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Review Article

Chemical Components and Biological Effects of Genus *Origanum*

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The plants from genus *Origanum* are common folk Chinese herbs used to treat a variety of diseases. They are also used as a spice, a seasoning, and an ornament. *Origanum* plants are rich in essential oils and also have other compounds including terpenoids, flavonoids, organic acids, and sterols. They have a variety of biological activities such as antispasmodic, anti-inflammatory, growth-promoting, antibacterial, antioxidant, and anticancer properties. The chemical components and biological effects of genus *Origanum* were summarized by different scientific databases such as Web of Science, SciFinder, Baidu Scholar, PubMed, ScienceDirect, and SpringerLink. In conclusion, recent studies were mainly focused on the activities of their essential oils. The research studies for nonvolatile constituents and their pharmacological activities are few. Therefore, research on compounds in genus *Origanum* plants can be strengthened and their application prospect can be explored so as to make better use of the resources of these plants.

1. Introduction

The genus *Origanum* (Lamiaceae) is an annual, perennial, and shrubby herb. It comprises about 15 to 20 species and is widely distributed throughout the world. There is only one species of genus *Origanum* (*O. vulgare*) in China, mainly distributed in Xinjiang, Gansu, Shanxi, Hubei, and Henan Provinces, etc. [1].

The whole plants of the genus *Origanum* can be used medicinally throughout the world. For example, *O. majorana* has been used in ancient Egypt as antiseptic, insect repellent, and expectorant and for arthritis, muscle pain, rheumatism, and other diseases and is now widely used in cooking seasonings and cosmetics. *O. vulgare* subsp. *glandulosum* (syn. *O. glandulosum*) is named 'Zaâter moulouk' in Tunisia. It is one of the most important plants of Lamiaceae economically, and several studies have shown that genus *Origanum* possessed the antimicrobial, antifungal, and insecticidal properties and antioxidant activities. In China, the whole plant of *O. vulgare* is a common Chinese herbal medicine in Chinese folk and was listed in Chinese Pharmacopoeia (1977 edition). It has the function of clearing away heat and reducing swelling and mainly used for sunstroke, cold, headache, acute enteritis, abdominal pain, and diarrhea. It is also used as a spice, condiment, and ornament.

Researches on genus *Origanum* are mainly carried out in Egypt, Tunisia, Turkey, and so on. The chemical constituents of genus *Origanum* are mainly essential oils, with the effects of removing phlegm, resisting spasm, nourishing and strengthening body, relieving pain, and having antisepsis, antibacterial, antimildew, antioxidation, and anticytotoxin effects. The nonvolatile constituents of *Origanum* plants are seldom studied, which mainly contain flavonoids, triterpenes, and organic acids. Therefore, systematic studies of their chemical constituents and biological activities are of great significance to elucidate its medicinal value.

2. Chemical Constituents

The essential oils of genus *Origanum* contain many active constituents. They have a broad spectrum of antibacterial, antitumor, and immunomodulatory effects, but there are few studies on the nonvolatile constituents, including flavonoids, organic acids, terpenoids, and sterols. The main constituents of essential oils from genus *Origanum* in the world are listed in Table 1 and the nonvolatile constituents of genus *Origanum* in the world are listed in Table 2.

2.1. Main Constituents of Essential Oils of Genus Origanum. Plants of genus *Origanum* are rich in essential oils and the main constituents are terpenoids, which mainly include carvacrol, thymol, carbamene, and terpilenol (Figures 1–3). [2–8, 18–20].

Hatipi collected 12 plants of *O. vulgare* from different parts in Kosovo. The essential oils were extracted by steam distillation and the yield of essential oils was 0.41–0.82% of dry weight. The main constituents included sesquiterpenoids (6.1–37.06%), monoterpenes (1.73–35.18%), oxygenated monoterpene (6.88–36.06%), oxygenated sesquiterpenoids (2.49–43.44%), 1, 8-cineole (1.31–13.54%), caryophyllene oxide (0.18–38.05%), (*E*)-β-caryophyllene (0.48–14.0%), *p*-cymene (1.27–19.62%), α-terpineol (1.05–19.23%), and germacrene D (0.35–16.09%) [19].

The essential oils from the above ground parts of *O. heracleoticum* and *O. majorana* made up 1.8% and 0.4% of their total dry weight, respectively. 55 compounds were identified from the essential oils, among which 35 compounds were from *O. heracleoticum*, accounting for 97.8% of the total oils, and 20 compounds were from *O. majorana*, accounting for 98.0% of the total oils. Oxygenated monoterpenes (80.1%) were the main constituents of *O. heracleoticum* essential oils, while monoterpenes (54.0%) were mainly found in *O. majorana* essential oils. Carvacrol (77.8%), *p*-cymene (5.3%), γ-terpinene (4.9%), and caryophyllene (1.3%) were the main components in *O. heracleoticum* essential oils. In *O. majorana* essential oils, the main constituents included terpineol (29.6%), 2-carene (20.1%), camphene (13.4%), and α-pinene (7.9%) [8].

Huo found monoterpenes and bicyclic sesquiterpenes were the main constituents of the essential oils of *O. vulgare* L. through the analysis of GC-MS, and the mass fractions of these two kinds of components in the essential oils of *O. vulgare* L. were 69.31% and 20.25%, respectively [20].

Gong identified 65 chemical constituents from the essential oils of genus *Origanum* plants in 6 different habitats from China and Pakistan by GC-MS and found that the main constituents of essential oils in 6 different habitats were all oxygenated monoterpenes [2].

Essential oils of *O. onites* aerial parts were analyzed by GC-MS with hydrodistillation (HD) and microwave-assisted HD (MWHD) methods. Thirty-one compounds were identified from HD method and 52 compounds were identified from MWHD method. Among them, carvacrol (76.8% HD and 79.2% MWHD) and thymol (4.7% HD and 4.4% MWHD) were the main constituents of these two essential oils [4]. Farhat found essential oils from the leaves of *O. syriacum* in Syria were mainly carvacrol (78.4%) and thymol (17.9%) analyzed by SPME GC/MS [7].

Shafaghat obtained 23 compounds from the essential oils of flowers, leaves, and stems of *O. vulgare* growing in northwest Iran by GC-MS, about 96.3% (19 compounds) of the flower oil, 92.8% (11 compounds) of the leaf oil, and 95.2% (12 compounds) of the stem oil. The dominant compounds in the flower, leaf, and stem oils were sesquiterpene (53.6%, 50.7%, and 70.4%, respectively) and linalyl acetate, sabinene, γ-terpinene and ocimene were the main constituents of the oil of the aerial parts of *O. vulgare* [6].

Aligiannis identified 48 compounds from the essential oils of *O. scabrum* and *O. microphyllum*, accounting for 98.59% and 98.66% of the total oils, respectively. Carvacrol, terpilenol, linalool, sabinene, and terpinene are the main constituents [5].

Spyridopoulou identified 64 compounds from essential oils of *O. onites*. The most abundant chemical constituent in essential oils is carvacrol (47.99%), which is consistent with those reported in literatures that the content of carvacrol in essential oils was between 50% and 85%. Other main constituents were identified as terp-1-in-4-ol (6.79%), sabinene hydrate (6.14%), γ-terpinene (5.20%), *p*-cymene (3.85%), and α-terpineol (3.76%) [3].

In conclusion, 92 compounds were found in essential oils to date, including monoterpenes (**1**–**49**), sesquiterpenoids (**50**–**69**), and other derivatives (**70**–**92**). Moreover, the chemical constituents of essential oils varied greatly with species in the genus *Origanum* and can be roughly divided into two categories: one is rich in carvacrol, thymol, cymene, and terpinene and the other is rich in coriandrol, germacrene D, and other ingredients. When the chemical constituents of essential oils in a certain plant were rich in the first group, then the compounds of the second group were few, and vice versa. Meanwhile, essential oils have many pharmacological activities. Therefore, understanding of their chemical compositions of essential oils thoroughly is more helpful to elucidate their material basis.

2.2. Nonessential Constituents of Genus Origanum

2.2.1. Flavonoids. 23 flavonoids (**93**–**115**) (Figure 4) were isolated from genus *Origanum* [9–14]. Compounds **93**–**107** belong to flavonoids, **108**–**111** belong to flavonols, and **112**–**115** belong to flavanone and their glycosides.

2.2.2. Organic Acids. 20 organic acid compounds (**116-135**) (Figure 5) were isolated from genus *Origanum* [9–16], mainly including phenols, cinnamic acids, and salvianolic acids.

2.2.3. Terpenes and Sterols. The terpenoids oleanolic acid (**136**), arbutin (**137**) [13], sterol stigmasterol (**138**) [11], β-sitosterol (**139**), and daucosterol (**140**) were isolated from genus *Origanum* (Figure 6) [15].

Table 1: The main constituents of essential oils from genus *Origanum* in the world.

