·综述·

蒺藜科驼蹄瓣属植物化学成分

杨晓绒[1,2]，张相锋[1]，张维[1]，南光明[2*]
（1. 伊犁师范学院 生物与地理科学学院，新疆 伊宁 835000；
2. 伊犁师范学院 新疆高校天然产物化学与应用重点实验室，新疆 伊宁 835000）

［摘要］ 全球约有蒺藜科驼蹄瓣属植物 150 种，主要分布在亚洲、非洲、澳洲及地中海地区该属植物具有耐旱、抗风沙和耐盐碱特性，种子所到之处皆容易生根发芽，适应性极强。对该属植物的研究主要集中在提取物或组分的药理活性及化学成分的分离鉴定方面，文献记载该属的 *Zygophyllum aegyptium*，*Z. album*，*Z. atriplicoides*，*Z. berenicense*，*Z. coccineum*，*Z. cornutum*，*Z. decumbens*，*Z. ducembens*，*Z. dumosum*，*Z. eichwaldii*，*Z. eurypterum*，驼蹄瓣（*Z. fabago*），*Z. gaetulum*，*Z. geslini*，*Z. melongena*，*Z. oxianum*，*Z. propinquum* 和 *Z. simplex* 等植物在民间用做草药或已被证明有生物活性，有的植物在亚洲、非洲地区民间被用于治疗糖尿病、高血脂、高血压、肥胖、腹泻和痉挛等；有的植物具有降糖、降压、降血脂、解痉、解热、抗腹泻、抑酶、抗氧化、抗炎、抗菌、抗癌等药理活性。驼蹄瓣属植物可以被用作防治代谢综合征，该属许多植物具有多种生物活性。对该属植物还有待于在以下几方面的进一步研究，①生物活性成分的活性导向分离；②分子机制的明确；③通过 HPLC，GC，LC-MS 等方法对生物活性成分的含量进行分析。该文综述了驼蹄瓣属植物中已分离和鉴定出的皂苷类、黄酮类、生物碱类和其他类化合物及其已知的药理活性。

［关键词］ 驼蹄瓣属；化合物；皂苷类；黄酮类；生物碱类及其他
［中图分类号］ R284.1；R2-031；R289；R29 ［文献标识码］ A ［文章编号］ 1005-9903(2018)12-0216-019
［doi］ 10.13422/j.cnki.syfjx.20181207
［网络出版地址］ http://kns.cnki.net/kcms/detail/11.3495.R.20180314.1509.003.html
［网络出版时间］ 2018-03-14 17:32

Review on Chemical Compounds from *Zygophyllum* Genus in Zygophyllaceae Family

YANG Xiao-rong[1,2], ZHANG Xiang-feng[1], ZHANG Wei[1], NAN Guang-ming[2*]
(1. *School of Biology and Geography Science*, *Yili Normal University*, *Yining* 835000, *China*;
2. *Key Lab of Natural Product Chemistry and Application in Xinjiang*,
Yili Normal University, *Yining* 835000, *China*)

［**Abstract**］ There are over 150 species in *Zygophyllum* genus in the world, distributed mainly in Asia, Australia, Africa and Mediterranean coast. These species have the properties of drought resistance, wind and sand resistance, and saline-alkali resistance. The seeds are easy to germinate everywhere, with high adaptability. The researches on this genus mainly focused on the pharmacological activities of extracts or fractions as well as the separation and identification of chemical constituents. *Z. aegyptium*, *Z. album*, *Z. atriplicoides*, *Z. berenicense*, *Z. coccineum*, *Z. cornutum*, *Z. decumbens*, *Z. ducembens*, *Z. dumosum*, *Z. eichwaldii*, *Z. eurypterum*, *Z. fabago*, *Z. gaetulum*, *Z. geslini*, *Z. melongena*, *Z. oxianum*, *Z. propinquum and Z. simplex* have been used as herbal medicines or have shown biological activities in studies. Some of them have been used in folk of Asian and African countries to treat the diseases such as diabetes, hyperlipidemia, hypertension, obesity, diarrhea and

［收稿日期］ 20171116(027)
［基金项目］ 新疆维吾尔自治区教育厅高校科研计划项目(XJEDU2013I32)；伊犁师范学院天然产物化学与应用重点实验室课题(2014YSHXYB01)
［第一作者］ 杨晓绒，博士，助教，从事植物资源与药理研究，Tel：0999-8996926，E-mail：xiaorong0325@163.com
［通信作者］ *南光明，博士，教授，从事有机化学和化学合成研究，Tel：0999-8120048，E-mail：nanguangming02@sohu.com

spasticity. Some of them have shown hypoglycemic, antihypertensive, hypolipidemic, antispasmodic, antipyretic, anti-diarrhea, inhibiting enzymes, anti-oxidation, anti-inflammatory, antibacterial, anti-cancer and other pharmacological activities. *Zygophyllum* genus can be used for prevention and treatment of metabolic syndrome; the plants have a variety of biological activities. Further researches on this genus are needed in the following aspects: ①bioactivity-guided isolation of the biological compounds; ②clarification of molecular mechanisms; ③content analysis of biological compounds by using HPLC, GC, and LC-MS etc. The saponins, flavonoids and other main compounds isolated and identified from *Zygophyllum* plants as well as their known pharmacological activities were reviewed in this paper.

[**Key words**] *Zygophyllum* genus; compounds; saponins; flavonoids; alkaloids and others

Zygophyllum, the largest genus in Zygophyllaceae family consists of about 150 species, is widely distributed in deserts and steppes from the Mediterranean to Central Asia, South Africa and Australia[1]. As succulent annual or biennial herbs, they grow in a prostrate or erect manner, branching from the base and reaching a height of 4 to 60 centimeters. They have yellow, orange or white flowers, with a large amount of fruits rising out of opposite leaf axils. *Zygophyllum* plants can resist drought, sand and wind, and some species have good saline-alkali resistance properties[2].

