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Composition of essential oil of leaves and fruits of green strawberry (*Fragaria viridis* Weston) growing wild in Northern Kazakhstan

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Summary

Fragaria viridis Weston essential oils from leaves and fruits were obtained by hydrodistillation. The composition of the essential oil from leaves and fruits was analyzed by GC-MS. 39 components were identified in leaves oil representing 67.3-80.7% of the oil composition. The main components of the essential oil from leaves of *F. viridis* were β-linalool (0.8-8.9%), *n*-nonanal (0.5-8.6%), tetradecanal (2.1-5.9%), nerolidol (2.1-4.8%), an unidentified component (1.9-6.6%), α-bisabolol (0.8-6.7%), phytol (18.4-47.4%), an unidentified component (0.9-8.2%) depending on the growth conditions. The fruit oil was composed of 34 compounds representing 42.0-70.7% of the total composition of the oil. The main components of the essential oil from fruits of *F. viridis* were *m*/*p*-xylene (2.4-14.0%), isoledene (4.7-8.5%), methyleugenol (3.3-8.4%), α-cedrene (2.5-3.9%), an unidentified component (3.4-9.1%), α-muurolene (6.8-11.3%), nerolidol (1.1-4.8%), α-cedrol (1.7-8.0%), α-bisabolol (2.3-5.0%), an unidentified component (0-25.6%) depending on the growth conditions. This is the first report of the chemical composition of the essential oils obtained from the leaves and fruits of green strawberry (*Fragaria viridis* Weston).

Key words: *Fragaria viridis* Weston; Green strawberry; Rosaceae; Leaves and fruits; Essential oil composition

Introduction

Genus *Fragaria* L. belongs to the family Rosaceae, subfamily Rosoideae and includes 24 species (POTTER et al., 2007; STAUDT, 2009; HUMMER et al., 2011). The genus *Fragaria* is included in the International Treaty on Plant Genetic Resources for Food and Agriculture for conservation and sustainable use of plant genetic resources for food and agriculture according to Food and Agriculture Organization of the United Nations (FAO, 2009).

There are 2 species - *Fragaria vesca* L. and *Fragaria viridis* Weston in Kazakhstan (PAVLOV, 1961).

Fragaria vesca L. occurs in a forest zone and is studied carefully. *Fragaria viridis* Weston grows in aspen and birch splittings, on open grassy mountainous slopes, margins and glades of mountainous forests, meadows and meadow steppes (PAVLOV, 1961). *Fragaria viridis* Weston is distributed in Europe and Asia: Western and Eastern Europe, except Portugal and a bigger part of Spain, Southern Mediterranean, the Baltic States, Belarus, Ukraine, Moldavia, Caucasia, European part of the Russian Federation, Western and Eastern Siberia, the Urals, Central Asia (PAVLOV, 1961), the Tianshan Mountains, Xinjiang, Northwest of China (JIAJUN et al., 2001), North of Iran (GHASEMI et al., 2015). Thus, *F. viridis* Weston is an Eurasian boreal forest-steppe species.

F. viridis Weston is a perennial rhizomatous herbaceous plant, up to 25 cm high with numerous adventitious roots. The stem is erect having the same length as the leaves or slightly longer than they are. The root leaves are on petioles, the stem leaves are assidenous or on a very short petiole. From above the leaves are green and lustrous, from below they are grayish. The inflorescence is not large, corymbose, friable and oliganthous. The pedicles are shortish. The flowers are comparatively large, up to 2.5 cm in diameter, usually monoclinous; the sepals are triangular, lanceolate and when there are the fruits are adpressed to them. The petals of the corolla are yellowish-white, roundish or inversely egg-shaped. The edges of the petals are arranged one after the other. The fruit is a false multinutlet. The fruits are globular or inversely egg-shaped; by a bigger part they are yellowish-white, at the top – reddish and sweet-scented. *F. viridis* blossoms in May and June (PAVLOV, 1961).

The leaves of *F. viridis* contain flavonoids (quercitrol, rutin, quercitrin, hyperoside), phenol-acids (chlorogenic acid, neochlorogenic acid, caffeic acid) (BAGDONAITE et al., 2012; GUSEV et al., 2016a), tanids (DOKUCHAEVA et al., 2015a), vitamins (vitamin C, tocopherol, carotene) (DOKUCHAEVA et al., 2015b), microelements (Cu, Cr, Ni, Co, Zn, Mn) (ZAITSEVA et al., 2010; DOKUCHAEVA et al., 2014), nitrogen-containing substance – choline (GUSEV et al., 2013), essential oil. The fruits of *F. viridis* contain carbohydrates (glucose, sucrose), flavonoids (rutin, hyperoside), phenol-acids (chlorogenic acid), vitamins (vitamin C, carotene, folic acid), essential oil (SOKOLOV, 1987).

In folk medicine the leaves and fruits of *F. viridis* are used as a vitaminous, antiphlogistic, diuretic, diaphoretic and choleretic remedy. It is used to treat anemia, in diseases of gastrointestinal tract. Besides the leaves have a styptic, astringent, wound healing effect and used for preparation of infusions, tinctures and tea. Infusion and decoction of leaves are applied at inflammation of mucous membranes of an oral cavity, at a headache, at jaundice, as antiseptic and outwardly – at rashes and dermatitis. Infusion of leaves *F. viridis* manifests antibacterial activity with regard to *Staphylococcus aureus* (GUSEV et al., 2016b), 1/10 infusion of leaves and its two times dilution reduces the growth of *Escherichia coli* colon bacillus (GUSEV et al., 2016c). The fruits have valuable food importance. They are used for food in boiled and dried forms and they are eaten fresh. Jams, syrups and pies are cooked from them.

Despite the fact that the natural habitat of *F. viridis* Weston is quite wide, literature review shows no reports on essential oil composition. There are a data about chemical composition of the essential oil of the leaves of *Fragaria vesca* L. The essential oil obtained from air-dried whole leaves of two cultivars of *Fragaria vesca* L. ("Rugia" and "Baron von Solemacher" cv.) growing in Poland distilled with steam and *m*-xylene addition in Deryng apparatus for 4 hours (yield of the oil 0.46-0.62%) was contained cumene (4.9-6.8%), linalool (13.4-14.1%), nonanal (18.7-20.1%), myrtenol (14.1-14.2%), citronellol (7.6-8.8%), geraniol (6.0-6.7%), dibutyl phthalate (6.3-12.0%) (NAJDA and DYDUCH, 2009). The essential oil obtained from air-dried leaves of *Fragaria vesca* L. growing in East Kazakhstan (yield of the oil 0.055%) was contained nonanal (2.5%), linalool

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(2.6%), dodecanoic (lauric) acid (3.4%), geranyl linalool (3.6%), phytol (17.6%), tetradecanoic (myristic) acid (4.8%), hexadecanoic (palmitic) acid (30.7%) (KUSHNARENKO et al., 2015). The compound of methyleugenol, detected in the result of analysis of volatile organic compounds from fruits of *F. viridis* growing in Germany (Dresden) using immersion stirbar sorptive extraction and gas chromatography with qMS detection, is characteristic for *Fragaria viridis* and can be used as an indicator for species identification (GRUNER et al., 2017).
The main purpose of this work was to study for the first time the chemical composition of the essential oil of the leaves and the fruits of *Fragaria viridis* Weston growing wild in Northern Kazakhstan.

Materials and methods

Plant material

Plant material collection was carried out in places of natural growth of *F. viridis* Weston in Northern Kazakhstan in Akmola region in the State National Natural Park "Burabay" and in the Branch of Northern region of the Republican State Communal Enterprise "Republican Forest Breeding Center". Specimens for the study were collected on 18 June 2018 in the stage of full blooming (leaves) (Fig. 1a) and 17 July 2018 in the stage of fruiting (fruits) (Fig. 1b). Identification and documentation (certificates of the specimens) of the plant species were made by Dr Tamara Stikhareva with the use of "Kazakhstan Flora" as the key for the plants (PAVLOV, 1961). Voucher specimens were deposited at the Department of Breeding of Kazakh Research Institute of Forestry and Agroforestry in Shchuchinsk under the herbarium code 18.06.2018/10. Characteristic of the places of collection and the yield of the oil from the leaves and fruits is given in Tab. 1. Fresh raw material was taken for isolation of essential oils from the leaves and the fruits.

Essential oil isolation

The essential oil of all the fresh samples of the leaves (100 g) and the fruits (100 g) was isolated by hydrodistillation for 3 hours with the use of the Clevenger-type apparatus.