Compound	Name	Source	Parts	Producing area	References
		Monoterpenes (**1–51**)			
1	Myrcene	*O. vulgare*	The whole plants	Anhui, China	[2]
2	Nerol	*O. onites*	Leaves, flowers	Athens, Greece	[3]
3	Geraniol	*O. vulgare*	The whole plants	Xinjiang, China	[2]
4	β-Citronellal	*O. onites*	Aerial parts	Izmir, Turkey	[4]
5	Acetic acid, geraniol ester	*O. vulgare*	The whole plants	Kunlun Mountain	[2]
6	Citronellol acetate	*O. vulgare*	The whole plants	Kunlun Mountain	[2]
7	Ocimene	*O. microphyllum*	Aerial parts	Crete	[5]
8	Citral	*O. onites*	Leaves, flowers	Athens, Greece	[3]
9	Citronellol	*O. vulgare*	The whole plants	Henan, China	[2]
10	Citronellyl formate	*O. vulgare*	The whole plants	Pakistan	[2]
11	Hydroxycitronellal	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
12	Neryl acetate	*O. onites*	Leaves, flowers	Athens, Greece	[3]
13	Linalool	*O. microphyllum*	Aerial parts	Crete	[5]
14	Linalyl acetate	*O. onites.*	Leaves, flowers	Athens, Greece	[3]
15	Epoxy linalool	*O. onites*	Leaves, flowers	Athens, Greece	[3]
16	α-Terpinene	*O. microphyllum*	Aerial parts	Crete	[5]
17	γ-Terpinene	*O. syriacum*	Leaves	Arabsalim, Lebanon	[7]
18	α-Phellandrene	*O. onites*	Leaves, flowers	Athens, Greece	[3]
19	Terpinolene	*O. microphyllum*	Aerial parts	Crete	[5]
20	β-Phellandrene	*O. scabrum*	Aerial parts	Peloponissos	[5]
21	Limonene	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
22	Cymene	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
23	Piperitol	*O. onites*	Leaves, flowers	Athens, Greece	[3]
24	Thymol	*O. scabrum*	Aerial parts	Peloponissos	[5]
25	p-Cymen-2-ol	*O. vulgare*	The whole plants	Pakistan	[2]
26	Terpinen-4-ol	*O. scabrum*	Aerial parts	Peloponissos	[5]
27	α-Terpineol	*O. microphyllum*	Aerial parts	Crete	[5]
28	p-Cymen-8-ol	*O. onites*	Aerial parts	Izmir, Turkey	[4]
29	trans-Dihydrocarvone	*O. heracleoticum*	Aerial parts	Salerno, Montecorice	[8]
30	Carvone	*O. onites*	Aerial parts	Izmir, Turkey	[4]
31	Isopiperitenone	*O. onites*	Leaves, flowers	Athens, Greece	[3]
32	Thymol methyl ether	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
33	Carvacrol methyl ether	*O. onites*	Leaves, flowers	Athens, Greece	[3]
34	Benzene, 1-methoxy-4-methyl-2-(1-methylethyl)	*O. vulgare*	The whole plants	Pakistan	[2]
35	Thymol acetate	*O. vulgare*	The whole plants	Anhui, China	[2]
36	Carvacrol acetate	*O. vulgare*	The whole plants	Anhui, China	[2]
37	α-Campholenal	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
38	Sabinene	*O. microphyllum*	Aerial parts	Crete	[5]
39	Thujene	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
40	Thujanol	*O. onites*	Leaves, flowers	Athens, Greece	[3]
41	Thujone	*O. onites*	Aerial parts	Izmir, Turkey	[4]
42	Sabinene hydrate	*O. scabrum*	Aerial parts	Peloponissos	[5]
43	α-3-Carene	*O. scabrum*	Aerial parts	Peloponissos	[5]
44	Pinocarvone	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
45	α-Pinene	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
46	β-Pinene	*O. scabrum*	Aerial parts	Peloponissos	[5]
47	α-trans-bergamotene	*O. vulgare*	The whole plants	Anhui, China	[2]
48	Camphene	*O. microphyllum*	Aerial parts	Crete	[5]

Table 1: Continued.

Compound	Name	Source	Parts	Producing area	References
49	Borneol	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
50	(Z)-β-Farnesene	*O. vulgare*	The whole plants	Anhui, China	[2]
51	(E, E)-α-Farnesene	*O. vulgare*	The whole plants	Xinjiang, China	[2]
	Sesquiterpenoids (**52–69**)				
52	Germacrene D	*O. onites*	Leaves, flowers	Athens, Greece	[3]
53	β-Sesquiphellandrene	*O. vulgare*	Leaves, flowers	Athens, Greece	[3]
54	β-Bisabolene	*O. onites*	Aerial parts	Izmir, Turkey	[4]
55	β-Bisabolene	*O. scabrum*	Aerial parts	Peloponissos	[5]
56	Germacrene B	*O. vulgare*	The whole plants	Xinjiang, China	[2]
57	Humulene	*O. microphyllum*	Aerial parts	Crete	[5]
58	γ-Muurolene	*O. vulgare*	The whole plants	Henan, China	[2]
59	γ-Cadinene	*O. onites*	Leaves, flowers	Athens, Greece	[3]
60	Cubenol	*O. vulgare*	The whole plants	Xinjiang, China	[2]
61	Cadinol	*O. onites*	Leaves, flowers	Athens, Greece	[3]
62	Limonene	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
63	α-Bulnesene	*O. vulgare*	The whole plants	Anhui, China	[2]
64	Caryophyllene	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
65	Caryophyllene oxide	*O. scabrum*	Aerial parts	Peloponissos	[5]
66	Spathulenol	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
67	Aromadendrene	*O. onites*	Leaves, flowers	Athens, Greece	[3]
68	Thujopsene	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
69	Copaene	*O. vulgare*	The whole plants	Henan, China	[2]
	Others (**70–92**)				
70	Octen-3-ol	*O. scabrum*	Aerial parts	Peloponissos	[5]
71	3-Octanone	*O. scabrum*	Aerial parts	Peloponissos	[5]
72	3-Octanol	*O. vulgare*	The whole plants	Henan, China	[2]
73	Methyl 2-methylbutyrate	*O. onites*	Leaves, flowers	Athens, Greece	[3]
74	Isoamyl acetate	*O. onites*	Leaves, flowers	Athens, Greece	[3]
75	Cis-rose oxide	*O. vulgare*	The whole plants	Xinjiang, China	[2]
76	Phenylacetaldehyde	*O. microphyllum*	Aerial parts	Crete	[5]
77	Eugenol	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
78	Camphor	*O. onites*	Leaves, flowers	Athens, Greece	[3]
79	p-Methylbenzaldehyde	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
80	Acetovanillone	*O. heracleoticum*	Dried aerial parts	Salerno, Montecorice	[8]
81	Eugenol methyl ether	*O. vulgare*	The whole plants	Anhui, China	[2]
82	Isoeugenol methyl ether	*O. vulgare*	The whole plants	Anhui, China	[2]
83	Elemicin	*O. vulgare*	The whole plants	Anhui, China	[2]
84	Myristicin	*O. vulgare*	The whole plants	Anhui, China	[2]
85	Apiol	*O. vulgare*	The whole plants	Anhui, China	[2]
86	Dill apiol	*O. vulgare*	The whole plants	Anhui, China	[2]
87	Cis-asarone	*O. vulgare*	The whole plants	Anhui, China	[2]
88	Asarone	*O. vulgare*	The whole plants	Anhui, China	[2]
89	5-Methylfurfural	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]
90	1, 5, 5, 8-Tetramethyl-12-oxabicyclo [9.1.0] dodeca-3, 7-diene	*O. vulgare*	The whole plants	Xinjiang, China	[2]
91	Indole	*O. onites*	Leaves, flowers	Athens, Greece	[3]
92	5-Phenylisoquinoline	*O. vulgare SSP.*	Flowers, leaves, stems	Astara, Iran	[6]

Table 2: Nonvolatile constituents of genus *Origanum* in the world.