A total of 17 species, 2 subspecies and 3 variants are distributing in deserts, Gobi and low hills of Northwest China, especially in Xinjiang province. *Z. macropodum*(大叶驼蹄瓣), *Z. fabago* subsp. *dolichocarpum*(长果驼蹄瓣), *Z. fabagoides*(拟豆叶驼蹄瓣) and *Z. iliense*(伊犁驼蹄瓣) distribute in Yili area, Xinjiang province, China. *Zygophyllum* plants are growing better with the increase of drought degree in some areas. Owning to their strong fitness, we can find *Z. macropodum* in the sandy-pebble bottom of dry river beds, deserted sloping field, on debris tailing of mountains and hills, stony slopes of hills and pebble deserts, road sides or woodlands in Yili.

Do these plants have some special uses? Many papers focused on: ①bioactivities such as anti-diabetic effect[3-6] of the total extraction or fractions from *Zygophyllum* plants and few papers on bioactivity-guided isolation; ②chemical structure of *Zygophyllum* compounds. *Z. fabago* was used to treat bronchitis, colds, toothache and intractable headaches in folk of Xinjiang and Inner Mongolia, China[7]. Some compounds were isolated and identified from *Z. fabago*(驼蹄瓣) in some researches[8-10]. It was found that *Z. macropodum* extraction had analgesic and anti-inflammation effects from one preliminary study(not published). Studies on drought resistance were far more than the studies on medicinal functions of *Zygophyllum* plants, and no animal studies were on the bioactivity and bioactivity-guided isolation of *Zygophyllum* plants in China. The literature from all over the world showed that *Zygophyllum* plants caused various biological effect including hypoglycemic[3-6,11-12], hypotension[13-14], antioxidant[15-16], anti-inflammatory[17-18], anticancer[19-20] and antipyretic effects[21] in animals, patients or cells. Therefore, *Zygophyllum* plants have the application prospects in medicine, but no one has summed up the compounds identified from *Zygophyllum* plants before. The aim of this paper is to review the research situations of *Zygophyllum* compounds and clarify the uses of these plants.

Water extraction of root, aerial parts or whole plants of many *Zygophyllum* plants have been used in folk medicines(Table 1).

The traditional treatment effect of *Zygophyllum* plants in folk occupy a leading position in medical systems of African and Mediterranean areas. They have been proved non-toxic to animals[32-33], and their pharmacological activities also have been well documented. The pharmacological actions of extraction or fraction of *Z. album*, *Z. coccineum*, *Z. gaetulum*, *Z. geslini*, *Z. potanini* and *Z. oxianum* have been studied in model animals or patients, including antidiabetic[3-6,11,34-36], antihypertensive and hypolipidemic activities[5,14,35], antioxidant[15-16,31], antimicrobial[37-39], anti-diarrheal[40-41], anticancer[19-20]

Table 1 Application of *Zygophyllum* plants in folk

No.	*Zygophyllum* plants	treatment	country or area
1	*Zygophyllum album*	Diabetes, dermatitis, spasms and dysmenorrhoea[22-23]	Algeria
2	*Z. coccineum*	Rheumatism, gout, hypertension and diabetes[24]	Moroccan
3	*Z. fabago*	Cough, sputum, disperse wind and pain[25]	Mongolia and China
4	*Z. fabago*	Bronchitis, colds, toothache and intractable headaches[7]	Xinjiang of China
5	*Z. fabago*	Rheumatism, worm infections, constipation, and asthma[26]	Mediterranean countries
6	*Z. fabago*	Worm infections, rheumatism, and asthma[26]	Turkey
7	*Z. fabago*	Worm infections and constipation[27]	Iran
8	*Z. fabago*	Inflammatory and painful symptoms from insect bites[28]	Azerbaijan province of Iran
9	*Z. gaetulum*	Spasm, eczema, stomach and liver diseases[29]	Moroccan
10	*Z. gaetulum*	Arterial hypertension and diabetes [30]	Errachidia of Morocco
11	*Z. geslini*	Diabetes[22-23]	Algeria
12	*Z. potanini*	Inflammation, liver cirrhosis, ulcer, wounds and degeneration of liver and bile, ascites tumors [31]	Mongolia

and anti-inflammatory activities[17-18].

A large number of compounds such as saponins and flavonoids have been isolated from *Zygophyllum* plants. The previous studies about *Zygophyllum* genus mainly focused on isolation of some compounds and observation of pharmacological effect of the plant extractions or fractions. The results showed that the studies on the following three aspects were insufficient: tracing in biological activity isolation, molecular mechanisms, and content determination of some important compounds or fractions.

In this review, we will briefly review the main compounds isolated from *Zygophyllum* plants, including saponins, flavonoids and others and their effects *in vitro* or *in vivo* in order to provide basis for further studies on *Zygophyllum* plants.

1 Main compounds

The identified compounds mainly include about 81 kinds of saponins, 51 kinds of flavonoids and some other important compounds since 1977. Each compound was isolated from one or several *Zygophyllum* species that we could search at present. These plants include: *Z. aegyptium*, *Z. album*, *Z. atriplicoides*, *Z. berenicense*, *Z. coccineum*, *Z. decumbens*, *Z. ducembens*, *Z. dumosum*, *Z. eichwaldii*, *Z. eurypterum*, *Z. fabago*, *Z. gaetulum*, *Z. geslini*, *Z. melongena*, *Z. oxianum*, *Z. propinquum* and *Z. simplex*.

1.1 Saponins A total of 81 kinds of saponins isolated from *Zygophyllum* species such as triterpenoidal saponins. Some saponins such as zygophyloside E existing in several *Zygophyllum* species were found gradually in *Z. coccineum*, *Z. dumosum*, *Z. gaetulum*, *Z. geslini*, and *Z. propinquum*. Some saponins were isolated only from one or two species. The presence of the ursane-type aglycone and the sulfonyl moiety in the compounds such as zygophyloside A-N may represent chemotaxonomic markers of this genus[42], and the mother nucleus structure of zygophyloside was shown in Fig. 1. The R_1, R_2 and R_3 of zygophyloside D, E and G were β-*D*-(2-*O*-SO_3H)-Quip-, H-and H-; β-*D*-(2-*O*-SO_3H)-Quip-, H-and-β-*D*-Glcp; and β-*D*-(2-*O*-SO_3H)-Quip-, H-and-β-*D*-Glcp, respectively.

