IRSTI 31.21 https://doi.org/10.26577/ijbch.2023.v16.i1.012

M.Zh. Zhumagul[1,2], S.A. Kubentayev [2], M.S. Kurmanbayeva [3],
A.B. Myrzagaliyeva [1], R.N. Suleimen [4*], Ye.M. Suleimen[5, 6], D. Samarkhanova[7]

[1]Astana International University, Astana, Kazakhstan
[2]Astana Botanical Garden, Institute of Botany and Phytoinroduction, Astana, Kazakhstan
[3]Al-Farabi Kazakh National University, Almaty, Kazakhstan
[4]Eurasian National University, Astana, Kazakhstan
[5]Kazakh University of Technology and Business, Astana, Kazakhstan
[6]Sh. Ualikhanov Kokshetau University, Kokshetau, Kazakhstan
[7]Nazarbayev University, Astana, Kazakhstan
*e-mail: kasim_rai@mail.ru
(Received January 27 2023; received in revised form 24 February 2023; accepted 9 March 2023)

Component composition of essential oil of *Rhodiola algida* (Ledeb.) Fisch & C.A. Mey and its biological activity

Abstract. For the first time the component composition of essential oil of *Rhodiola algida* (Ledeb.) Fisch & C.A. Mey. family Crassulaceae, collected in places of natural growth in July 2020 in the Kazakh Altai was studied. The component composition of essential oil of this species was determined by gas chromatography and chromatography-mass spectrometry. The method of chromatography-mass spectrometry detected 100 components, of which 79 substances were identified, accounting for 82-83% of the total essential oil. Antioxidant activity was determined by the FRAP method. *R. algida* essential oil showed low antioxidant activity compared with butyl hydroxyanisole (BHA) at concentrations of 0.25-1.0 mg/ml, confirming the antioxidant properties of *R. algida*. Based on the results of cytotoxic activity against *Artemia salina* L. larvae, it was concluded that *R. algida* essential oil has good lethal toxicity at all concentrations tested, which proves the cytotoxicity of *R. algida*. At present, studies of *R. algida* based on substances from this plant and methods of their analysis are of direct interest for phytopreparation.
Key words: *Rhodiola algida,* essential oils, components, antioxidant activity.

Introduction

Rhodiola algida (Ledeb.) Fisch & C.A. Mey. is a species of the family Crassulaceae, section Chamaerhodiola, genus Rhodiola, found in the alpine zone in the Arctic, Western and Eastern Siberia and Mongolia, Kazakhstan, Pakistan, China, Russia [1, 2]. *R. algida* has long been used in folk medicine in Qinghai and Tibet, and has been clinically proven to prevent many diseases [3, 4, 5, 6]. The interest in this plant is due to its component composition, which determines its species identity. *R. algida* plants are prescribed to increase physical endurance, performance, longevity, resistance to disease in high latitudes, as well as to treat fatigue, depression, nervous system disorders, etc. [7]. *R. algida* is one of the most effective species of rhodiola, and it has been clinically proven to enhance human immune responses [8, 9]. The role of *R. algida* as an immunomodulatory agent has been established [10]. It has also been established from the literature that salidroside is considered the most important bioactive component and is widely used as an indicator for assessing the quality of many species of rhodiola and products made from it [11]. Salidroside and tyrosol are the main components of *R. algida* [12].

R. algida is a rare species, under natural conditions, this plant is found in the Altai region of Western Siberia, as well as in the Daurian and in the west of the Angara-Sayan region of Eastern Siberia. On the territory of Kazakhstan, the species is found only in the char belt of the Kazakh Altai ridges. The species lives near watercourses, on wet, moss-covered rocks, stony slopes, near snowfields, on overgrown moraines, among mosses along river banks, and on gravel-lichen tundra [13].

Despite the harsh climate of the Altai, *R. algida* accumulates many useful biologically active compounds. According to scientists in the literature, this is the result of its adaptation to the harsh conditions in which it grows. The plant is called a red brush because of the decorative red color of its

stiff shoots and fruits, which really resemble a brush. *R. algida* extract promotes lymphocyte proliferation and shows antitumor effects, including in breast cancer [1, 14]. It has been proved that the plant increases immunity and can be used simultaneously with chemotherapy to alleviate oral ulcers [14]. *R. algida* fraction proved activity against chronic hypoxia-induced pulmonary arterial hypertension in rats [11-14].

R. algida affects the human immune system by nourishing and restoring blood, activating blood circulation against stasis. Its effectiveness can be demonstrated by increasing endurance, relieving fatigue, preventing altitude sickness and stimulating the nervous system [15-18]. *R. algida* extract protects muscle tissue, as evidenced by its ability to activate ATP synthesis and reduce inflammatory C-reactive protein and creatinine kinase levels [19,20]. And also in patients with superficial carcinoma of the bladder it improves T-cell immunity, leukocyte integrins [21,22].

Previously, the extractive composition of this plant was studied and flavonoids in the form of acetylated diglycosides were found [23].

In this article, we first presented the component composition of *R. algida* essential oil obtained by chromatography-mass spectrometry. The purpose of the study is to study the composition of biologically active substances of *R. algida*, on the basis of which new highly effective and low-toxic phytopreparations will be created in the future.

Materials and methods

Plant material. The underground part of *R. algida* raw materials (root) was collected in the flowering phase in August 2020, Kazakhstan Altai, Ivanovo ridge (50°31’93.68”N, 83°.88’93.90”E, 2010 m.a.s.l. (Figure 1).

The collected raw materials were dried and crushed. Herbarium samples of this plant are stored in the herbarium fund of the Astana Botanical Garden (NUR). Herbarium number 2005 15.07.2022 (Figure 2).

R. algida – a perennial herbaceous plant with a height of 6-18 cm. The root of this species is quite thick and long, while the rhizome is multi-headed. Stems are numerous, 6-18 cm high, 1.5-2.5 mm dia., densely oriolate. Leaves are alternate, 8-20 mm long, 1.5-3 mm wide, linear-oblong or linear, obtusely acuminate at the top, smooth-edged; inflorescence is dense, simple scutellum; flowers are 5-, rarely 4-membered, monoventate. Sepals are about 4 mm long, linear-oblong, blunt, reddish; petals are 7-8 mm long, ovate-lanceolate, bluntly pointed, white or pungent pink. Stamens 10, slightly shorter than or nearly equal to the petals, inner stamens fused by 1/3 of their length. The plant blooms in June in July and month [13, 25].