Compound	Name	Source	Parts	Producing area	References
		Flavonoids (**93–115**)			
93	Luteolin	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
94	Apigenin	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
95	Luteolin7-O-β-D-glucopyranoside	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
96	Luteolin7-O-β-D-glucuronide	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
97	Luteolin7-O-β-D-xylopyranoside	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
98	Apigenin7-O-β-D-glucuronide	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
99	Apigenin7-O-β-D-(6″-methyl) glucuronide	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
100	5, 6, 3′-Trihydroxy-7, 8, 4′-trimethoxyflavone	*O. majorana*	Dried aerial parts	Tokat, Turkey	[10]
101	5, 6, 4′-Trihydroxyl-7, 8-dimethoxylflavone	*O. x intercedens*	—	Greece	[11]
102	5, 6, 4′-Trihydroxyl-7, 3′-dimethoxylflavone	*O. x intercedens*	—	Greece	[11]
103	5, 6, 4′-Trihydroxyl-7, 8, 3′-trimethoxylflavone	*O. x intercedens*	—	Greece	[11]
104	6, 7, 4′-Trihydroxyflavone	*O. vulgare*	The whole plants	Guangdong, China	[12]
105	Tilianin	*O. vulgare*	The whole plants	—	[13]
106	5, 4′-Dihydroxyl-6, 7-dimethoxylflavone	*O. x intercedens*	—	Greece	[11]
107	5, 4′-Dihydroxyl-6, 7-dimethoxylflavone	*O. x intercedens*	—	Greece	[11]
108	Kaempferol	*O. vulgare*	—	—	[14]
109	Quercetin	*O. vulgare*	—	—	[14]
110	Morin	*O. vulgare.*	—	—	[14]
111	Galangin	*O. vulgare*	—	—	[14]
112	Naringin	*O. vulgare*	—	—	[14]
113	Hesperetin	*O. vulgare*	Dried aerial parts	—	[10]
114	Didymin	*O. vulgare*	The whole plants	Guangdong, China	[12]
115	Sagittatoside A	*O. vulgare*	The whole plants	—	[13]
		Organic acids (**116–135**)			
116	p-Dihydroxybenzene	*O. majorana*	Dried aerial parts	Tokat, Turkey	[10]
117	O-Dihydroxybenzene	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
118	1, 2, 4-Trihydroxyphenol	*O. vulgare*	The whole plants	Guangdong, China	[12]
119	4-Methyl-5-isopropyl catechol	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
120	Cinnamic acid	*O. vulgare*	—	—	[14]
121	2-Hydroxycinnamic acid	*O. vulgare*	—	Greece	[11]
122	4-Hydroxycinnamic acid	*O. dictamnus*	—	Greece	[11]
123	Caffeic acid	*O. vulgare*	—	—	[14]
124	Ferulic acid	*O. dictamnus*	—	Greece	[11]
125	Chlorogenic acid	*O. vulgare*	—	—	[14]
126	Rosmarinic acid	*O. vulgare*	The whole plants	Hubei, China	[16]
127	p-Hydroxybenzoic acid	*O. vulgare*	—	—	[14]
128	Protocatechuic acid	*O. vulgare*	The whole plants	Hubei, China	[16]
129	Hydroxy-3-methoxybenzoic acid	*O. vulgare*	The whole plants	Hubei, China	[16]
130	Hydroxy-4-methoxybenzoic acid	*O. vulgare*	The whole plants	Hubei, China	[16]
131	Syringic acid	*O. vulgare*	—	—	[14]
132	Salvianolic acid A	*O. vulgare*	Dried aerial parts	Taiwan, China	[10]
133	Salvianolic acid C	*O. vulgare*	Dried aerial parts	Taiwan, China	[10]
134	Lithospermic acid	*O. vulgare*	Dried aerial parts	Taiwan, China	[10]
135	Succinic acid	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
		Steroids and terpenes (**136–140**)			
136	Oleanolic acid	*O. vulgare*	The whole plants	—	[13]
137	Arbutin	*O. vulgare*	The whole plants	—	[13]
138	Stigmasterol	*O. minutiflorum*	—	—	[11]
139	β-Sitosterol	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
140	Daucosterol	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
		Others (**141–148**)			
141	Origalignanol	*O. vulgare*	Dried aerial parts	Taiwan, China	[9]
142	Origanol A	*O. vulgare*	The air-dried leaves	Ooty, India	[17]
143	Origanol B	*O. vulgare*	The air-dried leaves	Ooty, India	[17]
144	Ethyl rosmarinate	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
145	N-Butyl rosmarinate	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
146	p-Hydroxy benzaldehyde	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
147	Dihydrodehydrodiconiferyl alcohol	*O. vulgare*	Dried aerial parts	Hubei, China	[15]
148	Caffeic acid ethyl ester	*O. vulgare*	Dried aerial parts	Hubei, China	[15]

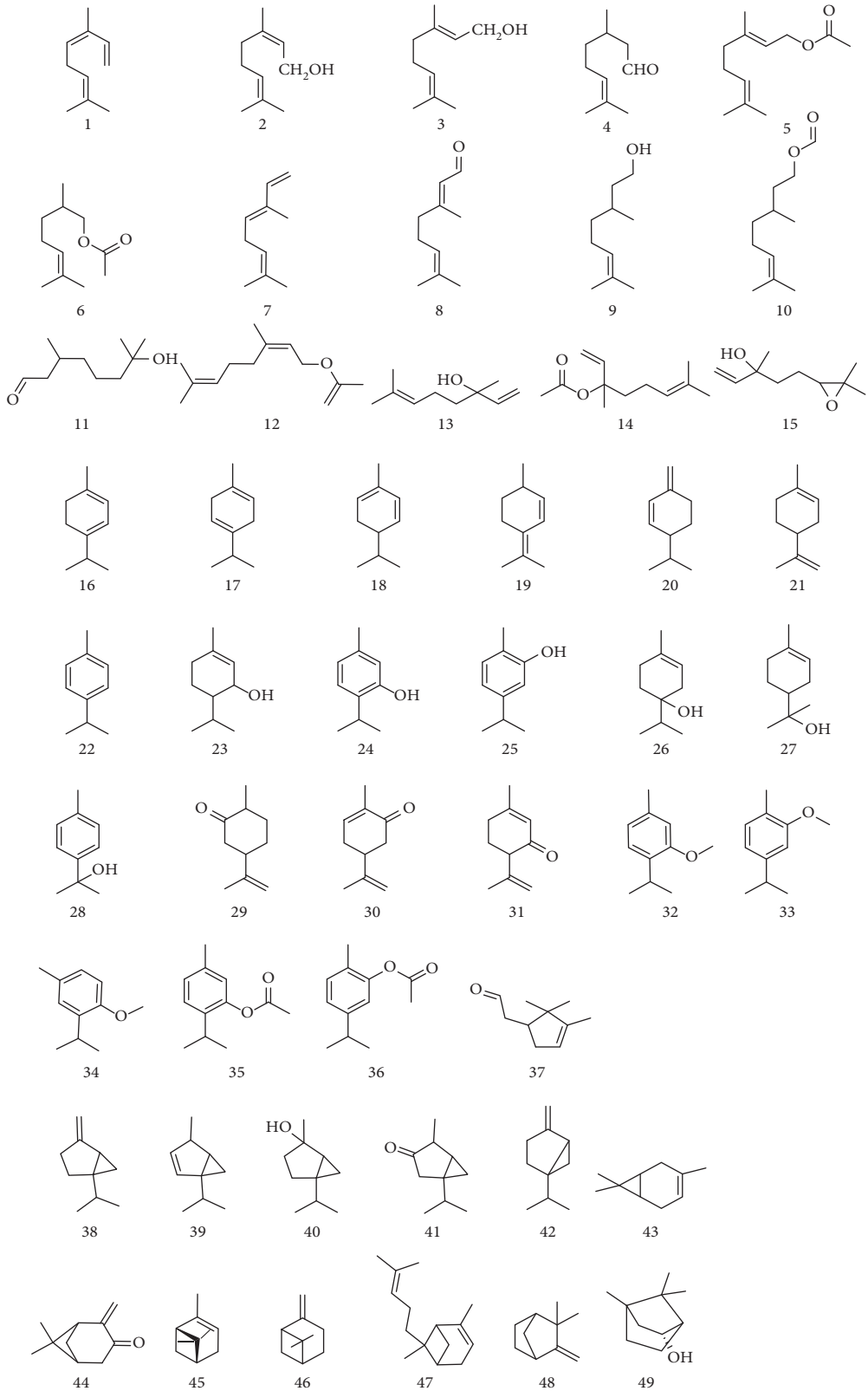


Figure 1: Monoterpenes of essential oils from genus *Origanum* in the world.

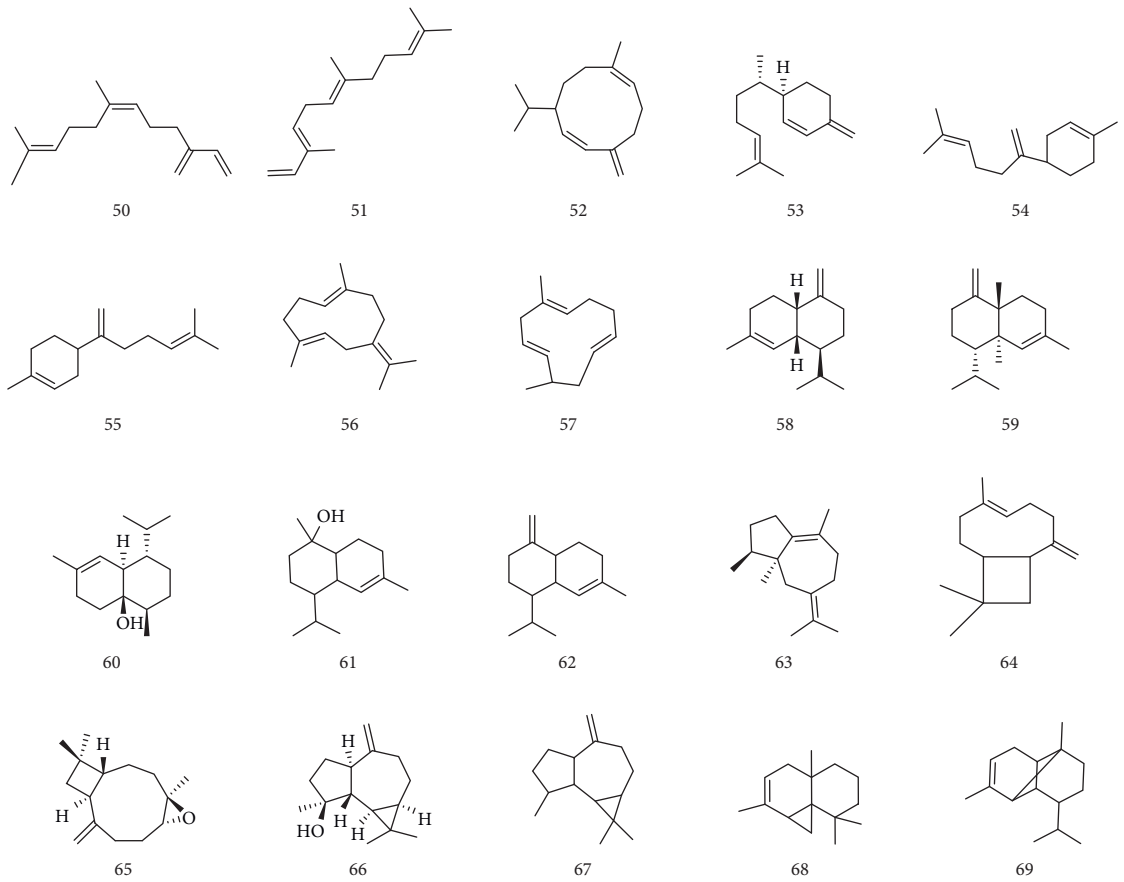


Figure 2: Sesquiterpenoids of essential oils isolated from genus *Origanum* in the world.