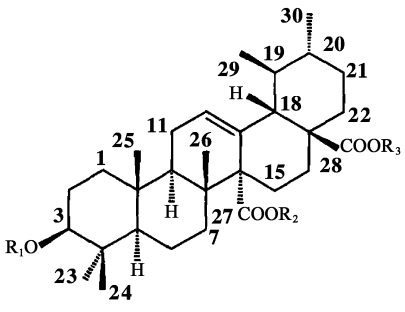

Fig. 1 Mother nucleus structure of zygophyloside

Zygofaboside A can inhibit urease activity to 87%. Zygophyloside I and M can reduce electrically stimulated contractions and morphine withdrawal in

guinea pig ileum. Some saponins can inhibit fungal or bacteria growth[20,37], and some can inhibit tumor cells[43] (Table 2). The activities of the most saponins isolated from *Zygophyllum* plants have not been studied and the contents of the useful saponins need further analysis.

Table 2 Identified saponins in *Zygophyllum*

No.	saponins	source	abbreviation	biological activities
1	3-*O*-[α-*L*-arabinopyranosyl-(1→2)-β-*D*-quinovopyranosyl] quinovic acid	*Zygophyllum propinquum*[44], *Z. coccineum*[45]	zygophyloside A	inhibit fungal growth[37]
2	3-*O*-[β-*D*-quinovopyranosyl] quinovic acid-27-*O*-[β-*D*-glucopyranosyl] ester	*Z. propinquum*[44], *Z. dumosum*[46]	zygophyloside B	
3	3-*O*-β-*D*-glucopyranosyl-quinovic acid	*Z. fabago*[43], *Z. melongena*[47], *Z. propinquum*[44]		inhibit snake venom phosphodiesterase-I[48]
4	sitosterol glucoside	*Z. simplex*[49]		
5	3-*O*-[α-*L*-arabinopyranosyl (1→2)-β-*D*-quinovopyranosyl]-quinovic acid-27-*O*-[β-*D*-glucopyranosyl] ester	*Z. propinquum*[50]	zygophyloside C	
6	3-*O*-[β-*D*-quinovopyranosyl]-quinovic acid	*Z. dumosum*[46], *Z. propinquum*[50], *Z. fabago*[51-52]		
7	14-decarboxyquinovic acid-3β-*O*-β-*D*-quinovopyranosyl (1→4)-quinovopyranoside	*Z. album*[53]		
8	quinovic acid 28-*O*-β-*D*-glucopyranosyl (2→1) β-*D*-glucopyranosyl ester	*Z. album*[53]		
9	quinovic acid 27-β-*D*-glucopyranosyl (2→1) β-*D*-glucopyranosyl ester	*Z. album*[53]		
10	quinovic acid-3-β-*O*-glucopyranosyl(2→1) rhamnopyranoside	*Z. album*[53]		
11	3-*O*-[β-*D*-2-*O*-sulphonyl quinovopyranosyl]-quinovic acid	*Z. propinquum*[54]	zygophyloside D	inhibit fungal growth[37]; potent cytotoxicity[55]
12	3-*O*-[β-*D*-2-*O*-sulphonyl quinovopyranosyl]-quinovic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. coccineum*[37], *Z. fabago*[51,56], *Z. gaetulum*[57-58], *Z. geslini*[59], Z. *oxianum*[6]	zygophyloside E	inhibit urease[6]; hypoglycemic effect[56]
13	3-*O*-[β-*D*-glucopyranosyl]-β-sitosterol	*Z. album*[20], *Z. atriplicoides*[60], *Z. coccineum*[61], *Z. propinquum*[50], *Z. simplex*[49]		antibacterial effect[28]; inhibit human leucocyte elastase[62]; a chemotaxonomic marker in *Zygophyllum* genus[63]
14	3-*O*-[β-*D*-2′-*O*-sulphonyl quinovopyranosyl]-decarboxy quinovic acid-28-*O*-[β-*D*-gluco-pyranosyl] ester	*Z. coccineum*[46], *Z. fabago*[51], *Z. propinquum*[50]		
15	quinovic acid-3β-*O*-β-*D*-quinovoside	*Z. album*[64]		
16	3β-*O*-β-*D*-quinovopyranosyl quinovic acid (28→1)β-*D*-glycopyranosyl ester	*Z. album*[20,46,64]		
17	quinovic β acid 3β-*O*-β-*D*-quinovopyranosyl (3→1)β-*D*-xylopyranoside	*Z. album*[64]		