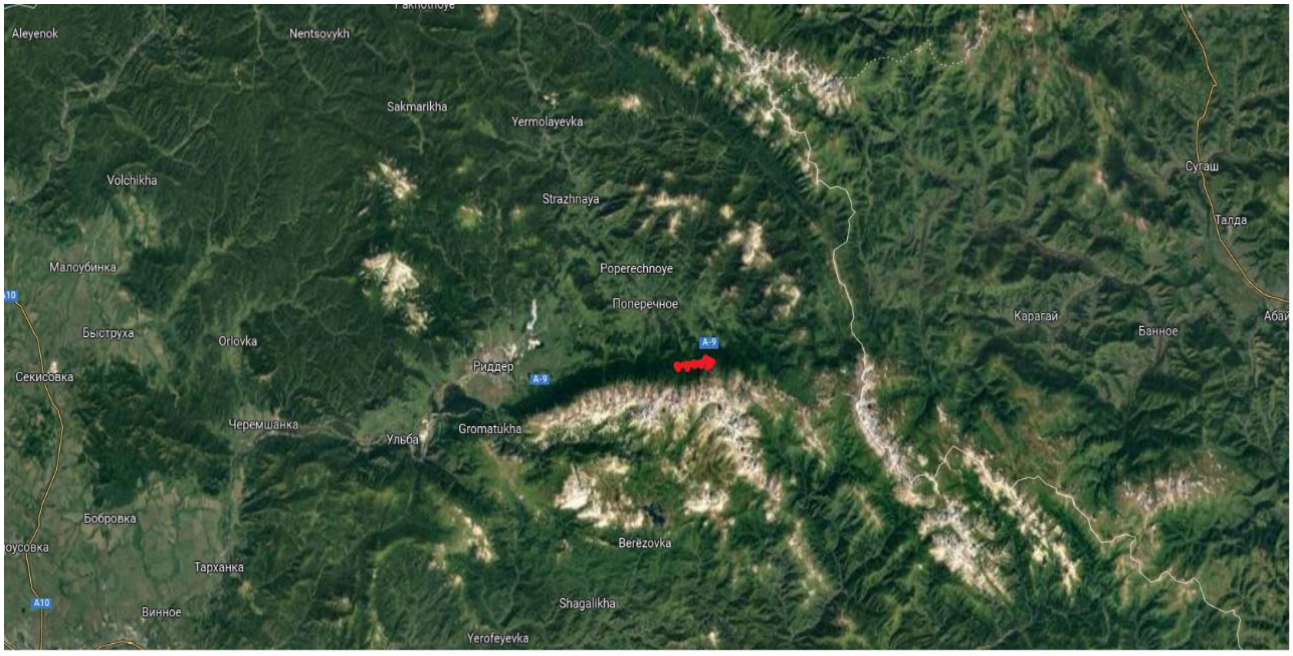

Figure 1 – Scheme map of the distribution of the *R. algida* in Kazakhstan Altai, Ivanovo ridge.

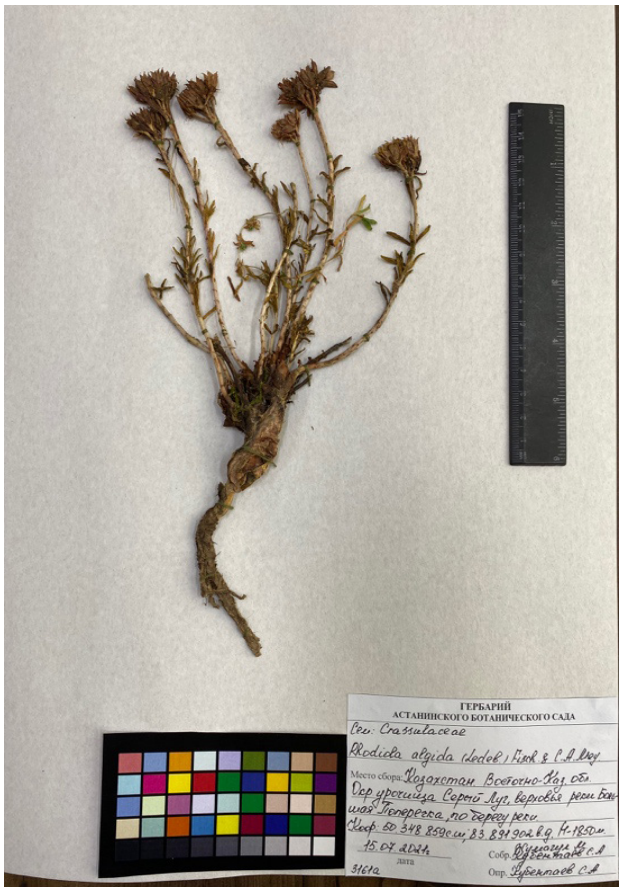

Figure 2 – Herbarium samples of *R. algida* (NUR)

Raw materials are collected and dried according to requirements of the State Pharmacopoeia of the Republic of Kazakhstan in edition I [24].

Ground dry air raw material was obtained by sedimentation (maceration) with 96% ethanol for 3 days at room temperature. Extraction was repeated twice. In the experiment, the essential oil-containing *R. algida* was slowly dried under vacuum and ground at room temperature 25-35 °C.

The more raw materials dried during drying, the higher is the activity and quality of glycosides, alkaloids and other compounds, enzymes in plant cells [24]. Essential oil was obtained from the crushed (up to 3-5 mm), dried masses 125 g of roots from plant material by water distillation on a Clevenger apparatus for 2 hours [26] using hexane as a trap for the selection of volatile components. The isolated volatile components were dried over Na_2SO_4, weighed, and stored in sealed dark glass bottles in a cool and dark place at 5°C. We obtained an essential oil of dark red color with a pleasant smell.

The component composition of *R. algida* essential oils was determined using a Clarus-SQ8 gas chromatograph with a mass spectrometric detector under similar conditions [27]. Chromatographic conditions: capillary column – RestekRxi®-1 ms 0.25 mm x 30 m x 0.25 µm, sample volume: 1.0 µl, carrier gas – He, carrier gas speed: 1 ml/min, split ratio 1:25, t of column: 40 °C, rise of 2 °C/min to 280 °C, t of evaporator – 280 °C, mass spectrometric detection: t – 240 °C, EI + = 70 eV, the scanning time from 4 to 120 minutes, the scan mode ion 39-500 m/z. The percentages of components are automatically calculated based on the total peak areas of the chromatogram of ions. Components were identified by mass spectra and the retention times, with use of NIST (National Institute of Standards and Technology) library.

Cytotoxic activity of R. algida essential oil. We have determined the cytotoxic activity of *R. algida* essential oil. Determination of activity was carried out according to the well-known method of survival of marine shrimp *Artemia salina* [28].

Separating funnel filled with 55 ml of artificial sea water and 200 mg of eggs *Artemia salina*. Allowed standing for 3 days at the air supply until soft crustaceans gave the egg. One side of the tube covered with aluminum foil, and 5 minutes later, the larvae that are going on the bright side of the funnel, removed Pasteur pipette.

20-40 larvae were placed in 990 µl of seawater into each of the 24 micro titer plates. Dead larvae were counted under a microscope. Added 10 µl of dimethylsulfoxide solution of 10 mg / ml sample. As a comparison, the drug actinomycin D or staurosporine. For a negative control 10 µl was added only DMSO. After 24 h of incubation and further maintaining micro titer plates for 24 hours (to ensure immobility) counts the dead larvae under the microscope.