2.2.4. Others. Origalignanol was isolated from *O. vulgare* by Lin (**141**) [9]. Origanol A (**142**) and origanol B (**143**) were isolated from *O. vulgare* by Gottumukkala [17]. Sun isolated ethyl rosmarinate (**144**), *N*-butyl rosmarinate (**145**), *p*-hydroxybenzaldehyde (**146**), dihydrodehydrodiconiferyl alcohol (**147**), and caffeic acid ethyl ester (**148**) from *O. vulgare* L. (Figure 7) [15].

3. Biological Effects

The researches on the biological effects of genus *Origanum* are mainly focused on its essential oils, which have a wide range of biological effects, including antibacterial, antioxidant, anticancer, and anti-inflammatory effects and immune regulation.

3.1. Antibacterial Effect. Essential oils from genus *Origanum* had a strong antibacterial and bactericidal effect, which is related to its phenols' constituents. Phenols act on the cell membrane of bacteria to make their proteins denaturation and change the permeability of cell membrane, or destroy protein synthesis by reacting with phospholipids in cell membranes and finally inhibiting the growth of microbial cells [21, 22].

The antibacterial activities of *O. dictamnus* essential oils against *Salmonella enteritis*, *S. typhimurium*, *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus epidermis,* and *S. aureus* were determined by disk diffusion method. The results showed that bacteriostatic effect on *S. aureus* was the strongest and on *S. typhimurium* was the weakest [23].

Laghmouchi determined the minimum inhibitory concentration (MIC: 0.06–0.25% (v/v)) and the minimum bactericidal concentration (MBC: 0.12–0.5% (v/v)) of essential oils from *O. compactum* against *E. coli*, *B. subtilis*, *S. aureus*, and *L. innocua* by the microdilution method. And thymol and carvacrol in essential oils played the key role in antibacterial activity through penetrating and depolarizing the plasma membrane. Meanwhile, *p*-cymene in essential oils could enhance the anti-*S. aureus* effect by promoting the transport of carvacrol in the plasma membrane and entering the lipid bilayer of *Staphylococcus aureus* [24].

The antibacterial activity of *O. acutidens* essential oils and its methanol extract against four fish pathogens, *S. aureus*, *L. garvieae*, *Yersinia ruckeri*, and *Aeromonas hydrophila,* were determined by disk diffusion assay. The results indicate that the methanol extract and the essential oils of *O. acutidens* may be valuable as potential antibacterial agents against the major fish pathogens [25].

Souza reported that essential oils from *O. vulgare* could block the production of enterotoxin of *S. aureus*. When the concentration reached 0.15 or 0.3 μL/mL, the growth of bacteria was significantly inhibited. When the concentration reached 0.6 or 1.2 μL/mL, the permeability of the cell membrane was changed and the cytoplasm was lost. These

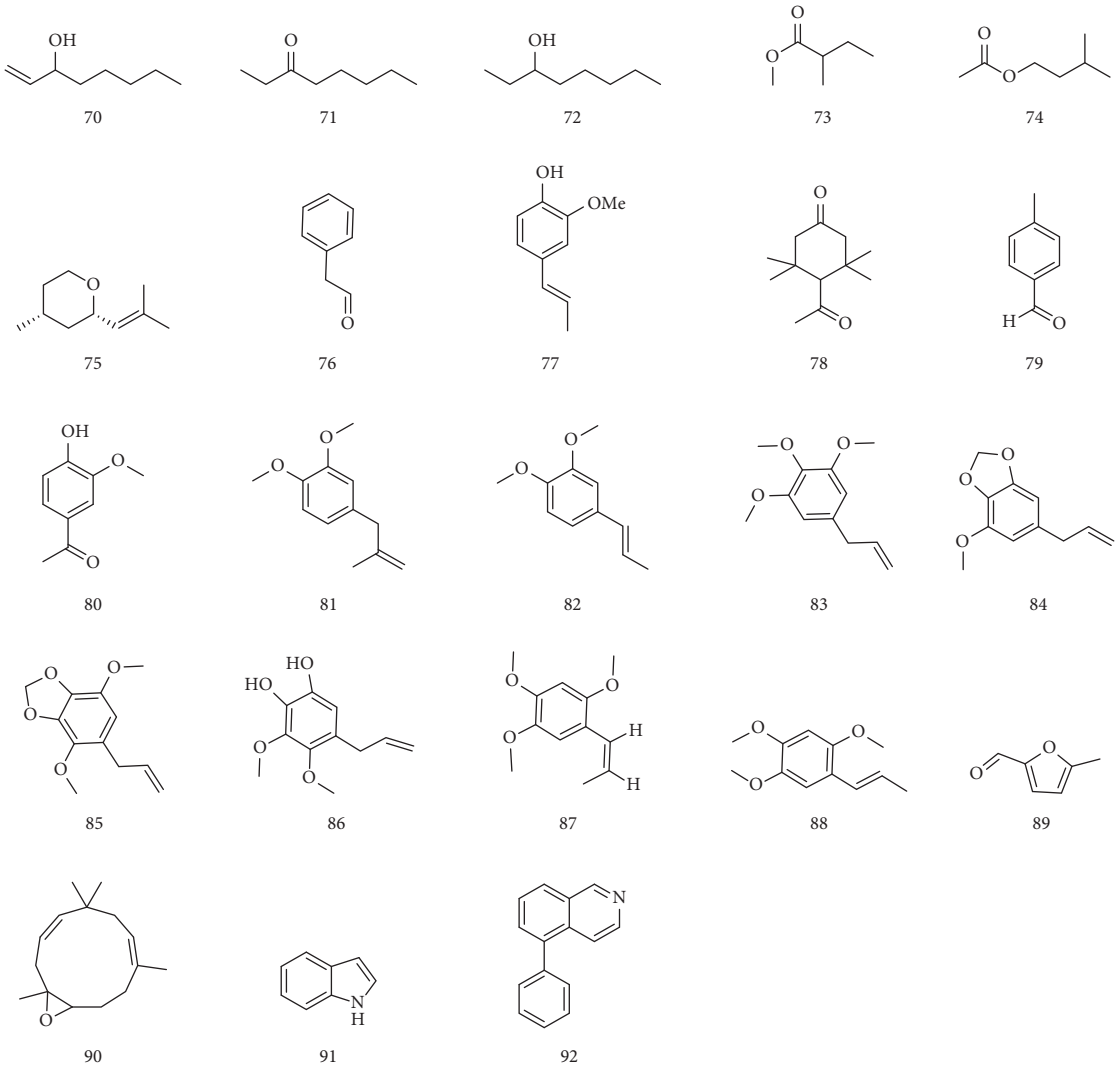


Figure 3: Other constituents of essential oils isolated from genus *Origanum* in the world.

suggested that essential oils from *O. vulgare* may prevent some of the symptoms caused by *S. aureus* enterotoxin [26].

Si studied the antibacterial effects of oregano essential oils (OEO) combined with antibiotics against extended-spectrum beta-lactamase (ESBL-) producing *E. coli* by two-fold dilution method. The results indicated that multiple drug-resistant *E. coli* was very sensitive to OEO essential oils and polymycin. The antibacterial effects of OEO in combination with kanamycin were independent against *E. coli*. The antibacterial effects of OEO in combination with fluoroquinolones, doxycycline, lincomycin, and maquindox florfenicol displayed synergism against *E. coli*. The antibacterial effects of OEO combined with amoxicillin, polymycin, and lincomycin showed an additive effect against *E. coli*. Thus, in clinical application, the dosage of chemical antibiotics can be reduced to lessen the adverse reactions of antibiotics [27].

3.2. Antioxidant Effect. Genus *Origanum* oils had a strong antioxidant effect and could protect cells from oxidative stress. Anastasia proved that *O. dubium* extract had strong antioxidant activity, antilipid peroxidation, and inhibitory activity of lipoxygenase by measuring the interaction between *O. dubium* extractive and 1, 1-diphenylphenylhydrazine (DPPH) radical [28].

Mechergui used the DPPH radical scavenging assay to determine the antioxidant activity of three essential oils of *O. vulgare* subsp. *glandulosum* (Desf.) from Tunisia. The results showed that the antioxidant activity of essential oils was mainly due to the presence of thymol and carvacrol and the presence of *p*-terpene. And antioxidant activity increased with the increase of total phenol content in essential oils [29].

O. majorana essential oils were found to be an effective antioxidant *in vitro* and exhibited concentration-dependent inhibitory effects on DPPH, hydroxyl radical, hydrogen peroxide, reducing power, and lipid peroxidation. The IC_{50} values were 58.67, 67.11, 91.25, 78.67, and 68.75 mg/mL respectively, while the IC_{50} values of standard antioxidants were 23.95, 44.97, 51.30, 42.22, and 52.72 mg/mL, respectively [30].