Gas Chromatography-Mass Spectrometry

The essential oils were analyzed qualitatively and quantitatively by GC-MS on an Agilent Technologies 7890A GC System with an Agilent Technologies 5975C mass-selective detector using an HP-5ms column (5% Phenyl Methyl Silox, 30 m × 250 mm × 0.25 mm) at carrier gas (He) flow rate 1 mL/min and vaporizer temperature 280 °C. The GC column was held at 50 °C for 12 min with the temperature programmed to 280 °C at 2 °C/min. Then, the temperature was held constant for 40 min. The samples (0.1 μL) were injected without flow division. Mass spectral recording conditions were 70 eV, mass range *m/z* 10-350.
The percent contents of the constituents were calculated automatically using peak areas in the total ion chromatogram without using correction factors. Constituents were identified using mass spectra, retention times, and the Wiley GC/MS library. The results were also confirmed by the comparison of the compounds with their relative retention indices in the literature (ADAMS, 2007). To obtain the retention indices there was used a standard solution of *n*-alkanes (C8-C24).

Results and discussion

Essential oils obtained from the leaves and fruits of *F. viridis* are colorless movable liquids with a specific scent. Depending on the growth places, fresh leaves from *F. viridis* contain from 0.003% (sample II) to 0.010% (sample III) of essential oils; the fruits contain from 0.010% (sample II) to 0.050% (sample IV) of essential oils.
The GC/MS analysis of the essential oils obtained from the studied materials revealed the presence of 77 (including 39 identified) compounds in leaves and 103 (including 34 identified) compounds in fruits of *F. viridis*. Data on quantitative and qualitative composition of the essential oils made of leaves and fruits of *F. viridis* are presented in Tab. 2-3 and in a Supplementary file (Fig. S1-S5).
The main compounds of the essential oil from leaves of *F. viridis* were alcohols (40.6-63.0%) and aldehydes (3.7-16.6%), from fruits – alcohols (8.5-22.9%), sesquiterpenes (18.7-21.7%), hydrocarbons (3.7-16.2%). Content of the alcohols and aldehydes was higher in the leaves than in the fruits (aldehydes were only found in samples

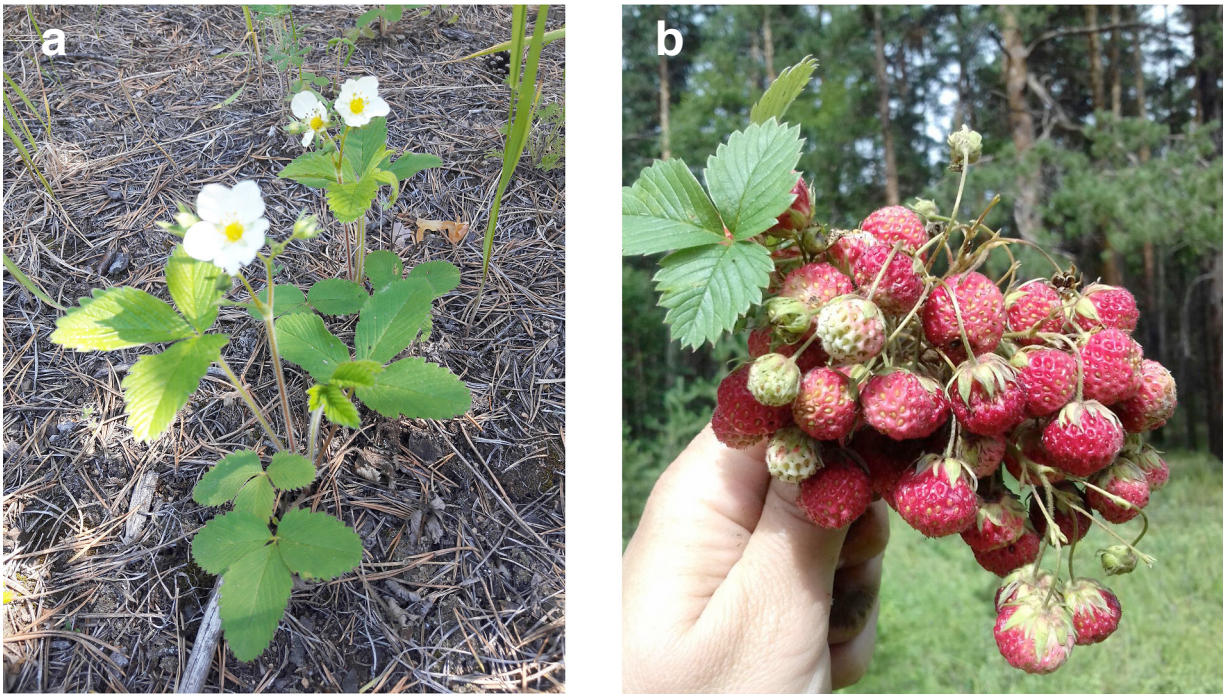

Fig. 1: *Fragaria viridis* Weston is in the stage of full blooming (*a*) and in the stage of fruiting (*b*)

Tab. 1: Description of the collected *F. viridis* Weston

Sample	Locality of collection	Description of collection	Latitude and longitude	Yield of the oil, %*	
				leaves	fruits
I	Akmola region, State National Natural Park "Burabay"	The glade adjacent to the pine forest (*Pinus sylvestris* L.), the age of which is 35-40 years, with density 0.6. Gramineous and strawberry community with the dominance of *Fragaria viridis* Weston, gramineous plants of *Festuca sulcata* Hack., *Stipa capillata* L. and others. The total projective cover of grass stand – 90-95%. The projective cover of *Fragaria viridis* – 85-90%. The height of *Fragaria viridis* – 8-15 cm.	52°57'N: 70°17'E	0.009	0.030
II	Akmola region, State National Natural Park "Burabay"	The glade adjacent to the pine forest (*Pinus sylvestris* L.), the age of which is 60-70 years, with density 0.4-0.5. Gramineous and forbs community with the dominance of *Fragaria viridis* Weston, *Galium verum* L., *Filipendula hexapetala* Gilib.и др. *Spiraea hypericifolia* L. is present there. The total projective cover of grass stand – 80-85%. The projective cover of *Fragaria viridis* – 25-30%. The height of *Fragaria viridis* – 7-10 cm.	52°57'N: 70°18'E	0.003	0.010
III	Akmola region, Branch of Northern region of the Republican State Communal Enterprise "Republican Forest Breeding Center"	The glade adjacent to forest cultures of the pine (*Pinus sylvestris* L.), the age of which is 35-40 years. Gramineous and forbs community with the dominance of *Fragaria viridis* Weston, gramineous plants of *Festuca sulcata* Hack., *Stipa capillata* L. and others. *Rosa cinnamomea* L. is present there. The total projective cover of grass stand – 80-90%. The projective cover of *Fragaria viridis* – 50-60%. The height of *Fragaria viridis* – 12-20 cm.	52°56'N: 70°17'E	0.010	0.040
IV	Akmola region, Branch of Northern region of the Republican State Communal Enterprise "Republican Forest Breeding Center"	The glade adjacent to birch forest (*Betula pendula* Roth.), the age of which is 55-60 years. Forbs community with dominance of *Fragaria viridis* Weston, *Potentilla argentea* L., *Filipendula hexapetala* Gilib. and others. The total projective cover of grass stand – 85-90%. The projective cover of *Fragaria viridis* – 60-70%. The height of *Fragaria viridis* – 10-15 cm.	52°55'N: 70°18'E	0.008	0.050
V	Akmola region, Branch of Northern region of the Republican State Communal Enterprise "Republican Forest Breeding Center"	The glade adjacent to forest cultures of the birch (*Betula pendula* Roth.), the age of which is 45-50years. Gramineous and forbs community with dominance of *Fragaria viridis* Weston, *Taraxacum officinale* Wigg., *Filipendula ulmaria* (L.) Maxim. The total projective cover of grass stand – 90-95%. The projective cover of *Fragaria viridis* – 70-75%. The height of *Fragaria viridis* – 18-28 cm.	52°56'N: 70°16'E	0.008	0.030

* Content of essential oil is given in % in regard to the mass of fresh raw material.

III and IV), while the content of sesquiterpenes and hydrocarbons (because of *m*/*p*-xylene) was higher in the fruits than in the leaves. The monoterpenes were only found in the fruits and only found in samples I and II. The oxides were only found in the leaves, and the tetrahydrofurans (vitispirane), furanones (2,5-dimethyl-4-methoxy-3(2*H*)-furanone) and phenylpropanoids (methyleugenol, estragole, anethole) were only found in the fruits.

The main components of the essential oil from leaves of *F. viridis* were β-linalool (0.8-8.9%), *n*-nonanal (0.5-8.6%), tetradecanal (2.1-5.9%), nerolidol (2.1-4.8%), an unidentified component (1.9-6.6%), α-bisabolol (0.8-6.7%), phytol (18.4-47.4%), an unidentified component (0.9-8.2%).

The main components of the essential oil from fruits of *F. viridis* were *m*/*p*-xylene (2.4-14.0%), isoledene (4.7-8.5%), methyleugenol (3.3-8.4%), α-cedrene (2.5-3.9%), an unidentified component (3.4-9.1%), α-muurolene (6.8-11.3%), nerolidol (1.1-4.8%), α-cedrol (1.7-8.0%), α-bisabolol (2.3-5.0%), an unidentified component (0-25.6%).