Mortality P determined by the following formula:

$$P = (A – N – B) / Z \times 100\%,$$

here A – amount of dead larvae after 24 h;

N – amount of larvae died before the test;

B – the average amount of larvae died in a negative control;

Z – the total amount of larvae.

Antiradical activity of R. algida essential oil. Determination of the iron-reducing potential of the studied samples by the FRAP method (Ferric Reducing Antioxidant Powerassay) [27, 28] (table 3).

0.25 ml of 0.2 M phosphate buffer (pH= 6.6) and 0.25 ml of 1% potassium hexacyanoferrate (III) solution are added to 0.1 ml of the studied substances in the concentration range 0.25; 0.5; 0.75; 1.0 mg/

ml. The reaction mixture is incubated for 20 min. at 50 °C, the reaction is stopped by adding 0.25 ml of 10% trichloroacetic acid solution. The mixture is centrifuged for 10 minutes (3000 rpm). The top layer of 0.5 ml is mixed with 0.5 ml of dist. water and 0.1 ml of 0.1% $FeCl_3$. The optical density (OD) is measured at 700 nm. The antioxidant activity (AA) of the samples was compared with AA butylhydroxyanisole (BHA).

Chromatographic analysis of the extract for the content of organic substances. Methods of analysis: gas chromatography with mass spectrometric detection (Agilent 7890A/5975C). Chromatographic conditions: sample volume 1.0 µl with flow division 10:1, chromatographic column DB-35MS (Agilent, USA) 30 m x 0.25 mm, film thickness 0.25 µm, column thermostat temperature: from 50ºC (1 min exposure) with heating rate 10ºC/min to 270ºC (15 min exposure), evaporator temperature: 250ºC, detection mode – ion monitoring in range m/z 34-750.

Results and discussion

In the work performed, retention index values were calculated for all detected peaks to add confidence in identification. Table 1 also shows that the library RI information in the NIST database was used to check the observed RI value. As can be seen from Table 1, the main components of *R. algida* essential oil are *n*-hexadecanoic acid – 6.8%, 9-octadecenic acid (*E*) – 5.9%, as well as unidentified compound – 6.8%, the main classes of *R. algida* essential oil are aldehydes and alcohols (hexanal, decadienal, nonanal, tetracosanal, 2-ethyl-1-hexanol,), organic acids (h- hexadecanoic acid, 9-octadecenoic acid(*E*)) and various esters of organic acids (methyl-(3-oxo-2-pentylcyclopentyl)-acetate, glycidyl palmitate). Marginal hydrocarbons (*n*-docosan, tetracosan, pentacosan, nonacosan), sterols and other components are present in small quantities.

Figure 3 shows a GC-MS chromatogram for *R. algida* essential oil.

The study of the action of *R. algida* plant essential oil on human cancer cells, is an important direction and can serve as an indication of the biosynthetic ability plants to form secondary substances possessing not only biological activity but also cytotoxic action. In this work we studied the cytotoxicity of essential oils derived from plants *R. algida*. The results of the studiesare presented in Table 2.

Table 1 – The essential oils of *R. algida*

RI calculation	RI lit	Component	Content %
799	800±2	Hexanal	0.9
982	993±2	2-Pentyl furan	0.2
1025	1030±3	2-Ethyl-1-hexanol	0.3
1034	1045±4	Benzyl Acetaldehyde	0.1
1102	1104±2	Nonanal	0.2
1143	1156±2	1-Ethenyl-4-methoxybenzene	0.2
1289	1295±3	2,4-Decadienal (E,Z)	0.2
1312	1317±5	2,4-Decadienal (E,E)	0.6
1496	1518±10	β-Cadinene	0.1
1644	1649±1	Methyl-(3-oxo-2-pentyl cyclopentyl)-acetate	0.8
1773		Unidentified 1	0.7
1798	1811±N/A	1,2-Diphenoxyethane	0.6
1844	1844±4	6,10,14-Trimethyl-2-pentadecanone	0.1
1952	1953±0	Z-11-Hexadecane	0.6
1968	1968±7	n-Hexadecanoic acid	6.8
2130	2133±12	9,12-Octadecadienoic acid (Z,Z)	2.5
2137	2175 iu	9-Octadecanoic acid(E)	5.9

Table continuation

RI calculation	RI lit	Component	Content %
2161	2172±7	n-Octadecanoic acid	0.7
2200	2200	n-Docosan	0.1
2330	2168 iu	Glycidyl palmitate	0.9
2337		Unidentified 2	1.7
2345		Unidentified steroid 1	0.4
2363		Unidentified 3	0.4
2369		Unidentified steroid 2	2.2
2396	2400	Tetracosan	0.7
2424	2430±2	n-Docosanal	0.6
2464		Unidentified4	1.8
2471		Unidentified 5	1.7
2502	2500	Pentacosan	1.9
2573		Unidentified 6	4.7
2590		Unidentified 7	2.0
2599	2611±2	Doxyl Acetate	1.2
2621	2632±9	Tetracosanal	1.1
2631		Unidentified 8	0.9
2666		Unidentified 9	0.7
2683	2700	Heptacosan	0.8
2691	2759±NA	2-Methylphenyldodec-2-en-1-fumaric acid silt ester	0.7
2756		Unidentified steroid 3	6.8
2798	2808±4	Tetracosyl Acetate	0.8
2823	2832±2	Hexacosanal	1.0
2878	2900	Nonacozan	1.3
2912		Unidentified 10	3.1
2927		Unidentified11	1.9
2996	3003±7	Hexacosyl Acetate	0.6
3017		Unidentified 12	0.7
3024	3036	Octacosanol	0.1
3050		Unidentified 13	2.1
3071	3040±NA	Stigmastan-3,5-diene	1.7
3076	3100	Gentriacontane	1.9
3123		Unidentified 14	1.3
3192		Unidentified 15	6.6
3221		Unidentified steroid 4	1.7
3243		Unidentified 16	2.6
3258		Unidentified 17	2.7
Total			82.9