续表 2

No.	saponins	source	abbreviation	biological activities
18	3β-*O*-β-*D*-quinovopyranosyl-quinovic acid (28→1) quinovopyranosyl ester	*Z. album*[64]		
19	3-*O*-[β-*D*-2-*O*-sulphonyl quinovopyranosyl]-quinovic acid-27-*O*-[β-*D*-glucopyranosyl] ester	*Z. album*[46], *Z. coccineum*[46], *Z. dumosum*[46,61], *Z. fabago*[51]	zygophyloside F	inhibit NO in lipopolysaccharide stimulated RAW264.7 macrophages[20]
20	β-*D*-glucuronic acid pyranosyl]-29-hydroxyoleanolic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. decumbens*[65]		
21	3-*O*-[β-*D*-quinovopyranosyl] quinovic acid 27-*O*-[β-*D*-glucopyranosyl] ester	*Z. dumosum*[46]		
22	3-*O*-[β-*D*-2-*O*-sulphonyl glucopyranosyl]-quinovic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. album*[20], *Z. coccineum*[61], *Z. propinquum*[54], *Z. fabago*[56], *Z. gaetulum*[58], *Z. geslini*[42]	zygophyloside G	inhibit urease to 60%[56]
23	3-*O*-[α-*L*-arabinopyranosyl-(1→2)-β-*D*-quinovopyranosyl]-quinovic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. coccineum*[45], *Z. dumosum*[61], *Z. geslini*[42]	zygophyloside H	
24	3-*O*-[β-*D*-glucuronic acid pyranosyl]-arjunolic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. decumbens*[65], *Z. gaetulum*[57]	zygophyloside I	
25	3-*O*-[β-*D*-glucuronic acid pyranosyl]-30-norajunolic acid-28-*O*-[β-*D*-glucopyranosyl] ester.	*Z. decumbens*[65]	zygophyloside J	
26	3-*O*-[β-*D*-glucuronic acid pyranosyl]-29-hydroxyoleanolic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. album*[20], *Z. decumbens*[65]	zygophyloside K	
27	3β-*O*-α-*L*-rhamnopyranosyl-(1→2)-α-*L*-arabinopyranosyl-(1→2)-β-*D*-glucopyranosylurs-20(21)-en-28-oic acid 28-*O*-[β-*D*-2-*O*-sulfonylglucopyranosyl] ester	*Z. gaetulum*[58]	zygophyloside I	reduce both electrically stimulated contractions and morphine withdrawal in isolated guinea pig ileum[66]
28	3β-*O*-[α-*L*-rhamnopyranosyl-(1→2)-α-*L*-arabinopyranosyl-(1→2)-β-*D*-glucopyranosyl] urs-20(21)-en-28-oic acid 28-*O*-[β-*D*-glucopyranosyl] ester	*Z. gaetulum*[58]	zygophyloside L	
29	3β-*O*-β-*d*-quinovopyranosyl-27-nor-olean-12-en-28-oic acid 28-*O*-β-*d*-glucopyranosyl ester	*Z. gaetulum*[58]	zygophyloside M	reduce both electrically stimulated contractions and morphine withdrawal in isolated guinea pig ileum[66]
30	3-*O*-β-*d*-glucopyranosyl quinovic acid 28-β-*d*-glucopyranosyl ester	*Z. gaetulum*[57-58], *Z. fabago*[67], *Z. propinquum*[61]		reduce the electrically induced contractions of isolated guinea pig ileum[57,68]
31	3β-*O*-β-*D*-glucopyranosylquinovic acid 28-*O*-β-*D*-glucopyranosyl ester	*Z. gaetulum*[58]		
32	3β-*O*-α-*L*-rhamnopyranosyl-(1→2)-*O*-α-*L*-arabinopyranosyl-(1→2)-β-*D*-glucopyranosyl) oxy]-ursan-20-β-28-olide	*Z. gaetulum*[57]	zygophyloside N	
33	28-β-*D*-glucopyranosyl ester of 3β,19β-dihydroxyurs-12-en-28-oic acid 3-*O*-β-*L*-arabinopyranoside	*Z. eichwaldii*[69]	zygoeichwaloside E	
34	3β,19β-dihydroxyurs-12-en-28-oic acid 3-*O*-β-*L*-arabinopyranoside	*Z. eichwaldii*[69]	zygoeichwaloside C	
35	28-*O*-β-*D*-glucopyranosyl ester of pomolic acid 3-*O*-β-*D*-2-*O*-sulfonylgalactopyranoside	*Z. eichwaldii*[70]	zygoeichwaloside I	

续表 2

No.	saponins	source	abbreviation	biological activities
36	3-*O*-α-*L*-(2-*O*-sulphonyl)-arabinopyranoside of 19-α-hydroxyursolic acid	*Z. eichwaldii*[71]	zygoeichwaloside G	
37	3-*O*-[α-*D*-glucopyranosyl-(1→2)-β-*D*-xylopyranosyl] hederagenin	*Z. atriplicoides*[60]	atriplicosaponin A	
38	27α-hydroxyurs-12-ene-3-*O*-[β-*D*-glucopyranosyl(1→4)(2-*O*-sulpho)β-*D*-quinovopyranoside]	*Z. atriplicoides*[60]	atriplicosaponin B	
39	3-*O*-α-*L*-rhamnopyranosyl-(1→2)-α-*L*-arabinopyranosyl-(1→2)-β-*D*-glucuronopyranosyl-urs-20(21)-en-28-oic acid-28-*O*-(2-*O*-sulfo-β-*D*-glucopyranosyl) ester	*Z. atriplicoides*[60]		Ursane type aglycone and the sulfonyl moiety in these molecules may represent chemotaxonomic markers of *Zygophyllum* genus[42]
40	3-*O*-(2-*O*-sulfo-β-*D*-glucuronopyranosyl)-urs-20-(21)-en-28-oic acid-28-*O*-(2-*O*-sulfo-β-*D*-glucopyranosyl) ester	*Z. atriplicoides*[60], *Z. geslini*[42]		
41	3-*O*-(2-*O*-sulfo-β-*D*-glucopyranosyl)-quinovic acid	*Z. geslini*[42]		
42	(3β)-3-{[6-deoxy-a-*L*-mannopyranosyl-(1→2)-a-*L*-arabinopyranosyl-(1→2)-β-*d*-glucopyranurosonyl] oxy} urs-20-en-28-oic acid 28-(2-*O*-sulfo-β-*d*-glucopyranosyl) ester	*Z. geslini*[42]		
43	(3β)-3-[(2-*O*-sulfo-β-*d*-glucopyranurosonyl) oxy] urs-20-en-28-oic acid 28-(2-*O*-sulfo-β-*d*-glucopyranosyl] ester	*Z. geslini*[42]		
44	3-*O*-[α-*L*-arabinopyranosyl-(1→2)-β-*D*-glucopyranosyl] quinovic acid 28-(β-*D*-glucopyranosyl) ester	*Z. geslini*[42]		
45	3β,23-di-*O*-sulfonyl-23-hydroxyurs-20(21)-en-28-oic acid 28-*O*-[β-*D*-glucopyranosyl] ester	*Z. fabago*[72]	zygofaboside A	inhibit urease to 87%[56]
46	3β,23-di-*O*-sulfonyl-23-hydroxyurs-20(21)-en-28-oic acid 28-*O*-[β-*D*-glucopyranosyl-(1→6)-β-*D*-glucopyranosyl] ester	*Z. fabago*[72]	zygofaboside B	
47	3-*O*-β-*D*-glucopyranosyl pyrocincholate	*Z. fabago*[43]		effectively inhibit the proliferation of the human ECA-109 cells (esophageal cancer)[43]
48	3-*O*-6-deoxy-β-*D*-glucopyranosyl-pyrocincholate	*Z. fabago*[43]		effectively inhibit the proliferation of the human ECA-109 cells
49	quinovic acid	*Z. fabago*[43]		effectively inhibit the proliferation of the human ECA-109 cells
50	3-*O*-6-deoxy-β-*D*-glucopyranosyl-quinovic acid	*Z. fabago*[43]		
51	3-*O*-6-deoxy-β-*D*-glucopyranosyl-cincholic acid	*Z. fabago*[43]		
52	3-*O*-[α-*L*-2-*O*-sulphonylarabinopyranosyl]-pomolic acid-28-*O*-[β-*D*-glucopyranosyl] ester	*Z. eichwaldii*[73]	zygoeichwaloside H	
53	3-*O*-[β-*d*-2-*O*-sulphonylglucopyranosyl]-pomolic acid-28-*O*-[β-*d*-glucopyranosyl] ester	*Z. eichwaldii*[73]	zygoeichwaloside K	
54	3β-[(2-*O*-sulfo-β-*D*-xylopyranosyl) oxy] urs-12-ene-27,28-dioic acid	*Z. fabago*[52]	zygophyloside O	
55	3β-[(2-*O*-sulfo-β-*D*-xylopyranosyl) oxy]-urs-12-ene-27,28-dioic acid 28-β-*D*-glucopyranoside	*Z. fabago*[52]	zygophyloside P	