Linalool is a monoterpene alcohol. It has floral and citrus-like note in strawberries. The presence of linalool as one of the main components of the essential oil in leaves of *F. viridis*, can be explained by hydrolysis of labile volatile component – linalyl acetate, which slowly disintegrates at hydrodistillation. Linalool turns into α-terpineol and *trans*-geraniol by means of isomerization at hydrodistillation (Tkachev, 2008). Linalool has anxiolytic, sedative, analgesic, anti-inflammatory, anticonvulsant, local anaesthetic, antimicrobial, anti-cancer, antioxidant, anti-nociceptive and antihyperalgesic activities (Kamatou and Viljoen, 2008; Aprotosoaie et al., 2014).

n-Nonanal is an alkyl aldehyde, and it has a strong fruity or floral odor. *n*-Nonanal has anti-inflammatory, antiviral (HIV), antitoxic, antioxidant, free radical scavenging, cardioprotectant, antitussive, hepatoprotectant, antihemorrhagic activities (Ramya et al., 2015).

Tetradecanal is a natural aldehyde prevailing in *Photobacterium phosphoreum* and other species of bacteria. It is contained in the essential oil of a camphor tree. Tetradecanal has a soft, rich aroma with a note of irises.

Nerolidol, or 3,7,11-trimethyl-1,6,10-dodecatrien-3-ol, is a sesquiterpene alcohol with a floral odour. Nerolidol has antiulcer, anti-cancer, antitumor, insect repellent, skin penetration enhancer, anti-nociceptive, anti-inflammatory, antiparasitic (anti-trypanosomal, anti-leishmanial, anti-schistosomal, anti-nematicidal, anti-malarial), anti-fungal, anti-biofilm, antimicrobial, antioxidant activities (Chan et al., 2016).

Tab. 2: Percentage composition of the essential oil from leaves of *F. viridis* Weston

Sr. No.	Component	RT (min)	RI	RI_{lit}	Content of components in samples (%)				
					I	II	III	IV	V
1	Unidentified component	5.138	3084	-	-	-	-	1.4	-
2	Unidentified component	5.691	743	-	1.2	-	-	1.0	1.3
3	Unidentified component	5.983	1436	-	1.2	-	-	1.1	1.4
4	Unidentified component	6.727	813	-	2.5	-	-	2.3	2.9
5	Benzeneacetaldehyde	8.043	1081	1048	2.3	-	-	1.7	1.0
6	β-Linalool	8.911	1082	1081	8.9	0.8	4.2	6.3	4.9
7	*n*-Nonanal	8.978	1104	1081	8.1	0.5	2.9	8.6	6.8
8	endo-Borneol	10.025	1138	1148	0.6	-	-	-	-
9	α-Terpineol	10.381	1143	1172	3.7	1.8	3.1	2.7	2.0
10	n-Decanal	10.531	1204	1183	1.3	-	0.9	1.0	0.8
11	3-Isopropylbenzaldehyde (Cuminic aldehyde)	11.130	1216	1244	0.7	-	0.7	-	-
12	*trans*-Geraniol	11.244	1228	1232	1.9	1.3	1.4	1.9	1.6
13	Nonanoic acid	11.357	1272	1268	1.1	1.5	1.1	2.0	1.0
14	Unidentified component	11.845	1485	-	0.8	-	-	0.7	-
15	2-Methoxy-4-vinylphenol	12.136	1293	1272	0.6	-	-	-	-
16	cis-3-Hexenyl tiglate	12.218	1275	-	0.9	0.7	-	1.3	-
17	n-Decanoic acid (n-Capric acid)	12.680	1372	1344	-	-	-	1.0	-
18	1,2-Dihydro-1,1,6-trimethylnaphthalene	12.715	1396	1332	1.3	0.7	1.1	0.8	0.6
19	Geranyl acetate	12.949	1352	1360	-	-	-	-	0.9
20	Unidentified component	13.100	1382	-	0.8	0.7	0.8	-	-
21	Unidentified component	13.185	1387	-	1.6	-	1.1	0.9	0.6
22	Unidentified component	13.475	1387	-	0.7	-	-	-	-
23	Caryophyllene	13.550	1494	1424	-	-	0.9	-	-
24	Unidentified component	13.615	1440	-	0.9	0.7	-	0.7	-
25	Unidentified component	13.730	1019	-	2.0	0.6	-	1.3	0.9
26	α-Curcumene	14.142	1524	1472	-	0.5	0.9	-	-
27	Unidentified component	14.156	2255	-	0.7	-	-	-	-
28	β-Ionone	14.198	1457	1486	1.9	0.7	1.2	1.1	1.0
29	Junipene	14.271	1398	1432	0.9	0.8	1.1	0.7	-
30	Tetradecanal	14.356	1601	1592	4.1	3.2	5.9	2.6	2.1
31	β-Bisabolene	14.402	1500	1500	1.1	-	1.4	0.9	1.1
32	δ-Cadinene	14.588	1469	1514	-	1.2	0.9	-	-
33	Unidentified component	14.650	1271	-	0.7	0.7	1.3	-	0.7
34	Unidentified component	14.784	1620	-	1.5	1.8	2.5	1.2	2.1
35	Dodecanoic (Lauric) acid	14.814	1570	1556	-	-	-	1.9	-
36	Nerolidol	14.900	1564	1545	3.4	2.1	4.8	2.5	2.6
37	*cis*-3-Hexenyl benzoate	15.009	1565	1544	-	0.8	-	0.6	-
38	Unidentified component	15.032	1682	-	0.9	-	-	-	-
39	Unidentified component	15.032	1634	-	-	-	1.2	-	-
40	(-)-Spathulenol	15.169	1536	1577	-	1.1	-	-	-
41	Unidentified component	15.198	1540	-	4.2	1.9	6.6	3.6	2.8
42	(-)-Caryophyllene oxide	15.238	1507	1576	0.7	0.6	1.0	-	0.6
43	Unidentified component	15.318	1614	-	-	0.5	-	-	-
44	Unidentified component	15.495	1605	-	0.6	-	1.4	-	0.8
45	Unidentified component	15.589	2924	-	1.9	1.3	2.6	2.1	2.6
46	Unidentified component	15.667	1326	-	0.8	0.8	1.4	1.0	1.1
47	1,11-Dodecadiene	15.810	1194	1169	-	-	-	-	1.5
48	Unidentified component	15.817	2103	-	1.2	1.1	2.1	1.1	-
49	Unidentified component	15.856	2044	-	0.6	0.7	0.9	-	-
50	α-Bisabolol	16.016	1625	1683	1.9	6.7	3.4	1.0	0.8
51	Unidentified component	16.176	1899	-	1.6	1.8	2.1	1.3	0.8
52	Tetradecanoic (Myristic) acid	16.502	1769	1748	-	-	-	1.1	-
53	Unidentified component	16.897	1548	-	-	-	1.2	1.3	-

Sr. No.	Component	RT (min)	RI	RI_{lit}	Content of components in samples (%)				
					I	II	III	IV	V
54	Unidentified component	17.114	1774	-	-	0.5	-	-	-
55	Hexahydrofarnesyl acetone	17.166	1754	-	0.8	1.4	1.3	0.8	0.6
56	Unidentified component	17.389	3364	-	0.6	0.5	-	-	-
57	Unidentified component	17.423	2045	-	-	0.5	-	-	-
58	Unidentified component	17.681	3031	-	1.0	-	-	-	-
59	Unidentified component	17.721	2732	-	0.8	-	-	-	-
60	Isophytol	17.887	1899	1938	1.8	1.0	2.2	1.7	-
61	Hexadecanoic (Palmitic) acid	17.944	1968	1942	-	-	1.5	-	-
62	Palmitic acid, ethyl ester	18.179	1978	1968	-	1.2	-	-	-
63	Unidentified component	18.471	2192	-	2.3	1.1	2.8	1.6	2.3
64	Unidentified component	18.768	2402	-	-	-	0.9	-	-
65	n-Nonadecanol-1	18.777	2153	2150	-	0.8	-	-	0.6
66	n-Eicosane	18.856	2000	2000	0.8	-	0.8	-	0.9
67	Phytol	18.976	2045	2104	18.4	47.4	23.6	25.0	37.1
68	(Z,Z,Z)-9,12,15-Octadecatrienoic acid, ethyl ester	19.317	2201	-	-	2.0	-	-	-
69	Ethyl stearate	19.432	2177	2181	-	0.9	-	-	0.7
70	Unidentified component	19.999	2215	-	0.7	1.8	2.5	0.6	1.5
71	n-Heneicosane	20.043	2109	2100	-	0.8	1.7	1.3	1.3
72	Unidentified component	20.582	1710	-	-	0.9	-	-	-
73	Unidentified component	20.599	3253	-	-	-	-	-	0.6
74	Unidentified component	21.164	1526	-	-	0.5	0.8	-	0.9
75	Unidentified component	21.818	2300	-	0.9	-	-	8.2	4.8
76	Unidentified component	22.053	1710	-	-	-	-	-	0.7
77	Unidentified component	22.505	2890	-	-	1.0	-	-	0.9
	Total				**100.0**	**100.0**	**99.2**	**100.0**	**100.0**
	Alcohols				40.6	63.0	42.6	41.2	49.7
	Aldehydes				16.6	3.7	10.4	13.9	10.6
	Ketones				2.7	2.1	2.5	1.9	1.6
	Carboxylic acids				1.1	1.5	2.5	5.9	1.0
	Phenols				0.6	-	-	-	-
	Esters				0.9	5.5	-	1.9	1.6
	Naphthalenes				1.3	0.7	1.1	0.8	0.6
	Sesquiterpenes				2.0	2.6	5.3	1.6	1.1
	Oxides				0.7	0.6	1.0	0.0	0.6
	Hydrocarbons				0.8	0.8	2.5	1.3	3.6
	Identified compounds				**67.3**	**80.7**	**68.0**	**68.4**	**70.5**