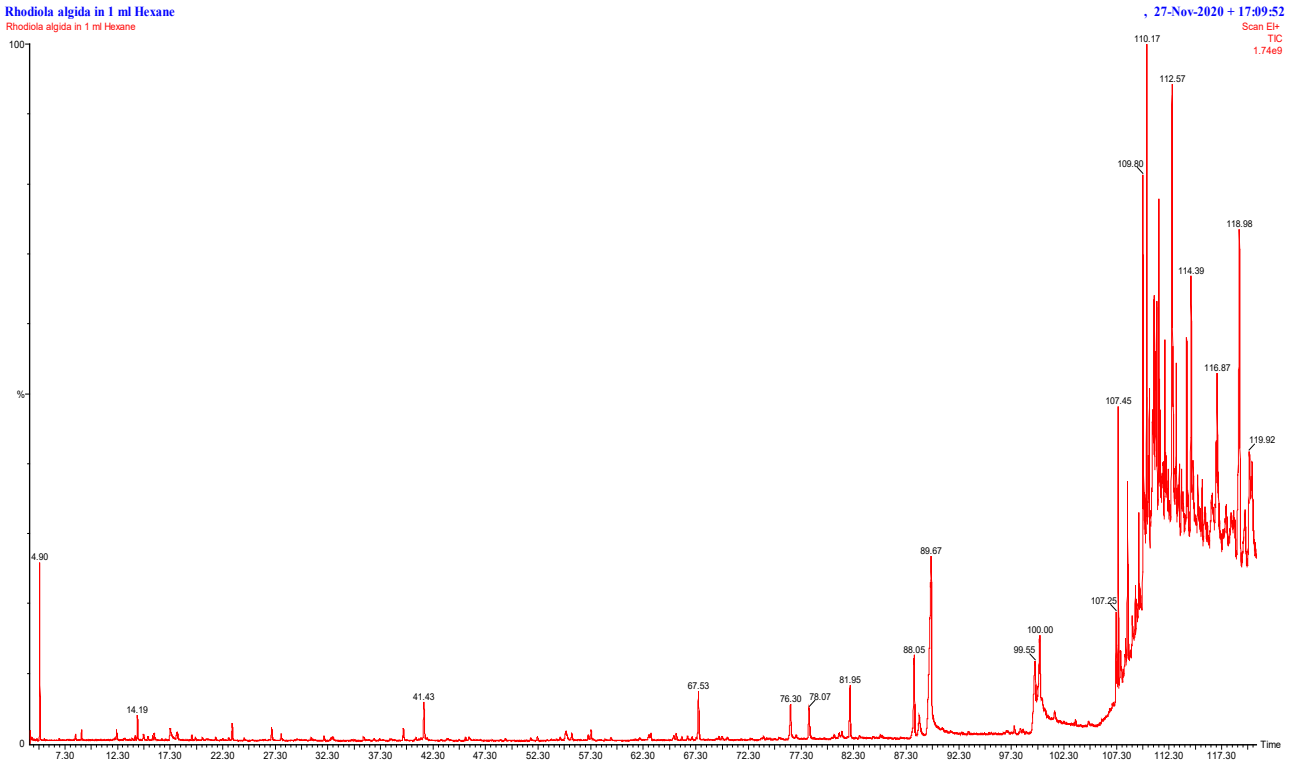

Figure 3 – Chromatogram of GC-MS of *R. algida* essential oil analysis

Table 2 – The cytotoxic activity of essential oils of *R. algida*

Parallel	The amount of larvae in the control		The amount of larvae in a sample			The amount of surviving larvae in the control, %	The amount of surviving larvae in sample, %	Mortality, P,%	The percentage of neurotoxicity, %
	survivors	died	survivors	died	paralyzed				
10 mg/ml									
1	20	1	0	29	0	96	0	96	0
2	22	0	0	24	0				
3	25	1	0	22	0				
Medium	22	1	0	25	0				
5 mg/ml									
1	20	1	0	28	0	96	0	96	0
2	22	0	0	21	0				
3	25	1	0	20	0				
Medium	22	1	0	23	0				
1 mg/ml									
1	20	1	1	19	0	96	4	92	0
2	22	0	2	25	0				
3	25	1	1	22	0				
Medium	22	1	1	22	0				

Results of the study the cytotoxic activity of essential oils are shown in Table 3. Based on the conducted experiment, it was found that *R. algida* essential oil in all tested concentrations (1, 5 and 10 mg/ml) exhibits acute lethal toxicity (96%) – all larvae die.

Table 3 – Changing the solutions optical density depending on the working concentration

№	Samples	Optical density value at concentration (mg/ml)			
		0,25	0,5	0,75	1,0
1	Butylhydroxyanisole (BHA)	1,6339	1,6785	1,7822	1,8032
2	*Rhodiola algida* (Rhalg)	0,4705	0,5031	0,5172	0,5425

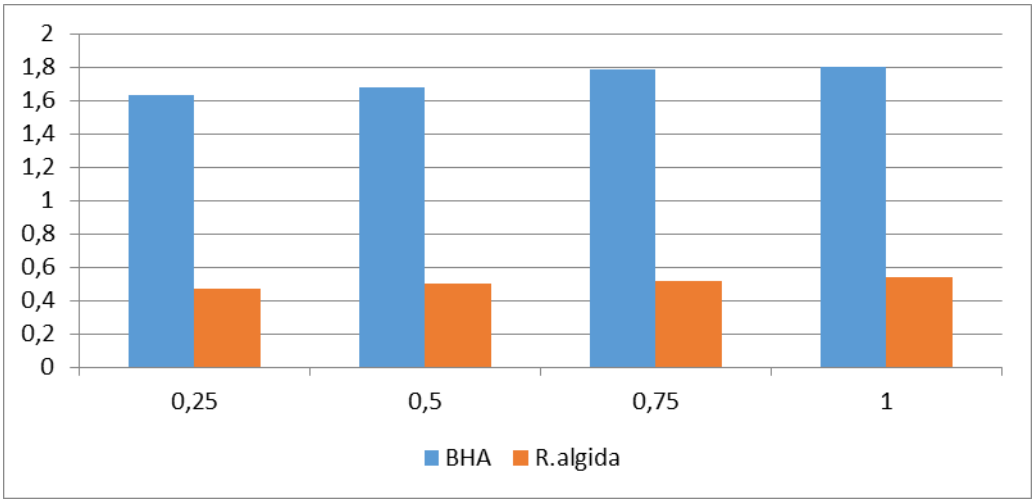

Figure 4 – The effect of the concentration of substances, mg/ml on the change in antioxidant activity

Based on the analysis of the data in Table 3 and Figure 4, it is clear that all the studied essential oils of *R. algida* in all concentrations of 0.25, 0.5, 0.75, 1 mg/ml have low (AA) compared to butylhydroxyanisole. According to the results of the experiment, it was found that *R. algida* essential oil has low anti-radical activity compared to the reference preparation butylhydroxyanisole.

Table 4 – Chromatographic analysis of *R. algida* extract

№	Retention time, min	Compound	Probability of identification, %	Percentage content, %	Formula	Activity	Literature
1	11,58	2-Cyclopenten-1-one, 2-hydroxy-	72	0,05	$C_9H_{12}O_2$	aroma of fresh citrus juice and may be used for perfumes, foods, and cosmetics	31
2	14,63	2-Hydroxy-gamma-butyrolactone	79	0,32	$C_4H_6O_3$	natural product found in Streptomyces albidoflavus, Aethus indicus, and other organisms with data available.	32