续表 2

No.	saponins	source	abbreviation	biological activities
56	3-*O*-(*β*-*D*-quinovopyranosyl)-pyrocincholate	*Z. fabago*[74]		anti-tumour; inhibit 80.3% ECA-109 activity by MTT assay at 50 mg·L^{-1}; inhibit NO[74]
57	3-*O*-(*β*-*D*-quinovopyranosyl) cincholic acid	*Z. fabago*[74]		
58	quinoviric acid-3-*O*-*β*-*D*-chicken glycoside	*Z. fabago*[74]		
59	nahagenin	*Z. fabago*[74]		inhibit NO[74]
60	quinoviric acid-3-*O*-*β*-*D*-glucoside	*Z. fabago*[74]		
61	3-*O*-(*β*-*D*-2-*O*-sulfonic acid chicken sugar)-28-*O*-(*β*-*D*-glucose quino)	*Z. fabago*[74]		
62	3*β*,24,28,30-tetrahydro-urs-20-ene-24-O-sulphonyl-3-*O*-[*β*-D-glucopyranosyl]-30-*O*-*β*-*D*-glucopyranoside	*Z. fabago*[74]	zygophyloside Q	
63	3*β*,24,28,30-tetrahydro-urs-20-ene-24-*O*-sulphonyl-3-*O*-[*β*-*D*-xylopyranosyl]-30-*O*-*β*-*D*-glucopyranoside	*Z. fabago*[74]	zygophyloside R	
64	3*β*,24-dihydroxyurs-20-ene-24-*O*-sulphonyl-28-oic acid	*Z. fabago*[10]	fabagoin 1	
65	(3*β*,4*α*)-3,23,30-trihydroxyurs-20-en-28-al-3,23-di(sulfate) sodium salt	*Z. fabago*[67]		inhibit urease to 75%[56]
66	(3*β*, 4*α*)-3, 23, 28-trihydroxyurs-20-en-30-yl-*β*-*D*-glucopyranoside 3,23-di(sulfate) sodium salt	*Z. fabago*[67]		
67	3*β*-*O*-[*β*-*d*-quinovopyranoside] quinovic acid 28-*O*-[*β*-*d*-glucopyranosyl] ester	*Z. fabago*[67]		
68	3-*O*-[*α*-*L*-arabinopyranosyl-(1 → 2)-*β*-*D*-glucopyranosyl] quinovic acid	*Z. coccineum*[37]	zygophyloside S	inhibit fungal growth[37]
69	3-*O*-[*β*-*D*-(2-*O*-sulphonyl)-quinovopyranosyl] quinovic acid	*Z. coccineum*[37]		inhibit fungal growth[37]
70	3-*O*-[*β*-*D*-glucopyranosyl] quinovic acid	*Z. coccineum*[37], *Z. fabago*[43,51], *Z. melongena*[47]		inhibit fungal growth[37]
71	3-*O*-[*β*-*D*-quinovopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	*Z. coccineum*[37], *Z. dumosum*[61], *Z. geslini*[59]		inhibit fungal growth[37]
72	3-*O*-[*β*-*D*-(2-*O*-sulphonyl) glucopyranosyl] quinovic acid	*Z. coccineum*[37]		inhibit fungal growth and show 77% fungal growth inhibition rate at a concentration of 30 μmol·L^{-1} against *Phomopsis viticola*[37]
73	3-*O*-[*β*-*D*-glucopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	*Z. coccineum*[37], *Z. dumosum*[61]		reduce the electrically induced contractions of isolated guinea pig ileum[57]
74	30-carboxy-3*β*-24-dihydroxy-urs-28,13*β*-lactam-*N*-acetate	*Z. eurypterum*[75]	atriplicoide A	
75	3*β*,24-dihydroxyursan-28,13*β*-olide	*Z. eurypterum*[75]	atriplicoide B	
76	3*β*,23, 30-trihydroxyurs-20-en-28-al-23-sulfate-3-*O*-*β*-*D*-xylopyranoside	*Z. fabago*[76]	zygofaboside C	
77		*Z. fabago*[9]	fabagoin A	
78		*Z. fabago*[9]	fabagoin B	
79	3,30-hydroxy-urs-12-en-27-28 dioic acid	*Z. fabago*[9]	fabagoin C	
80	3-*β*-*D*-xylopyranosyl-quinovic acid	*Z. fabago*[9]	fabagoin D	
81	3-*O*-(*β*-*D*-glucopyranosyl) quinovic acid (28→1)-(*β*-*D*-glucopyranosyl) ester	*Z. melongena*[47]		