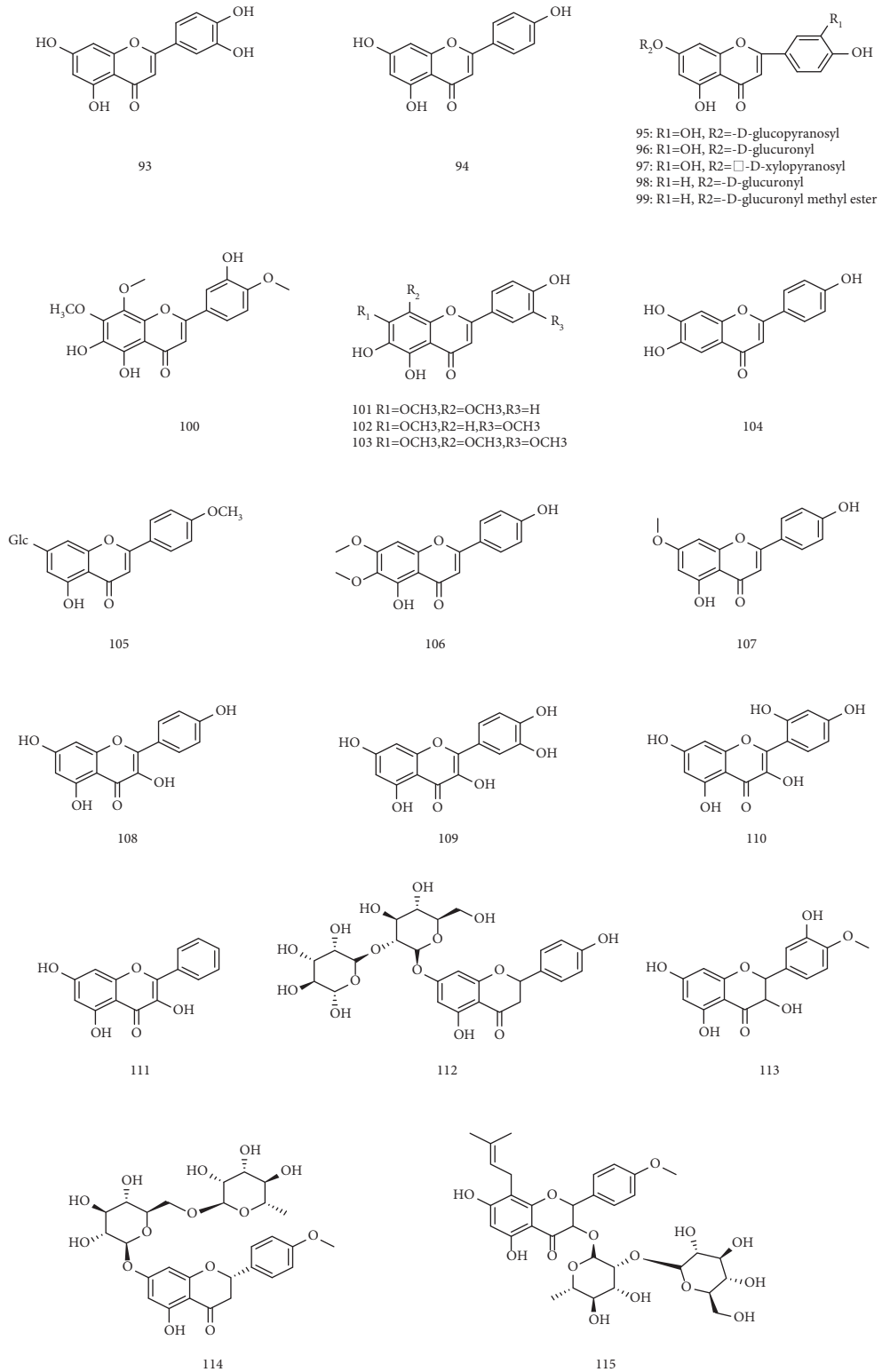


Figure 4: Flavonoids of nonvolatile constituents isolated from genus *Origanum* in the world.

Yao et al. found that adding proper amount of OEO to the diet could increase the total antioxidant level in the serum of weaned piglets, increase the activity of GSH-PX and SOD, reduce the content of lipid peroxide MDA, and enhance the antioxidant performance of the body [31]. Botsoglou found that adding 200 mg/kg of *O. vulgare* essential oils into the diet of rabbits could effectively delay the oxidation of fat, and its antioxidant capacity is equivalent to 200 mg/kg of α-tocopherol acetate [32]. Wang found that adding proper amount of OEO in rabbit feed could improve the activity of antioxidant enzymes in liver and serum [33]. Spiridon studied the antioxidant effect of essential oils *in*

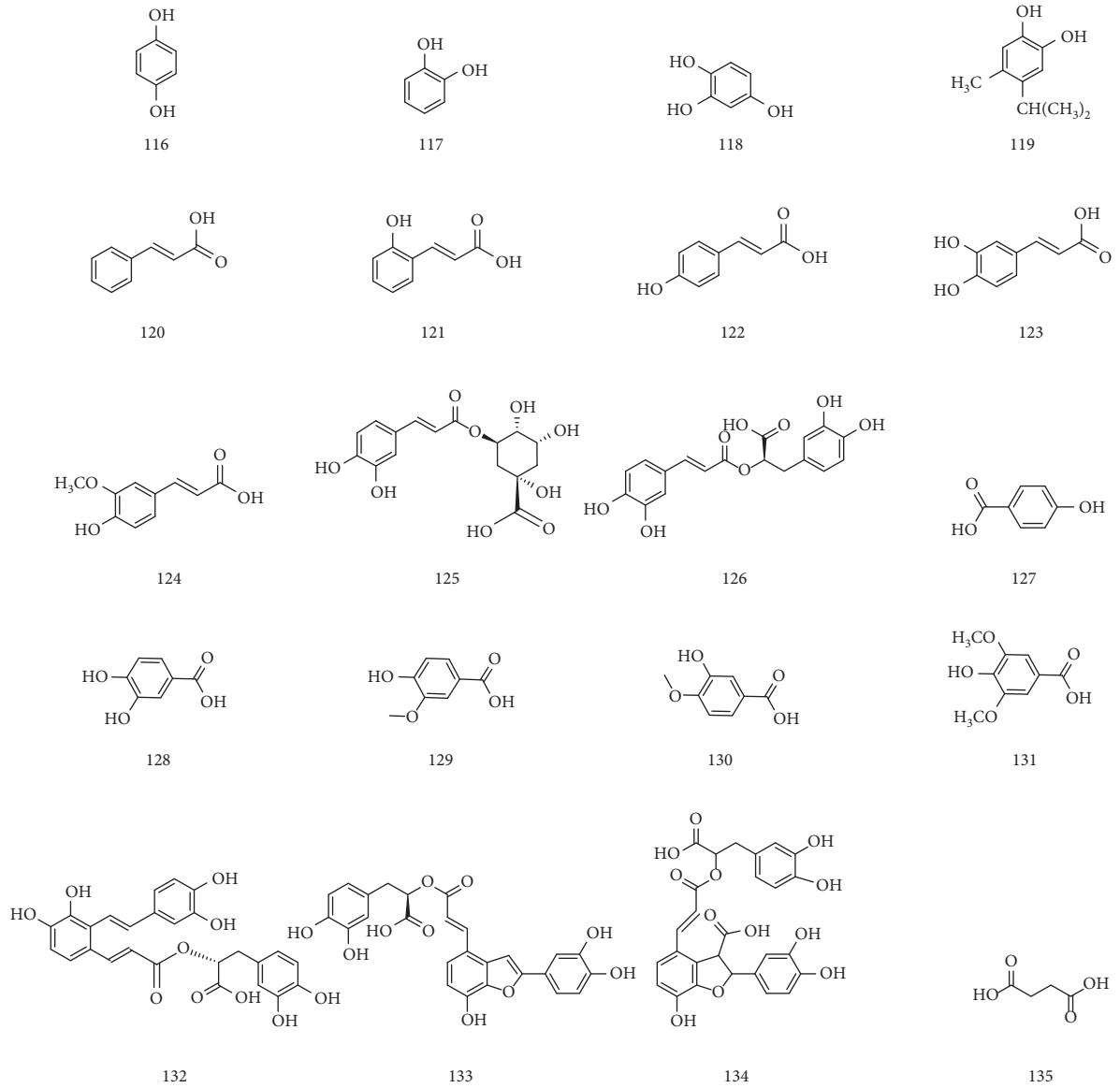


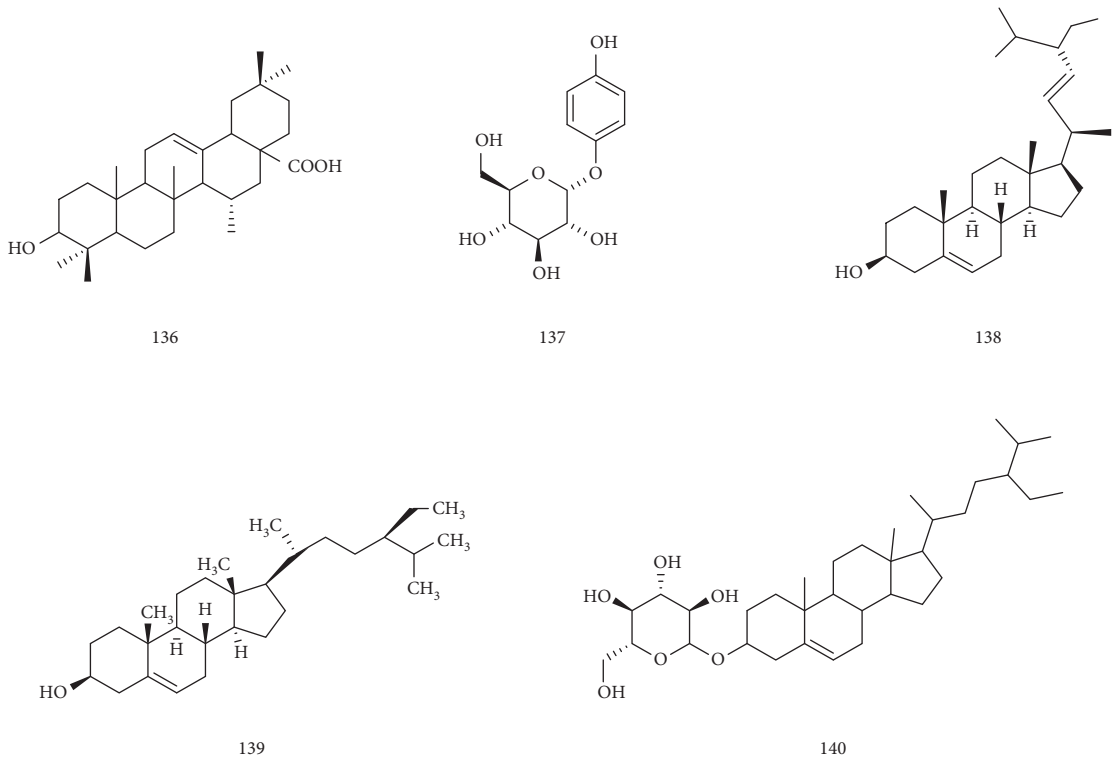
Figure 5: Organic acids of nonvolatile constituents isolated from genus *Origanum* in the world.

vitro from *O. vulgare* and found that the addition of its essential oils to edible sesame oils could prevent the oxidation of grease and maintain the stability of grease which showed that it had a good antioxidant effect [34].