Table continuation

№	Retention time, min	Compound	Probability of identification, %	Percentage content, %	Formula	Activity	Literature
3	14,81	1,3-Dioxol-2-one,4,5-dimethyl-	69	1,01	$C_5H_6O_3$	a dioxolanone derivative used in the preparation of synthetic chemotherapeutic antibiotics such as Prulifloxacin	33
4	15,39	Maltol	72	0,86	$C_6H_6O_3$	a naturally occurring organic compound that is used primarily as a flavor enhancer.	34
5	16,05	Phenylethyl Alcohol	92	0,92	$C_8H_{10}O$	colourless liquid that is slightly soluble in water, being found in a variety of essential oils.	35
6	16,86	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	88	0,60	$C_6H_8O_4$	natural substances and extractives	36
7	17,08	Cyclopropyl carbinol	73	0,41	C_4H_8O	natural product found in Portulaca oleracea	37
8	19,87	5-Hydroxymethylfurfural	85	0,60	C6H6O3	It is used to synthesize many useful compounds and new polymer materials, including resin plastics, diesel fuel additives, etc.	38
9	20,36	2-Methoxy-4-vinylphenol	86	0,32	$C_9H_{10}O_2$	It has a role as a pheromone, a flavouring agent and a plant metabolite.	39
10	21,97	2-(4-Methoxyphenyl)ethanol	84	3,72	$C_9H_{12}O_2$	natural product found in Nymphaea rudgeana, Amorphophallus albispathus, and Amorphophallus lacourii	40
11	22,21	1,2,3-Benzenetriol	91	6,06	$C_6H_6O_3$	a benzenetriol carrying hydroxy groups at positions 1, 2 and 3. It has a role as a plant metabolite.	41
12	23,76	Benzeneethanol, 4-hydroxy-	88	40,22	$C_8H_{10}O_2$	Naturally occurring or synthetic substances that inhibit or retard oxidation reactions. They counteract the damaging effects of oxidation in animal tissues.	42
13	24,89	Sucrose	73	4,61	$C_{12}H_{22}O_{11}$	It has a role as an osmolyte, a sweetening agent, a human metabolite, an algal metabolite.	43
14	25,93	β-D-Glucopyranose, 1,6-anhydro-	91	4,74	$C_6H_{10}O_5$	can be used as a precursor for the synthesis of quasi-linear polyglucose (PGlc) via cationic ring-opening polymerization.	44
15	28,19	d-Mannose	62	0,49	$C_6H_{12}O_6$	It has a mild diuretic effect, removes bacteria and microbes from the body, prevents the appearance of disorders in the reproductive system in men.	45

Table continuation

№	Retention time, min	Compound	Probability of identification, %	Percentage content, %	Formula	Activity	Literature
16	31,42	2,7-Anhydro-l-galacto-heptulofuranose	78	1,77	$C_7H_{12}O_6$	is a natural product found in Ardisia crenata, Panax ginseng	46
17	35,63	Heneicosane	91	0,58	$C_{21}H_{44}$	It has a role as a pheromone, a plant metabolite and a volatile oil component.	47
18	38,97	Hexacosane	89	0,48	$C_{26}H_{54}$	It has a role as a volatile oil component and a plant metabolite.	48
19	41,95	1-Docosanol, acetate	94	2,08	$C_{24}H_{48}O_2$	A carboxylic ester found in Paronychia kapela	49
20	42,07	Hentriacontane	88	0,64	$C_{31}H_{64}$	It has a role as an antitubercular agent.	50
21	42,52	Octadecanal	84	0,67	$C_{18}H_{36}O$	alpha-CH2-containing aldehyde Stichodactyla helianthus, Melia azedarach, and other organisms	51
22	43,40	1-Eicosanol	80	0,39	$C_{20}H_{42}O$	1-Eicosanol has been used in gradient HPLC-charged aerosol detection method for the detection of different lipids	52
23	44,90	Tetracosyl acetate	95	10,67	$C_{26}H_{52}O_2$	a sex pheromone produced by Ctenopseustis obliquana females	53
24	45,47	Pentadecanal-	81	0,50	$C_{15}H_{30}O$	It has a role as an antimicrobial agent, a volatile oil component and a plant metabolite.	54
25	46,29	10-Heneicosene	71	0,59	$C_{21}H_{42}$	natural product found in Hamamelis virginiana	55
26	47,66	Hexacosyl acetate	95	14,32	$C_{28}H_{56}O_2$	a component of flowers and vegetation that may provide antifungal and antibacterial activity.	56
27	50,23	Tetratetracontane	75	0,88	$C_{44}H_{90}$	It has a role as a human metabolite.	52
28	50,89	Vitamin E	84	0,40	$C_{29}H_{50}O_2$	orally bioavailable alpha form of the naturally-occurring fat-soluble vitamin E, with potent antioxidant and cytoprotective activities.	55
29	54,62	γ-Sitosterol	82	1,12	$C_{29}H_{50}O$	It has a role as a plant metabolite and a marine metabolite. It is a 3beta-sterol, a member of phytosterols and a 3beta-hydroxy-Delta(5)-steroid.	56

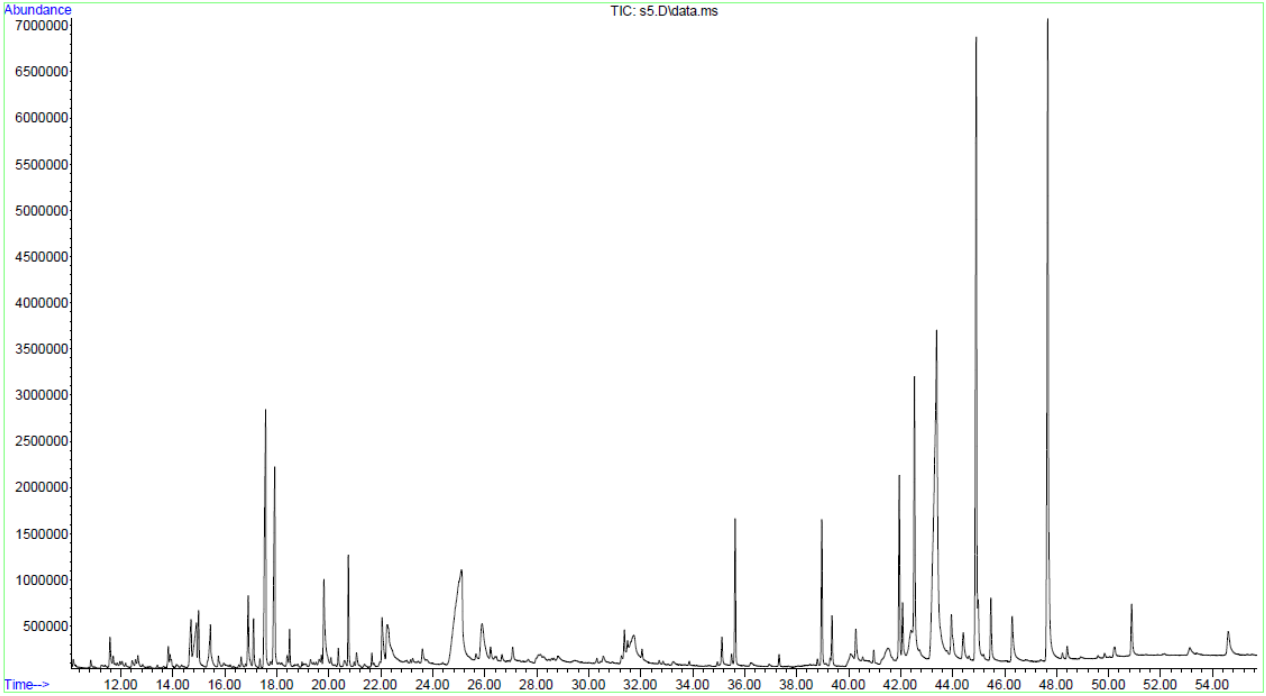

Figure 5 – Chromatogram of GC-MS analysis of *R. algida* ethanol extract

Antioxidants are molecules that inhibit the oxidation of other molecules. There are two main mechanisms of action of antioxidants [29]. The first mechanism is chain breaking, in which the primary antioxidant gives an electron to the free radical present in the system. The second mechanism is the removal of reactive nitrogen species (secondary antioxidants) by quenching the catalyst initiating the chain. Antioxidants can exert their effects on biological systems through various mechanisms as well as regulating gene expression [30]. Our primary results on antioxidant properties support this activity.