1.2 Flavonoids A total of 51 kinds of flavonoids isolated from *Zygophyllum* plants were listed in Table 3, including flavone and flavonol glycoside. The roles of flavonoids as plant systematic markers particularly depended on the glycosylation level. The identified aglycones were kaempferol, quercetin and isorhamnetin[77]. The core structure of flavonoids in *Zygophyllum* was shown in Fig. 2. Quercetin-3-*O*-rutinoside and isorhamnetin-3-*O*-rutinoside were considered as the chemotaxonomic markers of *Zygophyllum* plants[37]. Many of the flavonoids showed antioxidation and anticancer effect. Quercetin-3-*O*-rutinoside can target mitochondrial apoptotic pathway in acute lymphoblastic leukemia, protected against the functional impairment of the endothelium dependent vaso-relaxation caused by a reduction of nitric oxide availability in diabetes patients, protected against γ-radiation and showed antibacterial activity to *Staphylococcus aureus*. Isoquercetrin, kaempferol and quercetin-3-*O*-glucoside showed more potential pharmacology effects, respectively (Table 3).

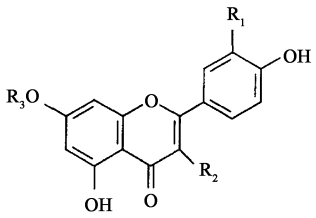

Fig. 2 Mother nucleus structure of flavonoids in *Zygophyllum*

Table 3 Identified flavonoids in *Zygophyllum* plants

No.	flavonoids	source	abbreviation	biological activities
1	2-(3, 4-dihydroxyphenyl)-3, 5, 7-trihydroxy-4H-chromen-4-one	*Zygophyllum album*[14], *Z. fabago* *Z. simplex*	quercetin	quercetin supplementation does not alter antioxidant status in humans[78]; it is a naturally occurring polar auxin transport inhibitor[79]; antioxidant[80]; anticarcinogenic[81]; antithrombotic[82]; anti-allergic[83]; antidiabetic[84]; antiobesity[85]; immune and inflammation-modulating activities[86]; anti-atherosclerotic, anti-proliferative, and anti-inflammatory effects of quercetin have been documented in many human *in vitro* and *in vivo* models[87]
2	quercetin-3-*O*-β-glucopyranoside	*Z. album*[88], *Z. simplex*[77,89]	isoquercetrin	protect PC12 cell by inhibiting reactive oxygen species (ROS)[90]; inhibit matrix metalloproteinase (MMP)-9 in HT-1080 cells[91]; improve cGMP in the brain of rats and strengthen electroacupuncture analgesia[92]
3	quercetin-3, 7-di-*O*-β-glucopyranoside	*Z. simplex*[89]		
4	quercetin-3-*O*-α-rhamnopyranosyl-(1→6)-*O*-β-glucopyranoside	*Z. album*[77,89], *Z. berenicense*[77], *Z. coccineum*[77], *Z. decumbens*[89]	quercetin-3-*O*-rutinoside	target mitochondrial apoptotic pathway in acute lymphoblastic leukemia[93]; protect against the functional impairment of the endothelium-dependent vasorelaxation caused by a reduction of nitric oxide availability in diabetes[94]; protect against γ-radiation[95]; inhibit methicillin resistant *Staphylococcus aureus*[96]
5	3, 5, 7-trihydroxy-2-(4-hydroxy-3-methoxyphenyl) chromen-4-one	*Z. album*[88], *Z. simplex*[49], *Z. fabago*[97]	isorhamnetin	show antioxidative activity and suppress the generation of the superoxide anion *in vitro*; be against BEL-7402 cells[98]
6	isorhamnetin 3-*O*-glucoside	*Z. album*[88], *Z. decumbens*[77], *Z. simplex*[49], *Z. fabago*[28]		show hepatoprotective effects[99]
7	quinovic acid 3-α-*L*-rhamnoside.	*Z. simplex*[49]		
8	kaempferol-3-*O*-rutinoside	*Z. album*[77], *Z. simplex*[49]		inhibit glucosidase[99]; decreases systolic, diastolic, mean arterial blood pressure and heart rate remarkably[100]; hepatoprotective effect[101]; antiglycation activity[102]; promote keratinocyte migration through focal adhesion kinase (FAK) and Rac1 activation[103]; inhibit adipogenesis in 3T3-L1 cells through the suppression of PPARγ and CCAAT-enhancer-binding protein α expression[104]