3.3. Anticancer Effect. Dhaheri demonstrated that *O. majorana* significantly inhibited the migration and invasion of the MDA-MB-231 cells by wound-healing assays. MMPs are known to play an important role in breast cancer cell invasion and metastasis. The protein level of MMP-2 and MMP-9 was found to be significantly reduced after *O. majorana* essential oils (OME) treated MDA-MB-231 cells. Meanwhile, *O. majorana* could decrease adhesion of MBAMB-231 to HUVEC, and the level of ICAM-1 protein decreased in concentration-dependent manner in OME-treated MDA-MB-231 cells. In addition, the inhibitory effect of OME on the growth and metastasis of chicken blastoma further confirmed its antibreast cancer activity in vitro [35].

O. onites essential oils (OOEO) exhibited a dose-dependent antiproliferative activity against four types of human cancer cells: melanoma cells (A375), breast cancer cells (MCF-7), hepatocellular carcinoma cells (HepG2), and colon cancer cells (HT-29) lines with IC_{50} values of 8.90 ± 0.70, 10.0 ± 1.7, 23.0 ± 4.2 and 0.35 ± 0.2 g/mL, respectively. Among the cell lines studied, colon cancer cells were the most sensitive to OOEO's antiproliferative activity. Moreover, when administered orally, OOEO inhibited the growth of colon carcinoma tumors in mice [3].

OEO could reduce cell density, slow cell growth, shrinking, fragmentation, and floating. MTT method was used to detect HepG2, human cervical cancer cell line (JTC-26) and lung cancer cell line A549 treated with OEO. It was found that the cells treated with OEO show obvious inhibition of cell growth. Bliss method calculated that the IC_{50} values of OEO against hepatocellular carcinoma cells HepG2, human cervical cancer cell line JTC-26, and lung



136 137 138

139 140

Figure 6: Steroids and terpenes of nonvolatile constituents isolated from genus *Origanum* in the world.

cancer A549 were 0.118, 0.118, and 0.059 mg/mL, respectively [36].

Sankar reported the cytotoxic effects of green silver nanoparticles synthesized by reducing 1 mM silver nitrate solution from *O. vulgare* water extract on human lung cancer A549 cells for the first time. Silver nanoparticles (500 g/mL) significantly inhibited cell growth, and the inhibition rate was up to 85%, which may be due to the presence of carvacrol, terpinenes, thymol, sabinene, linalool, terpinolene, quercetin, and apigenin in *O. vulgare* [37]. In addition, Jelnar found that in the essential oils of genus *Origanum*, there is a substance called trans-sabinene hydrate, which could play the role of antiproliferation of breast cancer cell line [38].

3.4. Anti-Inflammatory Effect. *O. vulgare* water extract intervenes with the RAW264.7 macrophage inflammatory model which was induced by LPS, TNF-α, and MCP-1 (monocyte chemotactic protein 1). PGE2, NO, and IL-6 were detected by ELISA. mRNA expression levels of TNF-α, IL-6, and MPC-1 (CC chemokine ligand 2) were detected by q-PCR. *O. vulgare* water extract had a good inhibitory effect on LPS-induced RAW264.7 macrophage inflammation by the detection of ELISA and mRNA expression levels. It could reduce the production of cytokines such as PGE2, IL-6, TNF-α, and MCP-1 in cells, as well as the expression levels of IL-6, TNF-α, and MCP-1 mRNA. These effects may be the mechanism of the anti-inflammatory activity of *O. vulgare* water extract [39].

Ocaña-Fuentes found that carvacrol and thymol from *O. vulgare* essential oils could reduce the synthesis of proinflammatory tumor necrosis factor, β-IL and synthesis of IL-6 cytokines, and increase the synthesis of anti-inflammatory IL-10. This indicated that some chemical components of *O. vulgare* essential oils have a strong anti-inflammatory effect on human THP-1 cells [40].

The effects of iNOS protein and COX-2 expression of rosmarinic acid, ursolic acid, and oleanolic acid from Oregano were observed by Nitrite Assay and western blotting. The reduced expression of iNOS protein by these compounds was consistent with reductions on the nitrite production assay, and these three compounds also suppressed COX-2 protein expression on western blotting, showing comparable anti-inflammatory activities contrasting to indomethacin, a recognized COX-2 inhibitor [41].

In addition, it had been reported that the methanol extract of *O. vulgare* can inhibit the secretion of COX-2 and have anti-inflammatory activity in human epithelial cancer cells. Methanol extract treatment specifically attenuated the proinflammatory response mediated by T helper 17 cells and enhanced anti-inflammatory T helper 2 and T regulatory cells through the impact on specific signalling pathways and transcription factors [42]. Yoshino et al. found that oregano extract exhibited anti-inflammatory activities in mouse models of stress-induced gastritis and contact hypersensitivity [43].

3.5. Immune Regulation. Both high and low doses of essential oils of *O. vulgare* had significant inhibitory effects on ear skin delayed hypersensitivity (DTH) induced by 2, 4-dinitrochlorobenzene through foot pad reaction and ear swelling test of mice. The determination of serum hemolysin and the spectrophotometric determination of spleen cell-

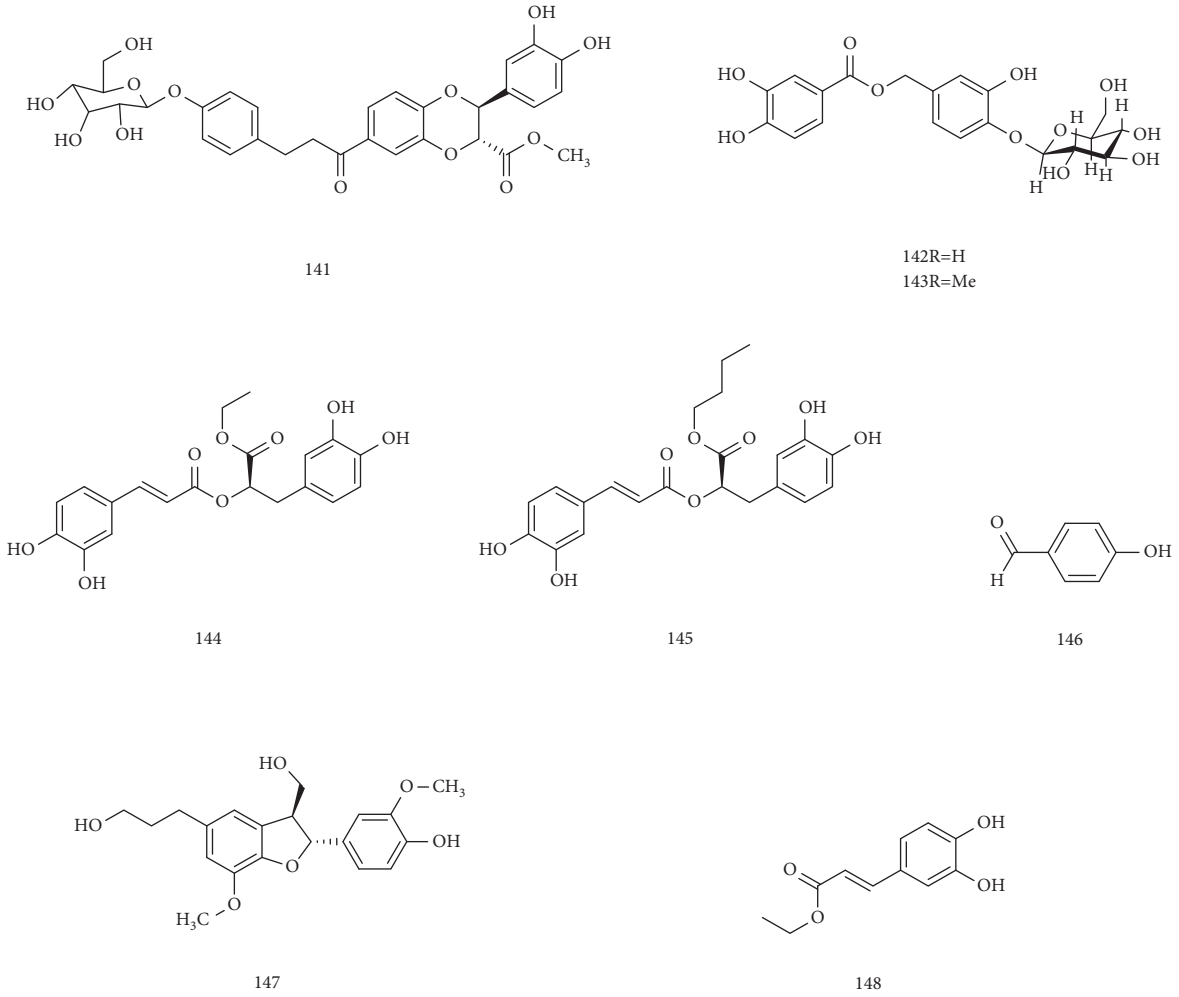


Figure 7: Other nonvolatile constituents isolated from the genus *Origanum* in the world.

mediated erythrocyte hemolysis showed that the high dose of essential oils could significantly inhibit the specific humoral immune function of mice. However, the low dose (50 mg/kg/d × 7 d) of essential oils had a very obvious promoting effect on the specific humoral immune function of mice. Moreover, the thymus and spleen of mice were significantly shrunk by a high dose of essential oils, but the spleen of mice was significantly enhanced by the low dose, which suggested that the essential oils of *O. vulgare* could affect the humoral and cellular immune function of mice [44].