According to the literature, 2-(4-Methoxyphenyl) ethanol is a natural product found in Nymphaea rudgeana, Amorphophallus albispathus and Amorphophallus lacourii. In the course of research into the mechanistic application of kinetic isotope effects, it became necessary to obtain 2-aryl ethanols labeled with carbon-14 at a specific position of the aryl ring. The authors report the synthesis of 2-(4-methoxyphenyl)ethanol (ring-1-14C) (I) from toluene, ring-1-14CJ (II) [40].

1,2,3-Benzenetriol is a benzenetriol with hydroxyl groups at positions 1, 2, and 3. It plays the role of a plant metabolite. The results by scientists show that adsorption can occur through OH dissociation of all three hydroxyl groups and that all three reaction pathways are kinetically and thermodynamically favorable. The proximity between OH groups in the molecule promotes intra- and intermolecular hydrogen bonding, which stabilizes single- and double-bonded adsorbate configurations and limits the reactivity of the functional groups [41].

Benzeneethanol, 4-hydroxy – naturally occurring or synthetic substances that inhibit or retard oxidation reactions. They counteract the damaging effects of oxidation in animal tissues. Scientists have confirmed that 4-hydroxy-benzene is a naturally effective nematicide [45].

Sucrose – plays a role as an osmolyte, a sweetener, a human metabolite, and an algae metabolite. The use of sucrose as a chemical raw material was first motivated by the desire to increase a small proportion of the total production intended for more valuable applications, mainly for non-food purposes. Certain microorganisms, yeasts, and bacteria can also convert sucrose to other alcohols, as well as to organic acids, amino acids, and vitamins. All of these biological processes have been improved with modern biotechnology, making them more chemically and economically efficient and directing them toward new and useful chemical products [46].

β-D-Glucopyranose, 1,6-anhydro- can be used as a precursor for the synthesis of quasi-linear

polyglucose (PGlc) by cationic ring polymerization. Thermal analysis of 1,6-anhydro-β-D-glucopyranose shows physical transformations of the molecule, including transition to solid state, melting and evaporation, as well as subsequent chemical ones [47].

Tetracosyl acetate is the sex pheromone produced by female Ctenopseustis obliquana. In addition to hydrocarbons, other compounds present on the cuticle also varied considerably among the queen species. These compounds included tetracosyl, hexacosyl and octacosyl acetates, hexadecanal and octadecanal [54]. In our studies, tetracosyl acetate was identified from *R. algida* plants.

Hexacosyl acetate – component of flowers and vegetation, which may provide antifungal and antibacterial activity. According to literature data, phytochemical study of Indigofera heterantha root oil showed that hexacosyl acetate has inhibitory potential in the composition [57]. Analyzing all the works of scientists conducted identification of the chemical composition of the plant *R. algida* and our data show the composition of this medicinal plant is unique.

Conclusion

The component composition of the essential oil of *R. algida* was established for the first time. The total number of components with a content exceeding 0.1% is 100, of which 79 components were identified, constituting 82.9% of the total weight of the introduced sample. The main component of rhodiola essential oil is n-hexadecanoic acid (6.8%), 9-octadecanoic acid(E), 5.9%. Based on the results obtained, the cytotoxic activity and antioxidant properties of the medicinal plant *R. algida* were determined. To our knowledge, this is the first study containing data on the cytotoxic and antioxidant activity of *R. algida* essential oil from the Kazakhstan Altai. The chemical composition of the plant extract was also described in detail. The oil obtained from the studied *R. algida* is of great interest from the pharmaceutical point of view due to its cytotoxic activity and antioxidant properties.

This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP13067774 Search for biologically active substances and their use in agriculture)

References

1. P. Bhardwaj., G. Bhardwaj., R. Raghuvanshi., M. S. Thakur., R. Kumar., O. P. Chaurasia. (2018). An Overview of Phytochemistry and Pharmacological Applications. *New Age Herbals*. 71–113. DOI: 10.1007/978-981-10-8291-7_5

2. POWO, (2021) "Plants of the World Online. *Facilitated by the Royal Botanic Gardens, Kew.* Published on the Internet; http://www.plantsoftheworldonline.org/ Retrieved 10.07.2022

3. Kelly, G.S., (2001) Rhodiola rosea: a possible plant adaptogen. *Alternative medicine review : a journal of clinical therapeutic* 6(3), 293-302.

4. Li, G., Gai, X., Li, Z., Chang, R., Qi, Y., Zhaxi, D., Jin, G., Nie, S., Wu, P., Lu, D., (2016) Preliminary study of active component and mechanism of Rhodiola algida var. tangutica on inducing rat pulmonary artery vasorelaxation. *Journal of Qinghai Medical College*(01), 40-45.

5. Li, H.X., Sze, S.C.W., Tong, Y., Ng, T.B., (2009) Production of Th1- and Th2-dependent cytokines induced by the Chinese medicine herb, Rhodiola algida, on human peripheral blood monocytes. *Journal of Ethnopharmacology* 123(2), 257-266

6. Lan, B., Hayama, E., Kawaguchi, N., Furutani, Y., Nakanishi, T., (2015) Therapeutic efficacy of valproic acid in a combined monocrotaline and chronic hypoxia rat model of severe pulmonary hypertension. *PLoS One* 10(1), e0117211.