续表 3

No.	flavonoids	source	abbreviation	biological activities
9	kaempferol-3-*O*-*β*-glucopyranoside	*Z. album*[105], *Z. simplex*[49], *Z. melongena*[47], *Z. fabago*[52]	astragalin	
10	6″-(2-*E*-butenoyl) isorhamnetin-3-*O*-glucoside	*Z. simplex*[49]		maybe anti-inflammatory[18]
11	malvidin 3-rhamnoside	*Z. album*[53]		antioxidant; resist lung carcinoma cell lines; anti-inflammatory in RAW264.7 macrophages[20]
12	quercitin-3-sulphate	*Z. album*[53]		same as above
13	3,4′,5,7-tetrahydroxyflavone	*Z. album*, *Z. berenicense*[77], *Z. coccineum*[77], *Z. decumbens*[77], *Z. dumosum*[106], *Z. eurypterum*[107], *Z. fabago*[97], *Z. simplex*[89]	kaempferol	lethal for spore germination of *V. albo-atrum* and *F. oxysporum* f. sp. *lycopersici*[106]; protect PC12 and T47D cells from *β*-amyloid induced toxicity[108]; anxiolytic effect through a *γ*-aminobutyric acid ergic mechanism; protect against amyloid *β*-peptide induced neurotoxicity in ICR mice[109]; anticancer effect[110-111]; aldose reductase inhibitor, anti-viral activity, and prevent cardiovascular disease[112]
14	isorhamnetin 3-*O*-(4″-sulfatyl-rutinoside)	*Z. dumosum*[113]		
15	3*β*-(3,4-dihydroxycinnamoyl)-erythrodiol.	*Z. geslini*[114]		antimicrobial; cytotoxic[114]
16	(−)-1,2-dihydroxy-4-(hydroxymethyl)-3,9-dimethoxypterocarpan	*Z. eurypterum*[107]	atricarpan A	inhibit butyrylcholinesterase, lipoxygenase and acetylcholinesterase[107]
17	(−)-2,3-ethylenedioxy-1,4-dihydroxy-9-methoxypterocarpan	*Z. eurypterum*[107]	atricarpan B	inhibit butyrylcholinesterase[107]
18	(−)-1,9-dimethoxypterocarpan-3-carboxylic acid	*Z. eurypterum*[107]	atricarpan C	inhibit butyrylcholinesterase[107]
19	(−)-2,9-dimethoxy-4-(5-oxohexyl) pterocarpan	*Z. eurypterum*[107]	atricarpan D	inhibit butyrylcholinesterase, lipoxygenase and acetylcholinesterase[107]
20	quercetin-3-*O*-glucoside	*Z. album*[88], *Z. eurypterum*[107], *Z. simplex*[77]		high antioxidant activity[74]; high phytotoxic effect[115]; wound healing activity *in vivo*[116]; anti-diabetic[117]; anti-allergic[118]; the acylated derivatives of it are more effective in anti-proliferation, anti-inflammation, and hyperlipidemic effects[119-120]; suppress pancreatic cancer cells migration[91]; inhibit adenylyl cyclase[121]; reduce transient Ca^{2+}[122]; anticancer cells selectively *in vitro*
21	stigmast-4-en-3-one	*Z. fabago*[123]		hypoglycemic effect
22	kaempferol 3-*O*-*β*-*D*-glucopyranoside	*Z. fabago*[123], *Z. melongena*[47]	astragalin	
23	astragalin 3-*O*″-sulfate	*Z. fabago*[124]		
24	(*E*)-*β*-damascenone	*Z. album*[125]		major components (11.8%) of the essential oil from *Z. album*[125]
25	isorhamnetin-3-*O*-[*α*-*L*-rhamnopyranosyl (1‴ → 6″)-*β*-*D*-glucopyranoside]	*Z. album*[14,89], *Z. atriplicoides*[60], *Z. coccineum*[77], *Z. decumbens*[77], *Z. dumosum*[113], *Z. cornutum*[126]	isorhamnetin-3-*O*-rutinoside (narcissin)	a chemotaxonomic marker of genus *Zygophyllum*[37]
26	isorhamnetin-3, 7-diglucoside	*Z. simplex*[127]		
27	isorhamnetin-3-*O*-(6′-malonyl) glucoside	*Z. simplex*[127]		

续表 3

No.	flavonoids	source	abbreviation	biological activities
28	quercetin-3-*O*-(6″-malonyl) glucoside	*Z. simplex*[127]		
29	*p*-hydroxy acetophenone	*Z. simplex*[127]		
30	*p*-hydroxy acetophenone glucoside	*Z. simplex*[127]		
31	androsin	*Z. simplex*[127]		anti-asthmatic effect[128]
32	stigmast-3,6-dione	*Z. simplex*[127]		
33	quercetin-3,7-di-*O*-β-glucopyranoside	*Z. album*[14], *Z. simplex*		
34	isorhamnetin-3-*O*-β-glucopyranoside-7-*O*-α-rhamnopyranoside	*Z. album*[14], *Z. simplex*[89]		
35	isorhamnetin-3-*O*-β-galactopyranoside	*Z. album*[14,89], *Z. simplex*[89]		
36	isorhamnetin-3-*O*-β-glucopyranoside	*Z. album*[14,89], *Z. decumbens*[89] *Z. simplex*[89]		
37	isorhamnetin-3-*O*-α-rhamnopyranosyl-(1→6)-*O*-β-galactopyranoside	*Z. album*[14,89]	isorhamnetin-3-*O*-robinoside	
38	2-(6,10-dimethylspiro[4,5]dec-6-en-2-yl)-2-propanol	*Z. fabago*[8]	hinesol	induce apoptosis through the c-Jun *N*-terminal kinase (JNK) signaling pathway in HL-60 cells[129]
39	12-hydroxy-valenc-1-en-2-one	*Z. fabago*[8]		
40	(6*S*, 7*E*)-6-hydroxy-4, 7-me-gastigmadien-3,9-dione	*Z. fabago*[8]		
41	3-hydroxy-5α, 6α-epoxy-β-ionone	*Z. fabago*[8]		
42	(3*S*, 5*R*, 6*S*, 7*E*)-3, 5, 6-trihydroxy-7-megastigmen-9-one.	*Z. fabago*[8]		
43	(6*R*, 7*E*, 9*R*)-9-hydroxy-4, 7-megastigmadien-3-one	*Z. fabago*[8]		
44	(*S*)-3-hydroxy-β-ionone	*Z. fabago*[8]		
45	blumenol A	*Z. fabago*[8]		resist human solid tumor cells[130]; blumenol A and grasshopper ketone may be the growth inhibitor in *Oryza sativa* variety *Awaakamai* and may play an important role in the allelopathy of *Awaakamai*[131]
46	2-(3, 4-dihydroxyphenyl)-3,5,7-trihydroxy-6-methoxy-4-benzopyrone.	*Z. coccineum*[39]		antimicrobial effect against *Staphylococcus aurous*, *Streptococcus pyogenes* and *Klebsiella pneumonia* etc.[39]
47	6-*C*-prenyl-7-*O*-[β-*D*-4‴-*O*-acetyl-glucopyranosyl-(1‴→2″)-β-*D*-glucopyranosyl]-apigenin	*Z. fabago*[28]	zygocaperoside	
48	isorhamnetin-3-*O*-β-*D*-rutinoside	*Z. simplex*[132]		
49	isorhamnetin-3-*O*-β-*D*-glucoside	*Z. simplex*[132]		
50	isorhamnetin-3-*O*-β-*D*-glucopyranoside	*Z. fabago*[97]		
51	luteolin-7-*O*-β-*D*-glucoside	*Z. simplex*[132]		

1.3 Other important substances β-Carboline was the core substance of the alkaloids of *Zygophyllum* (Fig. 3). The content of crude total alkaloids was about 0.12% from the dry aerial parts of *Z. album* and harmine was isolated and identified[88]. Harmane, harmine and harmol were separated from other *Zygophyllum* plants. Other important compounds such as (+)-*D*-pinitol, β-sitosterol and daucosterol were also isolated from some *Zygophyllum* plants. Both of (+)-*D*-pinitol and β-sitosterol had anti-diabetes activity. β-Sitosterol and daucosterol had many biological actions especially anticancer actions (Table 4). But the contents of them and their presence in other *Zygophyllum* species shall be further studied.