Tab. 3: Percentage composition of the essential oil from fruits of *F. viridis* Weston

Sr. No.	Component	RT (min)	RI	RI_{lit}	Content of components in samples (%)				
					I	II	III	IV	V
1	*m*/*p*-Xylene	5.479	907	862	14.0	8.1	2.4	5.0	2.6
2	α-Pinene	6.174	948	931	-	0.9	-	-	-
3	1,8-Cineole	7.854	1059	1023	1.2	2.3	-	-	-
4	2,5-Dimethyl-4-methoxy-3(2*H*)-furanone (Mesifuranne)	8.299	1058	-	-	1.3	1.9	1.9	1.2
5	β-Linalool	8.911	1082	1081	-	1.1	0.9	1.6	-
6	*n*-Nonanal	8.978	1104	1081	-	-	1.1	-	-
7	endo-Borneol	10.031	1138	1148	-	-	-	0.6	-
8	α-Terpineol	10.383	1143	1172	0.7	1.7	1.0	2.4	-
9	Estragole	10.477	1172	1177	-	0.8	2.3	0.7	0.5
10	n-Decanal	10.531	1204	1183	-	-	1.2	0.6	-
11	Chavicol	11.219	1203	1234	-	0.7	1.2	1.7	-
12	Unidentified component	11.358	2010	-	-	-	-	0.6	-

Sr. No.	Component	RT (min)	RI	RI_{lit}	Content of components in samples (%)				
					I	II	III	IV	V
13	Vitispirane	11.720	1347	1268	-	-	2.0	1.1	1.2
14	Anethole	11.747	1190	1264	-	0.9	-	-	-
15	Unidentified component	11.844	1172	-	-	0.8	-	-	-
16	Unidentified component	12.114	1402	-	-	-	-	-	0.5
17	2-Methoxy-4-vinylphenol	12.136	1293	1272	-	-	0.9	-	-
18	1,2-Dihydro-1,1,6-trimethylnaphthalene	12.715	1396	1332	1.0	1.2	3.6	1.8	1.1
19	Unidentified component	12.777	1416	-	-	-	0.9	-	-
20	Isoledene	12.967	1419	1388	5.7	8.5	4.7	7.1	5.8
21	Unidentified component	13.042	1440	-	0.7	0.9	-	0.7	0.8
22	Methyleugenol	13.226	1361	1402	-	7.6	5.4	8.4	3.3
23	Unidentified component	13.252	2057	-	0.8	-	-	-	-
24	α-Cedrene	13.488	1403	1405	3.6	2.5	3.9	3.7	2.8
25	Caryophyllene	13.544	1494	1424	-	-	-	0.6	-
26	Unidentified component	13.613	1424	-	-	2.3	1.9	2.7	0.7
27	Unidentified component	13.624	2443	-	0.5	-	-	-	-
28	Unidentified component	13.796	1116	-	0.9	-	-	-	-
29	Unidentified component	13.801	1184	-	-	1.1	1.2	1.3	0.7
30	Unidentified component	13.975	1440	-	7.1	9.1	3.6	7.1	3.4
31	Unidentified component	14.156	2255	-	-	0.8	1.2	1.1	-
32	Unidentified component	14.259	1273	-	-	2.5	-	-	-
33	Unidentified component	14.271	1598	-	1.5	-	2.2	2.0	1.1
34	α-Muurolene	14.363	1440	1490	10.3	6.8	11.3	9.2	9.5
35	β-Bisabolene	14.402	1500	1500	-	1.1	-	-	-
36	δ-Cadinene	14.586	1469	1514	0.6	0.7	1.1	1.2	0.6
37	Unidentified component	14.648	1445	-	0.8	-	-	-	-
38	Unidentified component	14.648	1382	-	-	1.4	-	-	-
39	Unidentified component	14.784	1757	-	1.3	1.4	-	1.1	-
40	Dodecanoic (Lauric) acid	14.791	1570	1556	-	-	1.2	-	-
41	Nerolidol	14.900	1564	1545	4.8	3.5	3.3	2.7	1.1
42	Unidentified component	15.014	2788	-	0.6	-	-	-	-
43	Unidentified component	15.117	1015	-	-	1.0	-	-	-
44	Unidentified component	15.129	1769	-	-	-	0.9	-	-
45	Unidentified component	15.129	2348	-	-	-	-	0.7	-
46	(-)-Spathulenol	15.169	1536	1577	1.7	1.2	-	0.9	-
47	Unidentified component	15.260	2294	-	0.9	-	-	-	-
48	Unidentified component	15.318	3167	-	0.6	-	-	-	-
49	Unidentified component	15.318	2732	-	-	0.7	-	-	-
50	α-Cedrol	15.432	1543	1595	8.0	1.7	6.0	5.4	4.4
51	Unidentified component	15.495	1445	-	0.8	-	-	-	-
52	Unidentified component	15.495	1382		-	1.5	-	-	-
53	Unidentified component	15.558	2788	-	0.6	-	-	-	-
54	Unidentified component	15.593	1528	-	1.9	2.5	1.4	1.4	1.5
55	Unidentified component	15.667	3074	-	0.7	-	-	-	-
56	Unidentified component	15.667	1849		-	1.2	-	-	-
57	Unidentified component	15.741	1602	-	1.4	-	1.2	1.0	1.4
58	Unidentified component	15.787	1494	-	-	-	-	-	1.0
59	Unidentified component	15.822	1598	-	1.8	2.2	2.5	2.6	1.6
60	α-Bisabolol	16.034	1625	1683	5.0	2.6	3.2	3.6	2.3
61	Unidentified component	16.113	1671	-	0.8	-	-	-	-
62	Unidentified component	16.176	1792	-	1.3	1.2	1.2	1.3	0.7
63	Unidentified component	16.245	1462	-	-	-	-	-	0.5
64	Unidentified component	16.267	2425	-	-	-	-	0.7	-
65	Unidentified component	16.330	2597	-	0.6	-	-	-	-
66	Unidentified component	16.342	3238	-	-	-	1.3	-	-
67	Unidentified component	16.348	1654	-	-	-	-	0.9	-