7. Arora R., Chawla R., Sagar R., Prasad J., Singh S., Kumar R et al (2005) Evaluation of radioprotective activities Rhodiola imbricate Edgew-ahigh altitude plant. *Mol Cell Biochem* 273:209–223

8. Germano C., Ramazanov Z., Bernal Suarez M. (1999) Arctic root (Rhodiola rosea): the powerful new ginseng alternative. *Kensington Publishing Corporation*, New York

9. Kelly GS. (2001) Rhodiola rosea: a possible plant adaptogen. *Altern Med Rev* 6:293–302

10. Li HX., Sze SCW., Tong Y., Ng TB. (2009) Production of Th1- and Th2-depend- ent cytokines induced by the Chinese medicine herb, Rhodiola algida, on human peripheral blood monocytes. *J Ethnopharmacol* 123:257–266

11. Cui S., Hu X., Chen X., Hu Z. (2003) Determination of p-tyrosol and salidroside in three samples of Rhodiola crenulata and one of Rhodiola kirilowii by capillary zone electrophoresis. *Anal Bioanal Chem* 377:370–374

12. Lu DX., Zhang SN., Wang WP., Zhen J. (2011) The Study of Cytostatic Effect on MCF-7 Cells of the Alcohol Extract of Rhodiola Algida Var. *Tangutica. In: 2011 3rd International Conference on Bioinformatics and Biomedical Technology* (ICBBT 2011), pp 228–230

13. Flora ya Kazakhstan. Vol.6. – Alma-Ata: *Nauka*, 1966, 345 p.

14. Wings TY Loo., LJ Jin., Louis WC Chow† ., Mary NB Cheung & Min Wang. Rhodiola algida improves chemotherapy-induced oral mucositis in breast cancer patients. *Expert Opin. Investig. Drugs* (2010) 19(Suppl.1):S91-S100

15. Darbinyan V., Kteyan A., Panossian A., et al. Rhodiola rosea in stress induced fatigue--a double blind cross-over study of a standardized extract SHR-5 with a repeated low-dose regimen on the mental performance of healthy physicians during night duty. 2000;7:365-71 2.

16. Shevtsov VA., Zholus BI., Shervarly VI., et al. A randomized trial of two different doses of a SHR-5 Rhodiola rosea extract versus placebo and control of capacity for mental work. *Phytomedicine* 2003;10:95-105

17. Spasov AA., Wikman GK., Mandrikov VB., et al. (2000). A double-blind, placebo-controlled pilot study of the stimulating and adaptogenic effect of Rhodiola rosea SHR-5 extract on the fatigue of students caused by stress during an examination period with a repeated low-dose regime. *Phytomedicine*;7:85-9

18. Abidov M., Crendal F., Grachev S., et al.(2003). Effect of extracts from Rhodiola rosea and Rhodiola crenulata (Crassulaceae) roots on ATP content in mitochondria of skeletal muscles. *Bull Exp Biol Med*;136:585-7

19. Abidov M., Grachev S., Seifulla RD., et al. Extract of Rhodiola rosea radix reduces the level of C-reactive protein and creatinine kinase in the blood. *Bull Exp Biol Med* 2004;138:63-4

20. Bocharova OA., Matveev BP., Baryshnikov AIU., et al. The effect of a Rhodiola rosea extract on the incidence of recurrences of a superficial bladder cancer (experimental clinical research). *Urol Nefrol (Mosk)* 1995;2:46-7

21. Colonna M. Can we apply the TH1-TH2 paradigm to all lymphocytes? *Nat Immunol* 2001;2:899-900

22. Kidd P. Th1/Th2 balance: the hypothesis, its limitations, and implications for health and disease. *Altern Med Rev* 2003;8:223-46

23. State Pharmacopoeia of the USSR. Issue. 2. General methods of analysis. *Medicinal plant raw materials of the Ministry of Health of the USSR.* 11th ed. – Moscow, 1990, 400 p.

24. State Pharmacopoeia of the Republic of Kazakhstan // B 3 t. – Almaty: Publishing house Zhibek, 2009. – T. 2. – 804 p.

25. https://www.plantarium.ru/page/view/item/31807.html

26. M. A. Zhunusova., E. M. Suleimen., Zh. B. Iskakova., M. Yu. Ishmuratova., R. M. Abdullabekova. Constituent Composition and Biological Activity of CO2-Extracts of Scabiosa isetensis and S. ochroleucaChem. *Nat. Compd*., 53 (4), 775-777 2017.

27. E. M. Suleimenov. The component composition of the Tragopogon orientalisvolatile constituents and its biological activity Chem. *Nat. Compd.*, 45 (5), 710-711 (2009).

28. G. G. Sisengalieva., E. M. Suleimen., I. Yu. Ishmuratova., Zh. B. Iskakova., K. Van Hecke. Constituent Composition and Biological Activity of CO2-Extracts of Scabiosa isetensis and S. ochroleuca. *Chem. Nat. Compd.*, 51, 544 (2015).

29. Rice-Evans CA., Diplock AT. Current status of antioxidant therapy. *Free Radic Biol Med.* 1993;15:77–96. [PubMed] [Google Scholar]

30. Krinsky NI. Mechanism of action of biological antioxidants. *Proc Soc Exp Biol Med.* 1992;200:248–54. [PubMed] [Google Scholar]

31. Yong Liu., Kai Xie., Yi Pan., Yujie Li., Hui Wang., Zhaoqing Jin2 and Chunman Zheng. 2017. Investigation of 4, 5-Dimethyl-1, 3-dioxol-2-one as Additives on the Storage Life of LiNi0.8Co0.15Al0.05O2/Graphite Batteries at Elevated Temperature. *Journal of The Electrochemical Society*, Volume 164, Number 14. https://iopscience.iop.org/article/10.1149/2.0301802jes

32. Katherine H. Thompson., Cheri A. Bartaa and Chris Orviga. Metal complexes of maltol and close analogues in medicinal inorganic chemistry. *Citation: Chem. Soc. Rev*., 2006,35, 545-556. https://doi.org/10.1039/B416256K

33. Scognamiglio L., Jonesb C.S. Letiziaa A.M. Apia. Food and Chemical Toxicology. Volume 50, Supplement 2, September 2012, Pages S224-S239. Fragrance material review on phenylethyl alcohol. *Research Institute for Fragrance Materials*, Inc., 50 Tice Boulevard, Woodcliff Lake, NJ 07677, USA. Leah Jones Consulting, 55 W 14th Street, New York, NY 10011, USA. https://doi.org/10.1016/j.fct.2011.10.028

34. Čechovská, L., Cejpek, K., Konečný, M. *et al.* On the role of 2,3-dihydro-3,5-dihydroxy-6-methyl-(4*H*)-pyran-4-one in antioxidant capacity of

prunes. *Eur Food Res Technol* **233,** 367–376 (2011). https://doi.org/10.1007/s00217-011-1527-4

35. Cyclopropyl Carbinol Rearrangement for Benzo-Fused Nitrogen Ring Synthesis. Prasath Kothandaraman,Chuhui Huang,Dewi Susanti,Dr. Weidong Rao,Prof. Dr. Philip Wai Hong Chan. First published: 21 July 2011. https://doi.org/10.1002/chem.201101363

36. 5-Hydroxymethylfurfural (HMF). A Review Focussing on its Manufacture. Dr. B. F. M. Kuster. First published: 1990. https://doi.org/10.1002/star.19900420808

37. Jeong, J.B., Hong, S.C., Jeong, H.J. et al. Anti-inflammatory effect of 2-methoxy-4-vinylphenol via the suppression of NF-κB and MAPK activation, and acetylation of histone H3. Arch. Pharm. Res. 34, 2109–2116 (2011). https://doi.org/10.1007/s12272-011-1214-9