Wang added OEO to broilers, and the results showed that at 42 days of age, the activity of acid α-naphthyl acetate esterase in T lymphocyte and the T lymphocyte conversion rate in the 100 mg/kg OEO group increased by 16.56% and 13.90%, respectively, compared with the control group ($P < 0.05$), which significantly enhanced the cellular immunity of broilers [45]. Malayoğlu added 500 mg/kg of *O. vulgare* essential oils to the diet of broilers and found a significant increase of IgG in the blood of broilers compared with the control group [46]. Hashemipour et al. indicated that long-term addition of carvacrol and thymol, the main components of OEO, could enhance cellular and humoral immunity of broilers [47].

3.6. Hypoglycemic Effect. *O. vulgare* leaves extract could inhibit gluconeogenesis, reduce lipid synthesis, and alleviate oxidative damage to reduce blood sugar. The *O. vulgare* extracts collected in October could effectively inhibit α-glucosidase, promote glucose absorption, reduce glycosylation levels, alleviate the oxidative damage caused by the overexpression of cytochrome P4502E1 (CYP2E1) in E47 cells, repair the activity of lactate dehydrogenase (LDH) in damaged cells, and reduce oxidative stress level caused by oxygen free radicals (ROS). The mechanism may be related to the reduction of the promoter activity of phosphoenolpyruvate kinase (PEPCK), the key factor of gluconeogenesis in HepG2 cells, and the expression of its mRNA and protein. It decreased the promoter activity of cholesterol regulating protein element (SREBP-1c), a key factor in lipid synthesis, and the expression of its mRNA and protein. It could also inhibit the expression of CYP2E1 mRNA and protein in E47 cells and increase the expression of glucose transporter 2 (GLUT2) mRNA and protein. Therefore, phenols and flavonoids may be the main active components in *O. vulgare* [48].

The water extract and methanol extract of *O vulgare* were used in C57BL/6 mice with multiple low-dose streptozotocin-induced diabetes, respectively. Water extract had no

effect on the induction of diabetes. Methanol extract could reduce the incidence of diabetes and maintain normal insulin secretion. Methanol extract prevented apoptosis of β cells by blocking caspase 3 *in vitro*, which may be relevant to rosmarinic acid, the dominant compound in methanol extract [42].

Vanadate was used as reference drug, and the hypoglycemic effect of *O. vulgare* was tested in normal and streptozotocin (STZ) induced diabetic rats. The results showed that *O. vulgare* leaves water extract had significant hypoglycemic effect on STZ diabetic rats. The low dose of *O. vulgare* water extract (20 mg/kg) for 2 weeks was enough to normalize blood glucose levels in severely diabetic rats with fasting blood glucose of more than 20 mM. Furthermore, *O. vulgare* leaves extract had no effect on basal plasma insulin concentration of normal and diabetic rats. This indicate that *O. vulgare* extract could inhibit glucose production in the liver, but not related to insulin secretion by islet cells [49].

3.7. Growth-Promoting Effect. The unique aroma of *O. vulgare* essential oils could stimulate the appetite of animals, stimulate the receptors of digestive tract, activate the activity of digestive enzymes, and promote the absorption of nutrients in the feed. The main chemical constituents of *O. vulgare* were thymol and carvol, which could enhance the barrier function of the intestinal tract and reduce the infection rate of pathogenic microorganisms to epithelial cells. In addition, the unique bactericidal and bacteriostatic effects of *O. vulgare* essential oils inhibit the growth of harmful bacteria in the intestinal tract of animals, maintain the balance of intestinal flora, and improve the absorption capacity of animals to nutrients, thereby improving the utilization rate of feed and ultimately promoting the growth of animals [13].

A comparative study on adding OEO and virginiamycin to chicken feed showed that the activity of intestinal protease in the group with the addition of OEO was 50% higher than that in the group with the addition of virginiamycin. The feed conversion rate of the OEO group was better than that of the virginiamycin group [50].

3.8. Liver Protection Effect. Ali found that *O. vulgare* leaf extract not only led to a significant decrease in serum ALT, AST, and ALP but also prevented liver damage [51].

3.9. Antispasmodic Effect. Different gastrointestinal smooth muscles were cultured to study the antispasmodic action of *O. compactum in vitro*. The results showed that aqueous extract of *O. compactum* powder could inhibit the effects of acetylcholine, histamine, serotonin, $BaCl_2$, 1, 1-dimethyl-4-phenylpiperazinium iodide, and nicotine responses to the guinea pig ileum and also block contractions elicited by electrical coaxial stimulation. Thymol and carvacrol were the active components of antispasmodic effect, which could block the release of intracellular bound Ca^{2+} and prevent the extracellular Ca^{2+} influx into smooth muscle cells [52].

3.10. Insecticidal Effect. El-Akhal found *O. majorana* essential oils could kill Culex pipiens larvae with LC_{50} 258.71 mg/L, which showed that *O. majorana* essential oils were an important natural insecticide [53].

Víctor tested the inhibitory activity of *O. compactum* essential oils to parasitic nematode Anisakis simplex and found that *O. compactum* essential oils showed a dose-dependent larvicidal activity at 24 and 48 h after treatments. All larvae were killed at doses of 1 μL/mL after 24 h. The effects of carvacrol and thymol on the larvae were similar to those of the oils. However, carvacrol exhibited a stronger activity than *O. compactum* and thymol, indicating that carvacrol might be responsible for the larvicidal effects [54].

3.11. Enzyme Inhibition. Goun discovered that aristolochia acid I and aristolochia acid II in *O. vulgare* could strongly inhibit thrombin activity [55]. Victor found *O. compactum* essential oils, carvacrol, and thymol had inhibitory effects on acetylcholinesterase [54]. The inhibitory activity of tyrosinase was detected by mushroom tyrosinase with arbutin as a positive control. The values for tyrosinase inhibitory activity of *O. vulgare* essential oils, ethanol extract, and arbutin were calculated to be $6.5 \pm 0.2\%$, $26.5 \pm 0.3\%$, and $50.0 \pm 0.1\%$, respectively. Both *O. vulgare* essential oils and ethanol extract had certain inhibitory effects on tyrosinase activity [56]. The pharmacological activities of *Origanum* plants are listed in Table 3.

4. Summary and Prospects

In summary, the essential oils of genus *Origanum* are the research focus and the components were mainly analyzed by GC-MS. The results showed that essential oils' compositions and content depend on the different parts of the plants and the origin of the plants. The main chemical components of essential oils are terpenoids and they have many pharmacological activities such as antibacterial, antioxidant, anticancer, anti-inflammatory, immune regulative, hypoglycemic, and growth promoting.

The essential oils of genus *Origanum* can be developed as a natural food additive because of its strong antibacterial and bactericidal effects. It also can be used as a natural growth promoter and insecticide. However, the anticancer and antioxidation studies of essential oils in *Origanum* plants are mainly conducted *in vitro* experiments. It can be further studied *in vivo* and the mechanism can be discussed. At present, the studies on the activities of *Origanum* plants are mainly focused on the extract of essential oil. In the future, the research can be transferred to the biological activity of monomer compounds of essential oil in *Origanum* plants.

In addition, the researches for nonvolatile constituents and their pharmacological activities are few. Therefore, the research on nonvolatile constituents of genus *Origanum* also

Table 3: Pharmacological activities of *Origanum* plants.