Sr. No.	Component	RT (min)	RI	RI_{lit}	Content of components in samples (%)				
					I	II	III	IV	V
68	Unidentified component	16.411	1416	-	-	-	1.1	1.4	-
69	Unidentified component	16.542	1392	-	-	-	-	-	0.8
70	Unidentified component	16.639	1325	-	0.8	-	1.1	1.2	1.1
71	Benzyl benzoate	16.700	1733	1725	1.0	1.7	1.2	1.2	-
72	Unidentified component	16.765	2597	-	0.6	-	-	-	-
73	Unidentified component	16.771	1462	-	-	-	0.8	-	-
74	Unidentified component	16.771	1602	-	-	-	-	0.7	-
75	Unidentified component	16.765	1926	-	-	-	-	-	0.7
76	Unidentified component	16.800	2597	-	0.8	-	-	-	-
77	n-Octadecane	16.811	1810	1800	-	-	1.3	-	0.6
78	Unidentified component	16.885	1414	-	-	-	-	1.0	-
79	Unidentified component	17.000	1610	-	-	1.2	-	-	-
80	Unidentified component	17.114	2597	-	0.5	-	-	-	-
81	Hexahydrofarnesyl acetone	17.166	1754	-	2.0	2.7	3.0	1.9	1.7
82	Unidentified component	17.389	1917	-	0.6	0.6	1.2	0.9	1.0
83	Unidentified component	17.595	2275	-	-	0.7	-	-	-
84	Unidentified component	17.601	1293	-	-	-	0.8	-	-
85	Unidentified component	17.719	2528	-	-	0.7	0.8	-	0.5
86	Unidentified component	17.801	1801	-	-	-	1.4	0.6	0.9
87	Unidentified component	17.887	2155	-	0.9	-	-	-	-
88	Unidentified component	17.887	1526	-	-	0.9	-	-	-
89	Unidentified component	17.938	4083	-	1.6	-	-	-	-
90	Hexadecanoic (Palmitic) acid	17.947	1968	1942	-	-	1.0	-	1.0
91	Palmitic acid ethyl ester	18.178	1978	1968	-	0.7	3.9	2.3	1.8
92	Unidentified component	18.402	2456	-	0.8	-	-	-	-
93	Unidentified component	18.471	2192	-	3.1	2.7	2.6	1.6	0.9
94	n-Eicosane	18.850	2009	2000	1.2	1.2	-	0.7	0.8
95	Phytol	18.983	2045	2104	2.8	1.1	1.8	1.2	0.6
96	Unidentified component	19.100	2085	-	-	-	-	-	6.6
97	Unidentified component	19.174	2456	-	-	-	-	-	0.5
98	Unidentified component	19.872	3227	-	-	-	-	-	0.5
99	n-Heneicosane	20.044	2109	2100	1.0	-	-	-	-
100	Unidentified component	20.262	3227	-	-	-	-	-	0.8
101	Unidentified component	20.370	3350	-	-	-	-	-	25.6
102	Unidentified component	20.565	2127	-	-	-	-	-	1.3
103	Unidentified component	21.034	3227	-	-	-	-	-	1.9
	Total				**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
	Alcohols				22.9	12.9	16.2	18.5	8.5
	Aldehydes				-	-	2.3	0.6	-
	Ketones				2.0	2.7	3.0	1.9	1.7
	Furanones				-	1.3	1.9	1.9	1.2
	Carboxylic acids				-	-	2.2	-	1.0
	Phenols				-	0.7	2.1	1.7	-
	Esters				1.0	2.4	5.1	3.5	1.8
	Phenylpropanoids				-	9.2	7.7	9.1	3.8
	Naphthalenes				1.0	1.2	3.6	1.8	1.1
	Monoterpenes				1.2	3.3	-	-	-
	Sesquiterpenes				20.2	19.6	21.0	21.7	18.7
	Tetrahydrofurans				-	-	2.0	1.1	1.2
	Hydrocarbons				16.2	9.2	3.7	5.7	3.9
	Identified compounds				**64.5**	**62.6**	**70.7**	**67.5**	**43.0**

Phytol, or 3,7,11,15-tetramethyl-2-hexadecen-1-ol, is an acyclic diterpene alcohol. Phytol has anti-nociceptive, antioxidant, anti-inflammatory, antiallergic, antimicrobial (against *Mycobacterium tuberculosis*, *Staphylococcus aureus*), anticonvulsant, antispasmodic, anticancer, anxiolytic, metabolism-modulating, cytotoxic, autophagy-inducing, apoptosis-inducing and immune-modulating activities (DE MORAES et al., 2014; SILVA et al., 2014; ISLAM et al., 2018). Since the essential oil contains a large amount of phytol in leaves, we have every reason to believe that it is native and it is not the product of hydrolytic destruction of chlorophyll. Formation of hexahydrofarnesyl acetone is probably connected with oxidative destruction of phytol as a result of durational boiling under access for air. The origin of isophytol can be connected with the secondary conversion of phytol – with isomerization (TKACHEV, 2008).

Xylene is an aromatic hydrocarbon, a colourless liquid with an aromatic odour. Xylene is not a natural component, it is an environmental pollutant. It has non-cancerous effects on human health. High amount and duration of xylene can lead to toxicity of blood. Detection of *m*/*p*-xylene in the essential oil of the fruits of *F. viridis* can be explained by its sorption from the atmosphere (air, precipitations) since it is well known that the sources of emission of *m*/*p*-xylene to the environment are cigarette smoke, industry effluents, laboratory vapors, paint and varnish, vehicle emissions, petroleum pollutant (NIAZ et al., 2015). The essential oil from leaves of *F. viridis* did not contain *m*/*p*-xylene even in a trace amount. It is an interesting fact that the collection of the fruits was carried out far from all the above-listed sources. This suggests that *m*/*p*-xylene can spread over considerable distances in the atmosphere. The presence in fruits of green strawberry of lipophilic components - essential oil exhibits uptake of lipophilic compounds such as *m*/*p*-xylene (GÓRNA-BINKUL et al., 1996). The essential oil from the fruits of *F. viridis* growing on the territory of State National Natural Park "Burabay" (sample I – 14.0%, sample II – 8.1%) contained the largest amount of *m*/*p*-xylene.

Isoledene is a sesquiterpene. Isoledene, a rich sub-fraction from oleogum resin of *Mesua ferrea,* induces apoptosis in HCT 116 cells by modulating the activity of multiple proteins (ASIF et al., 2016).

Methyleugenol is a phenylpropanoid and natural component of essential oils. It is used as a flavoring agent in food and beverages, and a fragrance ingredient in cosmetic products. Methyleugenol has antibacterial, antifungal, antinematodal, insect attractant/ repellent activities; relaxant and antispasmodic actions on the ileum; a depressive effect on the central nervous system with anesthetic, myorelaxant, hypothermic, and anticonvulsant properties (ÇERKEZKAYABEKIR et al., 2010; GOSWAMI et al., 2017).

α-Cedrol is a sesquiterpene alcohol with a very weak aroma. It has antibacterial, sedative activities (KAGAWA et al., 2003). α-Cedrol is dehydrated to α-cedrene in the presence of acid. So α-cedrene can be an artifact of α-cedrol. The ratio of α-cedrol and α-cedrene will often depend on the method of isolation (SELL, 2010).

α-Muurolene is a cadinane sesquiterpenoid. Pinaceae *spp*., pine pitch (*Pinus sylvestris* L.) is the source of α-muurolene. It is known as fungal metabolite found in *Coprinus cinereus* (AGGER et al., 2009), in endophytic fungi *Diaporthe* spp., isolated from the medicinal plant *Catharanthus roseus* (YAN et al., 2018).

α-Bisabolol is a monocyclic sesquiterpene alcohol. α-Bisabolol has anti-inflammatory, antioxidant, anti-irritant, antimicrobial, antispasmodic, anti-allergic, anticancer, anticholinesterase and vermifuge activities (KAMATOU and VILJOEN, 2010).

It is well known that essential oils' biological activity may depend on the major components or amplifying the effect of the interaction between the major and some minor components. According to literature, the main components of the essential oil from the leaves and fruits of *F. viridis* such as linalool, *n*-nonanal, nerolidol, phytol, methyleugenol, cedrol and α-bisabolol have anti-inflammatory, antimicrobial, antioxidant, anticancer, antinociceptive, anxiolytic and sedative activities. There is a high probability that the essential oil from leaves and fruits of *F. viridis* will have the aforesaid activities.

Sample II is noteworthy. Content of α-bisabolol and phytol in the leaves was higher and content of linalool and *n*-nonanal was lower compared with the other samples; content of isoledene in the fruits was higher, and content of α-muurolene and α-cedrol was lower compared with the other samples. Perhaps this is due to the growth conditions. Unlike other samples, sample II grew at dry conditions (conditions in which the amount of soil moisture is insufficient for optimal plant development). The projective cover (25-30%), the height (7-10 cm) of *Fragaria viridis* and the yield of the oil from leaves (0.003%) and fruits (0.010%) of sample II were lower, compared with other samples.

We should also pay attention to some components which presents in the essential oil in small amounts. For example, anethole – a phenol methyl ether, was detected only in the fruits of sample II (0.9%). Anethole belongs to antioxidant compounds. The given substance is most probably prevents the peroxidation of lipids and increases the resistance of the plant to unfavorable factors of the environment. Anethole is also an initial product in biosynthesis of other bioactive substances (LYUTIKOVA and TUROV, 2011). In the fruits of sample III at concentration 0.9% and in the leaves of sample I at concentration 0.6% there was identified 2-methoxy-4-vinylphenol (4-vinylguaiacol), which is possibly participates in biosynthesis of vanillin and pyrocatechin.

The main characteristic volatile compounds in strawberry fruits are furanones, esters, terpenoids, sulfur compounds and benzenoids (YAN et al., 2018). 2,5-Dimethyl-4-methoxy-3(2*H*)-furanone, or mesifuranne, (1.2-1.9%), detected in the essential oil of fruits of green strawberry, has the sweet and caramel-like aroma. 1,2-Dihydro-1,1,6-trimethylnaphthalene, or 3,4-dehydroionene, was found in the essential oil of the fruits and foliage of strawberry (STOLTZ et al., 1970) and was found in the essential oil of the leaves (0.6-1.3%) and fruits (1.0-3.6%) of green strawberry. Vitispirane, or 2,10,10-trimethyl-6-methylidene-1-oxaspiro[4.5]dec-7-ene, is tetrahydrofuran, which was identified in wine, grape juice, vanilla beans and was detected in the essential oil of the fruits of green strawberry (1.1-2.0%); it is component of aroma of wine, raspberry, yellow passion fruit, black tea, and it has camphor or eucalyptus odour (BLAŽEVIĆ and MASTELIĆ, 2008; FERREIRA and DE PINHO, 2004). According to the analysis of components, identified in the essential oil of fruits of *Fragaria viridis*, we can assume that the main characteristic volatile compounds in the fruits of green strawberry are furanones (2,5-dimethyl-4-methoxy-3(2*H*)-furanone), naphthalenes (1,2-dihydro-1,1,6-trimethylnaphthalene), phenylpropanoids (methyleugenol, estragole), esters (palmitic acid ethyl ester, benzyl benzoate), terpenoids (α-cedrol, nerolidol, α-bisabolol, α-terpineol, β-linalool), tetrahydrofurans (vitispirane). Thanks to the complex of these volatile compounds, the fruits of green strawberry have a strong specific smell of honey, musk and wine.