38. L. Labanauskas., E. Udrenaite., P. Gaidelis., A. Brukštus. Synthesis of 5-(2-,3- and 4-methoxyphenyl)-4H-1,2,4-triazole-3-thiol derivatives exhibiting anti-inflammatory activity, Il Farmaco, Volume 59, Issue 4, 2004, Pages 255-259, ISSN 0014-827X, https://doi.org/10.1016/j.farmac.2003.11.002. (https://www.sciencedirect.com/science/article/pii/S0014827X03002982)

39. Adsorption of homo-trifunctional 1,2,3-benzenetriol on the Ge(100)-2x1 surface Tania E. Sandoval and Stacey F. Bent*Department of Chemical Engineering, Stanford University, 443 Via Ortega, Stanford, California 94305, United States https://doi.org/10.1021/acs.langmuir.7b00872

40. Tao Li ., Hongyun Wang., Xiubo Xia., Shoujun Cao., Jiangang Yao., Lili Zhang. Inhibitory effects of components from root exudates of Welsh onion against root knot nematodes.. Published: July 30, 2018 https://doi.org/10.1371/journal.pone.0201471

41. J.C.Lee S.N.Timasheff. 25 July 1981, The stabilization of proteins by sucrose. 2021. *Journal of Biological Chemisrty* https://doi.org/10.1016/S0021-9258(19)68947-7

42. Y. J. Park., H. S. Kim and G. A. Jeffrey. The crystal structure of 1,6-anhydro-[beta]-D-glucopyranose. *Acta Cryst.* (1971). B27, 220-227 https://doi.org/10.1107/S0567740871001936

43. Xing Hu.,Yaning Shi., Peng Zhang., Ming Miao., Tao Zhang., Bo Jiang. d-Mannose: Properties, Production, and Applications: An Overview. First published: 26 May 2016 https://doi.org/10.1111/1541-4337.12211

44. Huiyan Zhang Rui Xiao Denghui Wang Guangying He Shanshan Shao Jubing Zhang Zhaoping Zhong. Biomass fast pyrolysis in a fluidized bed reactor under N2, CO2, CO, CH4 and H2 atmospheres. *School of Energy and Environment, Southeast University*, Nanjing 210096, China. Received 19 October 2010, Revised 16 December 2010, Accepted 16 December 2010, Available online 23 December 2010. https://doi.org/10.1016/j.biortech.2010.12.075

45. Author(s) : Mendki, M. J., Ganesan, K., Shri Prakash., Suryanarayana, M. V. S., Malhotra, R. C. ; Rao, K. M. ; Vaidyanathaswamy, R. Heneicosane: an oviposition-attractant pheromone of larval origin in Aedes aegypti mosquito. Author Affiliation : Defence Research & Development Establishment, Jhansi Road, Gwalior 474 002, India. Journal article : *Current Science* 2000 Vol.78 No.11 pp.1295-1296 ref.7 https://www.cabdirect.org/cabdirect/abstract/20000508818

46. Rukaiyat M., Garba S., Labaran S. Antimicrobial activities of hexacosane isolated from Sanseveria liberica (Gerome and Labroy) plant //*Adv Med Plant Res*. – 2015. – Т. 3. – №. 3. – С. 120-125. http://www.netjournals.org/pdf/AMPR/2015/3/15-028.pdf

47. Measurement of .gamma..infin. using gas-liquid chromatography. 1. Results for the stationary phases n-octacosane, 1-docosanol, 10-nonadecanone, and 1-eicosene. Ulrich Weidlich and Juergen Gmehling. *Journal of Chemical & Engineering* Data 1987 32 (2), 138-142. DOI: 10.1021/je00048a003 https://doi.org/10.1021/je00048a003

48. Antiinflammatory Effect of Oldenlandia diffusa and its Constituent, Hentriacontane, through Suppression of Caspase-1 Activation in Mouse Peritoneal Macrophages. Su-Jin Kim.,Won-Seok Chung.,Sung-Soo Kim.,Seong-Gyu Ko., Jae-Young Um. First published: 11 March 2011 https://doi.org/10.1002/ptr.3443

49. Schomburg, D., Stephan, D. (1998). Octadecanal decarbonylase. In: Schomburg, D., Stephan, D. (eds) *Enzyme Handbook* 17. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-58969-0_15

50. Polymorphism of N-Alkanols: 1-Heptadecanol, 1-Octadecanol, 1-Nonadecanol, and 1-Eicosanol. L. Ventolà., M. Ramírez., T. Calvet., X. Solans., M. A. Cuevas-Diarte., P. Negrier., D. Mondieig, J. C. van Miltenburg, and H. A. J. Oonk. Chemistry of Materials 2002 14 (2), 508-517. DOI: 10.1021/cm011010h https://doi.org/10.1021/cm011010h

51. Built to change: dominance strategy changes with life stage in a primitively eusocial bee.

Margarita Orlova, Erin Treanore, Etya Amsalem. *Behavioral Ecology*, Volume 31, Issue 6, November/December 2020, Pages 1361–1368, https://doi.org/10.1093/beheco/araa093 Published: 07 October 2020

52. Annarita Ricciardelli., Angela Casillo., Rosanna Papa., Daria Maria Monti., Paola Imbimbo., Gianluca Vrenna., Marco Artini., Laura Selan., Maria Michela Corsaro., Maria Luisa Tutino & Ermenegilda Parrilli (2018) Pentadecanal inspired molecules as new anti-biofilm agents against Staphylococcus epidermidis, *Biofouling*, 34:10, 1110-1120, DOI: 10.1080/08927014.2018.1544246 https://doi.org/10.1080/08927014.2018.1544246

53. R. J. Bartelt., L. L. Jackson, Hydrocarbon Component of the Drosophila virilis (Diptera: Drosophilidae) Aggregation Pheromone: (Z)-10-*Heneicosene*, Annals of the Entomological Society of America, Volume 77, Issue 4, 1 July 1984, Pages 364–371, https://doi.org/10.1093/aesa/77.4.364

54. J.G. Hawke., A.E. Alexander. The Influence of Surface-Active Compounds upon the Diffusion of Gases across the Air–Water Interface, Editor(s): Victor K. La Mer, *Retardation of Evaporation by Monolayers*, Academic Press, 1962, Pages 67-73, ISBN 9781483229478, https://doi.org/10.1016/B978-1-4832-2947-8.50010-0.

55. Kraus M. et al. High-mobility copper-phthalocyanine field-effect transistors with tetratetracontane passivation layer and organic metal contacts //*Journal of Applied Physics*. – 2010. – Т. 107. – №. 9. – С. 094503. https://doi.org/10.1063/1.3354086

56. Brigelius-Flohé R., Traber M. G. Vitamin E: function and metabolism //*The FASEB journal.* – 1999. – Т. 13. – №. 10. – С. 1145-1155. https://doi.org/10.1096/fasebj.13.10.1145

Content