Type of the activities	Subjects	Activities	Supplement	References
Antibacterial effect	*O. dictamnus* essential oils	Against *salmonella enteritis*, *Salmonella typhimurium*, *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus epidermis,* and *Staphylococcus aureus.*	The inhibitory zone diameters of the six colonies were 25 ± 0.5 mm, 20 ± 0.7 mm, 30 ± 1.0 mm, 25 ± 0.5 mm, 25 ± 0.5 mm, 34 ± 0.5 mm, respectively.	[23]
	O. compactum essential oils	Against *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*, and *Listeria innocua.*	The minimum inhibitory concentration (MIC: 0.06–0.25% (v/v)) and the minimum bactericidal concentration (MBC: 0.12–0.5% (v/v)).	[24]
	Methanol extract and *O. acutidens* essential oils	Obviously inhibit *Staphylococcus aureus*, *Lactococcus garvieae*, *Yersinia ruckeri*, and *Aeromonas hydrophila.*	The mean inhibitory zones of methanol extract and *O. acutidens* essential oils on the bacterial strains were 28.0 ± 1.2 mm and 36.7 ± 0.7 mm.	[25]
	O. vulgare L. essential oils	Inhibit *Staphylococcus aureus.*	When the concentration reached 0.15 or 0.3 μL/mL, the growth of bacteria was significantly inhibited.	[26]
	OEO	The antibacterial effects of OEO in combination with fluoroquinolones, doxycycline, lincomycin, and maquindox florfenicol displayed synergism against *Escherichia coli*. The antibacterial effects of OEO combined with amoxicillin, polymycin, and lincomycin showed an additive effect against *Escherichia coli.*	—	[27]
Antioxidant effect	*O. dubium* extract	Antioxidant activity, antilipid peroxidation, and inhibitory activity of lipoxygenase.	—	[28]
	O. vulgare L. subsp. *glandulosum* (Desf.) essential oils	Scavenge the DPPH radicals.	The IC_{50} values of three kinds of essential oils ranged from 59 to 80 mg/L.	[29]
	O. majorana essential oils	Exhibited concentration-dependent inhibitory effects on DPPH, hydroxyl radical, hydrogen peroxide, reducing power, and lipid peroxidation.	IC_{50} values of 58.67, 67.11, 91.25, 78.67, and 68.75 mg/mL, respectively.	[30]
	O. vulgare L. essential oils	Increase the total antioxidant level in the serum of weaned piglets, increase the activity of GSH-PX and SOD, reduce the content of lipid peroxide MDA, and enhance the antioxidant performance of the body.	—	[31]
	OEO	Effectively delay the oxidation of fat.	Adding 200 mg/kg of *O. vulgare* L. essential oils into the diet of rabbits.	[32]
	OEO	Improve the activity of antioxidant enzymes in liver and serum of rabbit.	—	[33]
	O. vulgare essential oils	The addition of its essential oils to edible sesame oils could prevent the oxidation of grease and maintain the stability of grease.	—	[34]

Table 3: Continued.

Type of the activities	Subjects	Activities	Supplement	References
Anti-cancer effect	*O. majorana* essential oils	Significantly inhibited the migration and invasion of the MDA-MB-231 cells.	Suppress the phosphorylation of IκB, downregulate the nuclear level of NFκB, and reduce nitric oxide (NO) production in MDA-MB-231 cells.	[35]
	O. onites essential oils (OOEO)	Exhibit a dose-dependent antiproliferative activity against four types of human cancer cells: melanoma cells (A375), breast cancer cells (MCF-7), hepatocellular carcinoma cells (HepG2), and colon cancer cells (HT-29) lines.	The antiproliferative effect (lowest IC_{50} value for 72 h) was observed in the HT-29 ($0.35 \pm 0.2\,\mu$g/mL) followed by A375 ($8.90 \pm 0.7\,\mu$g/mL), MCF-7 ($10.0 \pm 1.7\,\mu$g/mL), and HepG2 ($23.0 \pm 4.2\,\mu$g/mL).	[3]
	OEO	Inhibit liver cancer HepG2, son of man cervical cancer JTC-26, and lung cancer A549 growth.	The IC_{50} values of OEO against liver cancer HepG2, son of man cervical cancer JTC-26, and lung cancer A549 were 0.118, 0.118, and 0.059 mg/mL, respectively.	[36]
	O. vulgare water extract	Green silver nanoparticles synthesized by reducing 1 mM silver nitrate solution from *O. vulgare* water extract (500 g/mL) significantly inhibited human lung cancer A549 cells growth.	The green synthesized silver nanoparticles against human lung cancer A549 cell line (LD 50–100 μg/ml).	[37]
	Trans-sabinene hydrate from genus *Origanum* essential oils	Antiproliferation of breast cancer cell line.	—	[38]
Anti-inflammatory effect	*O. vulgare* L. water extract	Have a good inhibitory effect on LPS-induced RAW264.7 macrophage inflammatory.	Reduce the production of cytokines such as PGE2, IL-6, TNF-α, and MCP-1 in cells, as well as the expression levels of IL-6, TNF-α, and MCP-1 mRNA.	[39]
	O. vulgare essential oils	*O. vulgare* essential oils have a strong anti-inflammatory effect on human THP-1 cells.	Carvacrol and thymol from *O. vulgare* essential oils could reduce the synthesis of proinflammatory tumor necrosis factor, β-IL, and synthesis of IL-6 cytokines and increase the synthesis of anti-inflammatory IL-10.	[40]
	Rosmarinic acid, ursolic acid, and oleanolic acid from oregano	Exhibit comparable anti-inflammatory activities contrasting to indomethacin, a recognized COX-2 inhibitor.	Reduce expression of iNOS protein and suppress COX-2 protein expression.	[41]
	The methanol extract of *O. vulgare*	Inhibit the secretion of COX-2 and had anti-inflammatory activity in human epithelial cancer cells.	Methanol extract specifically attenuated the proinflammatory response mediated by T helper 17 cells and enhanced anti-inflammatory T helper 2 and T regulatory cells.	[42]
	Oregano extract	Exhibit anti-inflammatory activities in mouse models of stress-induced gastritis and contact hypersensitivity.	—	[43]

Table 3: Continued.

Type of the activities	Subjects	Activities	Supplement	References
Immune regulation	*O. vulgare* L. essential oils	Both the high dose of 100 mg/kg/d × 7 d and the low dose of 50 mg/kg/d × 7 d had obvious inhibitory effect on the specific cellular immune function of normal mice. The dose of 50 mg/kg/d × 7 d significantly promoted the humoral immunity of mice, and 100 mg/kg/d × 7 d significantly inhibited the humoral immunity of mice.	—	[44]
	OEO	Carvacrol and thymol of OEO could enhance cellular and humoral immunity of broilers.	—	[45]
Hypoglycemic effect	*O. vulgare* leaves extract	Significant hypoglycemic activity.	By inhibiting α-glucosidase activity, promoting glucose uptake, and inhibiting glycation.	[48]
	Methanol extract of *O. vulgare*	Methanol extract could reduce the incidence of diabetes and maintain normal insulin secretion.	Methanol extract prevented apoptosis of β cells *in vitro* by blocking caspase 3.	[42]
	O. vulgare leaves water extract	*O. vulgare* leaves water extract had significant hypoglycemic effect on STZ diabetic rats.	The low dose of *O. vulgare* water extract (20 mg/kg) for 2 weeks was enough to normalize blood glucose levels in severely diabetic rats with fasting blood glucose of more than 20 mM.	[49]
Growth-promoting effect	*O. vulgare* L. essential oils	Stimulate the appetite of animals, maintain the balance of intestinal flora, and improve the absorption capacity of animals to nutrients, promoting the growth of animals.	—	[13]
	OEO	Improve feed conversion rate.	—	[50]
Liver protection effect	Ethanol extract of *O. vulgare* leaves	The concentration of ethanol extract of *O. vulgare* leaves below 500 mg/kg had protective effect on paraquat-induced hepatotoxicity in rats.	—	[51]
Antispasmodic effect	Aqueous extract of *O. compactum* powder	Exhibit antispasmodic effect.	Aqueous extract of *O. compactum* powder inhibited the effects of acetylcholine, histamine, serotonin, $BaCl_2$, 1, 1-dimethyl-4-phenylpiperazinium iodide, and nicotine responses on the guinea pig ileum and also blocked the contractions elicited by electrical coaxial stimulation.	[52]
Insecticidal effect	The essential oil from the leaves of *O. majorana*	Exhibit significant *Culex pipiens*-larvicidal activity.	The LC_{50} and LC_{90} are 258.71 mg/L (lower limit-upper limit: 126.99–527.06 mg/L) and 580.49 mg/L and 580.49 mg/L (lower limit-upper limit:354.51–950.53 mg/L), respectively.	[53]
	O. compactum essential oils	Larvicidal activity of *O. compactum* essential oil against *Anisakis simplex* L3 larvae.	LD_{50} 0.429 mg/ml at 24 h and 0.344 mg/ml at 48 h. The mortality (%) after 24 and 48 h of treatment at 1 μl/ml was 100%.	[54]

Table 3: Continued.

Type of the activities	Subjects	Activities	Supplement	References
Enzyme inhibition	Aristolochia acid I and aristolochia acid II extracted from *O. vulgare* *O. compactum* essential oils, carvacrol and thymol from *O. compactum* essential oils	Inhibit thrombin activity.	—	[55]
		Inhibit acetylcholinesterase activity.	*O. compactum* essential oils (IC_{50} 0.124 mg/ml), carvacrol (IC_{50} 0.113 mg/ml), and thymol (IC_{50} 0.625 mg/ml).	[54]
	O. vulgare essential oils, ethanol extract	Inhibit tyrosinase activity.	The values for tyrosinase inhibitory activity of *O. vulgare* ethanol extract, essential oil, and arbutin (positive control) were calculated to be $6.5 \pm 0.2\%$, $26.5 \pm 0.3\%$ and $50.0 \pm 0.1\%$, respectively.	[56]

can be strengthened and its application prospect can be explored so as to make better use of the resources of this plant.

Conflicts of Interest

All authors declare that they have no conflicts of interest.

Authors' Contributions

Li Zhou and Fatma Al-Zahra K. K. Attia performed literature collection and writing and original draft preparation. Lijun Meng and Sitan Chen analyzed and summarized data. Wenyi Kang and Zhenhua Liu critically reviewed the manuscript. Zhenhua Liu, Changyang Ma, and Lijun Liu supervised project administration. Wenyi Kang provided resources, funding, and reviewed the manuscript. All the authors contributed to the article and approved the submitted version.

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