Conclusion

The composition of the essential oil from the leaves and fruits of *Fragaria viridis* Weston growing wild in Northern Kazakhstan was studied for the first time. Comparison of the chemical composition of the essential oils from the leaves and fruits of *Fragaria viridis* collected in different habitats has shown that the qualitative composition of the main components remains homotypic (except for the minor components), only the quantitative content of separate substances is subjected to changes that depends on the growth conditions. Indirectly, it can be assumed that the essential oil from leaves and fruits of *F. viridis* will have anti-inflammatory, antimicrobial, antioxidant, anticancer, antinociceptive, anxiolytic and sedative activity.

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Supplementary material

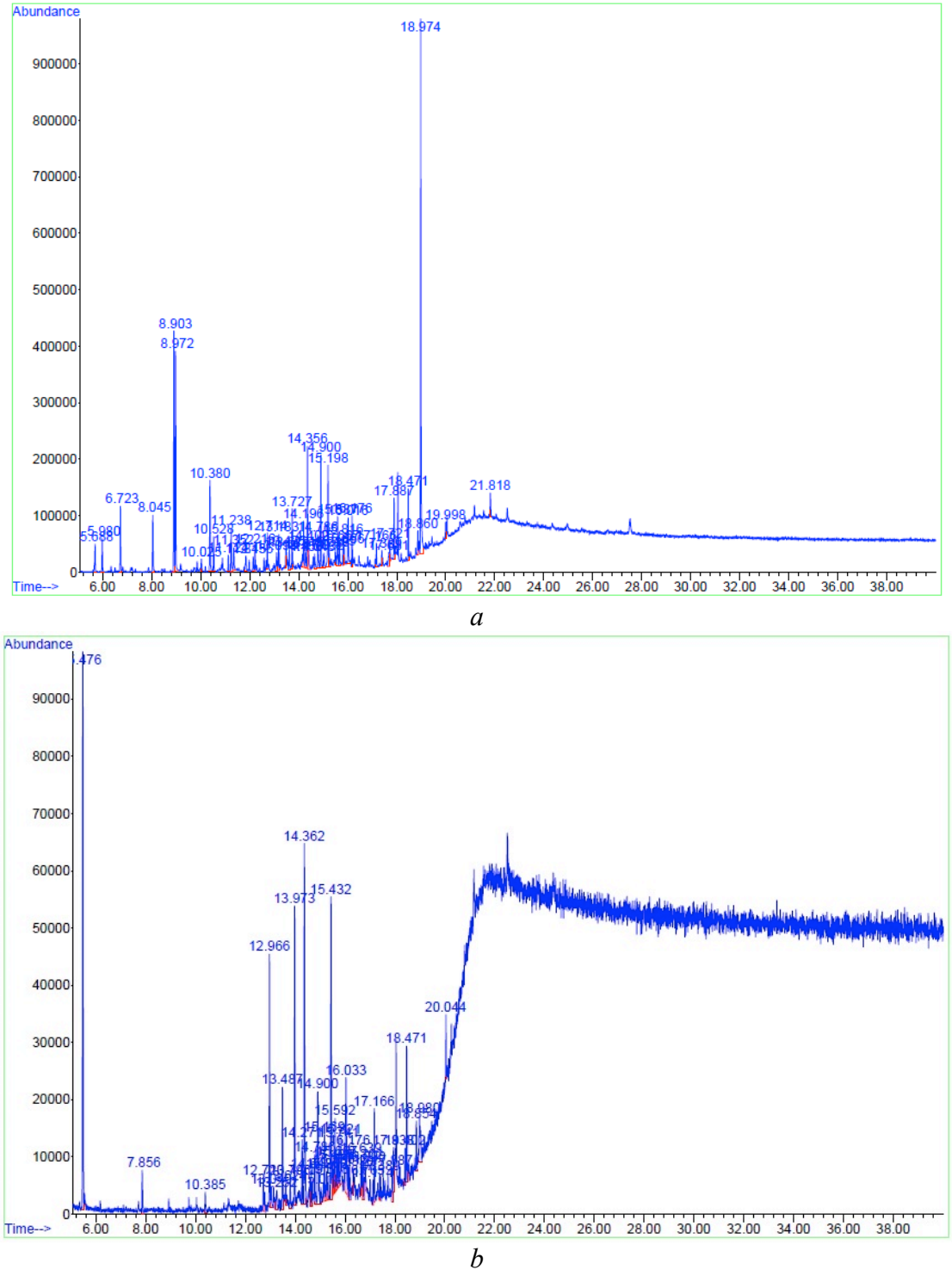
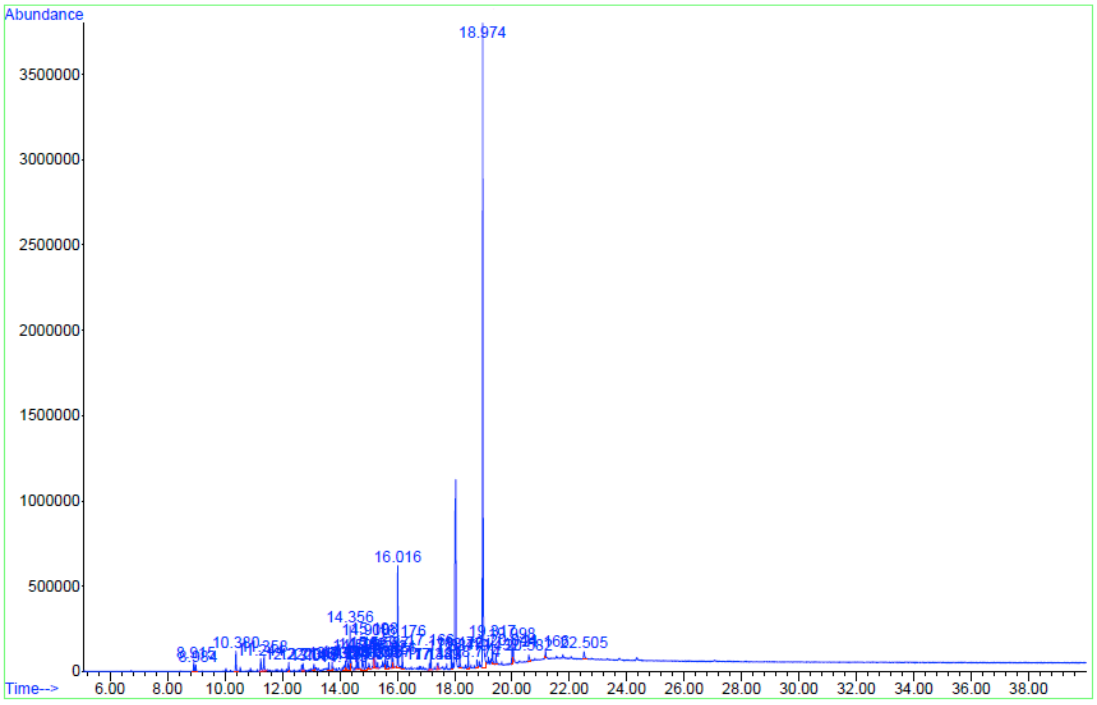


Fig. S1: GS-MS chromatogram of leaves (*a*) and fruits (*b*) of essential oil of *F. viridis* Weston from sample I



