, V.T. Vele, V.V. Vlatka and M.M. Slobodan (2013). Pyrrolizidine alkaloids and fatty acids from the endemic plant species *Rindera umbellata* and the effect of lindelofine-N-oxide on tubulin polymerization, *Molecules* 18, 10694-10706.
- [14] A. Ivanova, J. Serly, V. Christov, B. Stamboliyska and J. Molnar (2011). Alkaloids derived from genus Veratrum and Peganum of Mongolian origin as multidrug resistance inhibitors of cancer cells, *Fitoterapia* 82, 570–575.
- [15] E. Roeder (1999). Analysis of pyrrolizidine alkaloids, *Curr. Org. Chem*. **3**, 557–576.

- [16] R.W. Miller, F.R. Earle, I.A. Wolff and A.S. Barclay (1968). Search for new seed oils, XV. Oils of Boraginaceae, *Lipids* **3**, 443–445.
- [17] K. Saburo and U. Sei-ichi (1937). A new unsaturated fat acid, C₁₀H₁₈O₂, present in the oil of *Rindera obtusiloda Bull.*, *Chem. Soc. Jpn*. **12**, 226.
- [18] N.K. Yuldasheva, N.T. Ulchenko and A.I. Glushenkova (2012). Lipids from fruit of *Rindera oblongifolia*, *Chem. Nat. Compd.* **47**, 981–982.
- [19] S.A. Shakhnoza and A.I. Glushenkova (2012). In: Lipids, Lipophilic Components and Essential Oils from Plant Sources, Springer Science-Business Media, LLC **2**, pp.168.
- [20] É.I. Gigienova, A. Akramova and A.U. Umarov (1977). The seed oil of *Rindera oblongifolia*, *Chem. Nat. Compd.* **12(1)**, 21-24.
- [21] A.I. Glushenkova, N.T. Ul'chenko and N.K. Yuldasheva (2012). Lipids from fruit of *Rindera* oblongifolia, Chem. Nat. Compd. 47(6), 981-982.
- [22] T.B. Cansu, M. Yucel, K. Sinek, C. Baltaci, Ş. A.Karaoğlu and N. Yayli (2011). Microwave assisted essential oil analysis and antimicrobial activity of *M.alpestris* subsp. Alpestris, *Asian. J. Chem.* 23(3), 1029-1031.
- [23] D.C.J. Asghari, C.K. Touli and M. Mazaheritehrani (2012). Microwave-assisted hydrodistillation of essential oils from *Echinophora platyloba*, *J. Med. Plants Res.* 6(28), 4475-4480.
- [24] G.A. Cardoso-Ugarte, G.P. Juárez-Becerra, M.E. SosaMorales, A. López-Malo (2013). Microwaveassisted extraction of essential oils from Herbs, *J. Microwave Pow. Electromagn. Ener.* **47** (1), 63-72.
- [25] H. Shamkhani, N. Nasiri, A. Aliahmedi and A. Sanboli (2016). Essential oil composition and antimicrobial activity of *Tanacetum hololeucum* from Iran, *Rec. Nat. Prod.* **10:6**, 818-823.
- [26] R.P. Adams (2004). Identification of essential oil components by gas chromatography/mass Spectrometry. 4th Ed., Allured publishing Corp., Carol Stream, Illinois. 1-698.
- [27] N. Yaylı, A. Yaşar, N. Y.İskender, N. Yaylı, T.B. Cansu, K. Coskunçelebi and Ş. Karaoğlu (2010). Chemical constituents and antimicrobial activities of the essential oils from *Sedum pallidum var. bithynicum* and *S.spurium* Grown in Turkey, *Pharm. Biol*. **48**(2), 191-194.
- [28] N. Kahriman, Z. Şenyürek, V. Serdaroğlu, A. Kahriman and N. Yaylı (2015). Chemical composition and biological activity of essential oils of *Sempervivum brevipilum* Muirhead, *Rec. Nat. Prod.* **9(4)**, 603-608.
- [29] T.B. Cansu, B. Yaylı, T. Özdemir, N. Batan, Ş. A.Karaoğlu, N. Yaylı (2013). Antimicrobial activity and chemical composition of the essential oils of mosses *Hylocomium splendens* (Hedw.) Schimp. and *Leucodon sciuroides* (Hedw.) Schwagr. growing in Turkey, *Turkish J. of Chem.* **37**(13), 213 219.
- [30] D. Kremer, V. Matevski, V. Dunkić, N. Bezi and E Stabentheiner (2016). Essential oil contents and micromorphological traits of *Stachys iva* Griseb. and *S. horvaticii* Micevski (Lamiaceae), *Rec. Nat. Prod.* **10**, 228-239.
- [31] S.D. Hatipoglu, N. Hatipoglu, T. Dirmenci, A.C. Goren, T. Ozturk and G. Topcu (2016). . Determination of volatile organic compounds in forty five *Salvia* species by thermal desorption-GC-MS technique, *Rec. Nat. Prod.* **10**, 659-700.
- [32] CLSI. Clinical and Laboratory Standards Institute (1999). Methods for Determining Bactericidal Activity of Antimicrobial Agents, Approved Standard-Seventh Edition, 26-A, 19(18).
- [33] CLSI. Clinical and Laboratory Standards Institute (2003). Susceptibility testing of mycobacteria, nocardiae, and other aerobic actinomycetes, Approved Standard- Second Edition, 24-A, **23**(18).



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