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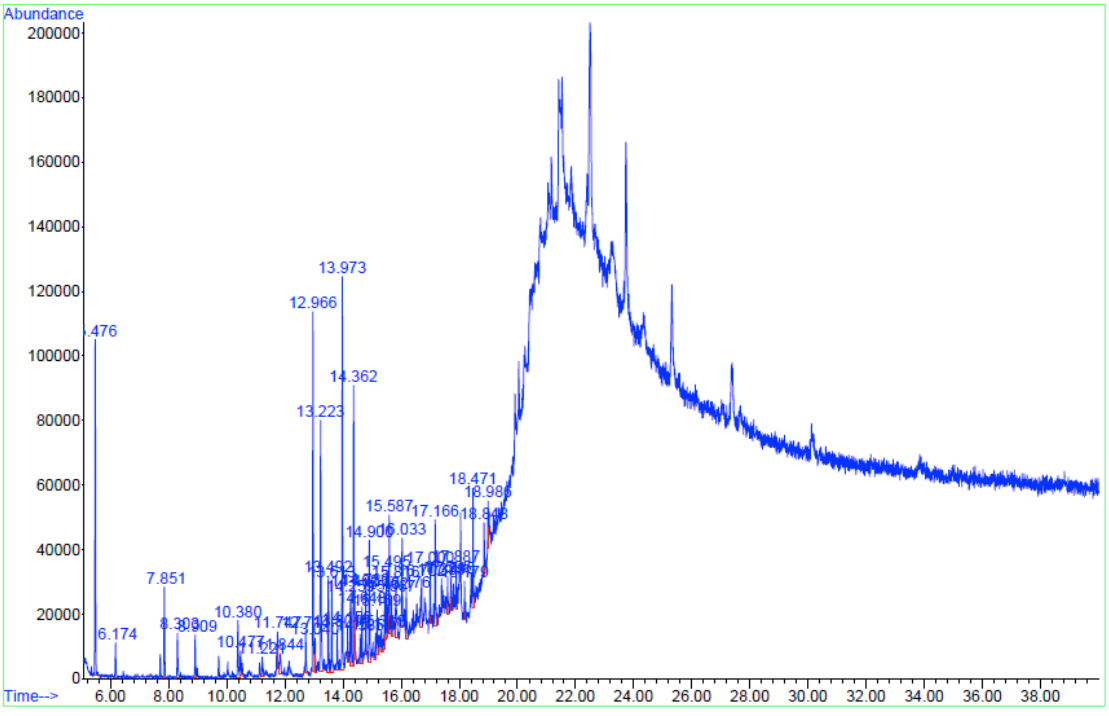

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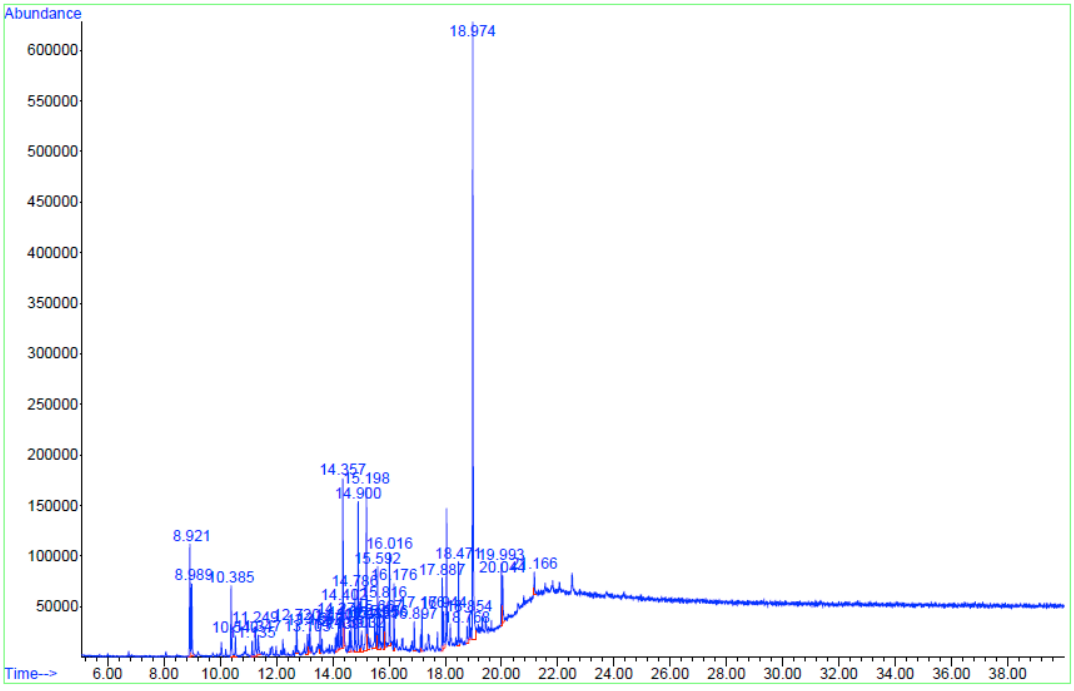
Fig. S2: GS-MS chromatogram of leaves (*a*) and fruits (*b*) of essential oil of *F. viridis* Weston from sample II



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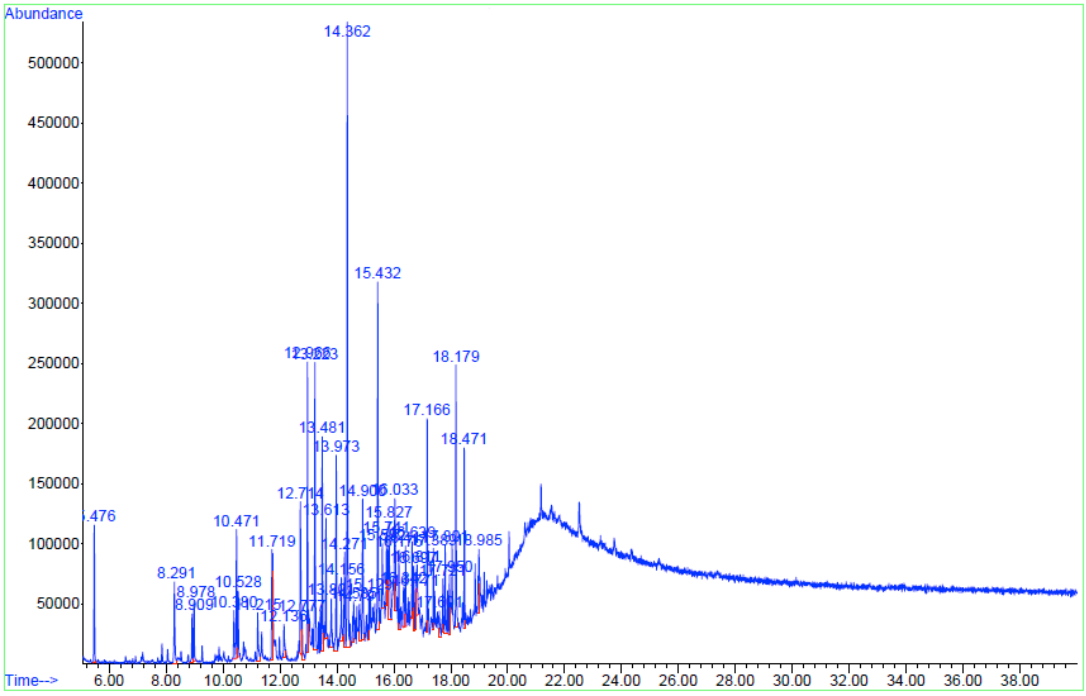

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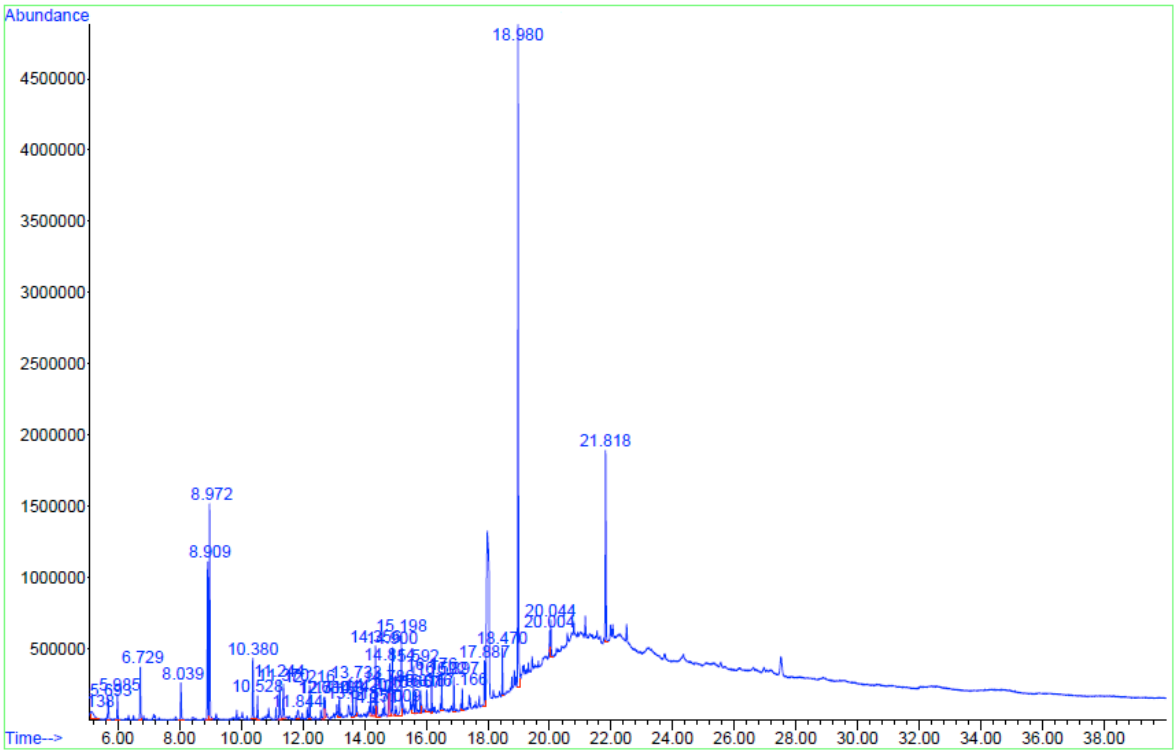
Fig. S3: GS-MS chromatogram of leaves (*a*) and fruits (*b*) of essential oil of *F. viridis* Weston from sample III



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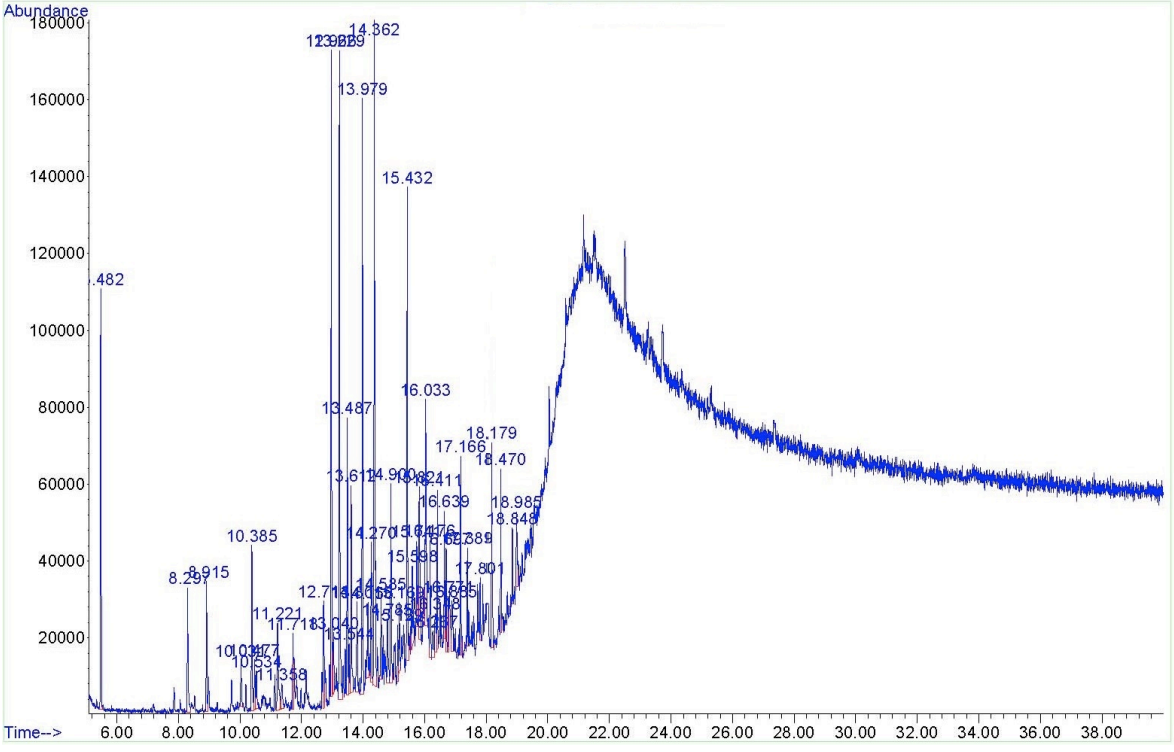

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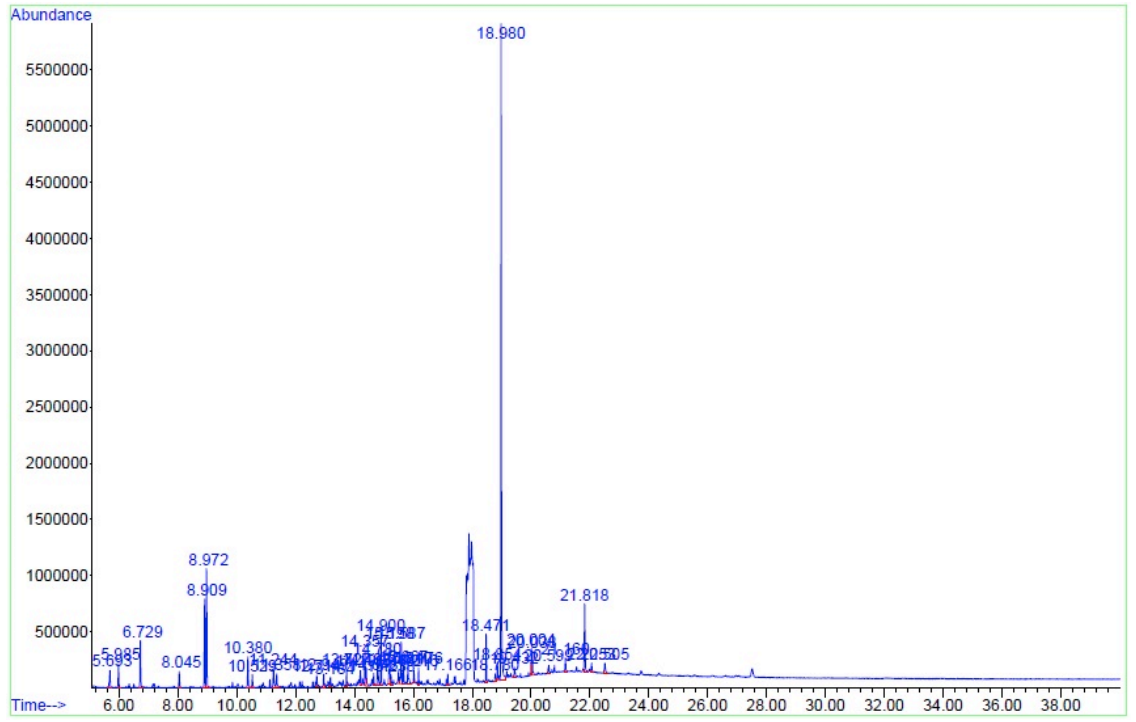
Fig. S4: GS-MS chromatogram of leaves (*a*) and fruits (*b*) of essential oil of *F. viridis* Weston from sample IV



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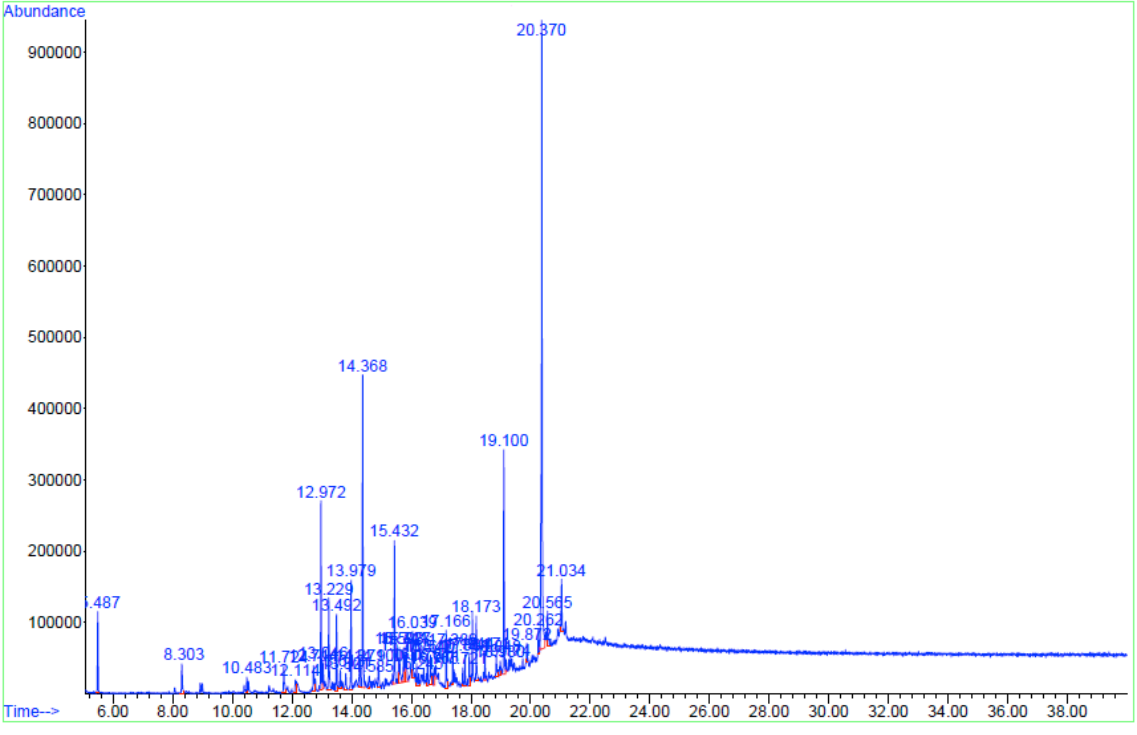

b

Fig. S5: GS-MS chromatogram of leaves (*a*) and fruits (*b*) of essential oil of *F. viridis* Weston from sample V