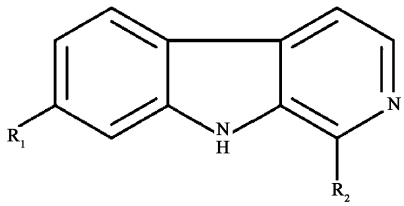

Fig. 3 Mother nucleus structure of alkaloids in *Zygophyllum*

Table 4 Other important substances isolated from *Zygophyllum*

No.	substances	source	abbreviation	biological activities
1	1-methyl-β-carboline	*Zygophyllum album*[88] *Z. fabago*[88]	harmane	a neurotoxin that is strongly associated with essential tremor, one of the most common neurological diseases in the elderly; a monoamine oxidase inhibitor and believed to be the main endogenous ligand for the benzodiazepine receptor
2	7-methoxy-1-methy-β-carboline	*Z. album*[88], *Z. fabago*[88]	harmine	inhibit breast cancer cell line (MDA-MB-231); reduce resistance to the anticancer drugs mitoxantrone and camptothec[133]
3	1-methyl-2, 9-dihydro-pyrido[3, 4β]indol-7-one	*Z. gaetulum*[134]	harmol	
4	erythrodiol-3-caffeate	*Z. propinquum*[50]		
5	3β-(3,4-dihydro-xycinna-moyl)-erythrodiol	*Z. propinquum*[50]		show significant *in vitro* cytotoxicity against KB cells with an inhibitory concentration 50% of 4 μmol·L^{-1}[114]
6	(1*S*,2*S*,4*S*,5*R*)-6-metho-xycyclohexane-1,2,3,4,5-pentol	*Z. melongena*[47]	(+)-*D*-pinitol.	anti-diabetes[135]; anti-inflammatory[136]
7	(3*S*,8*S*,9*S*,10*R*,13*R*,14*S*,17*R*)-17-[(2*R*,5*R*)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol	*Z. cornutum*[126], *Z. fabago*[123], *Z. oxianum*[19], *Z. simplex*[18], *Z. xanthoxylum*[137]	β-sitosterol.	antimicrobial effect[138]; anti-inflammatory[139]; anticancer; angiogenic[140]; antioxidant[141-142]; immunomodulatory[143]; anti-hyperlipidemic activity[144]; antiatherosclerosis[145]; antidiabetes[146-147]
8	(2*R*,3*R*,4*S*,5*S*,6*R*)-2-(3*S*,8*S*,9*S*,10*R*,13*R*,14*S*,17*R*)-17-[(2*R*,5*R*)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta-α-phenanthren-3-yl]oxy]-6-(hydroxymethyl)oxane-3,4,5-triol	*Z. fabago*[123]	daucosterol	immunoregulatory[148]; promote the proliferation of neural stem cells[149]; daucosterol derivatives have antibacterial activity[150]; inactivation of phosphatidylinositol-3 kinases/protein kinase B (PI3K/Akt) pathway and up regulation of phosphatase and tensin homolog (PTEN) gene in human breast adenocarcinoma cells[151]; inhibit cancer cell proliferation by inducing autophagy[152]; protect neurons against oxygen glucose deprivation[152]; promote proliferation osteoblast like cells by 45.8%[149,153]; inhibit colon cancer cell migration and invasion[154]; neuroprotective effect[155]; protect MC3T3-E1 cells against H_2O_2 induced injury via regulating insulin-like growth factor 1 (IGF-1) pathway[152]; a possible lead compound for allergic transfusion reactions[156]
9	gentisic acid	*Z. album*[14], *Z. simplex*[89]		

续表 4

No.	substances	source	abbreviation	biological activities
10	gentisic acid 5-*O*-α-rhamnopyranoside	*Z. album*[14], *Z. simplex*[89]		
11	1-hexyl-2-nitrocyclexane	*Z. coccineum*[38]		antifungal activity against *Aspergillus flavus*, *Cladosporium* sp., *Alternaria alternata* and *Fusarium solani* and the effects of NO 7, 8 and 9 to *Cladosporium* sp. were 89.8%, 88.9% and 88.6%, respectively[38]
12	2-octadecyl-propane-1, 3-diol	*Z. coccineum*[38]		same as above
13	octadecanal	*Z. coccineum*[38]		same as above
14	(7*R*, 8*S*, 8′*S*)-4, 9, 4′-trihydroxy-3, 3′-dimethoxy-4′-sulfonyl-7, 9′-epoxylignan	*Z. aegyptium*[157]		
15	myricitrin	*Z. simplex*[132]		

2 Discussion and prospect

Different substances in *Zygophyllum* plants had the same effect different substances in *Zygophyllum* plants had antidiabetic effect, including total extract[3-4]; butanol soluble fraction and aqueous fraction from the water extraction[158], the essential oil from *Z. album*[5] and purified total triterpene[6], (*E*)-β-damascenone[5], quercetin-3-*O*-rutinoside[89,94], quercetin-3-*O*-glucoside, stigmast-4-en-3-one, (+)-*D*-pinitol[135] and β-sitosterol[146-147].

The chloroform-methanol(2∶1) extract from aerial parts of *Z. oxianum*[19], dichloromethane extract of *Z. album*[20], quercetin[81], isoquercetrin and quercetin-3-*O*-glucoside[91], quercetin-3-*O*-rutinoside[93], kaempferol[110-111], kaempferol 3-*O*-rutinoside[103], isorhamnetin[98], malvidin 3-rhamnoside and quercitin-3-sulphate[20], hinesol[129], blumenol A[130], 3β-(3, 4-dihydroxycinnamoyl)-erythrodiol, harmine[133], 3β-(3, 4-dihydroxycinnamoyl)-erythrodiol[114], β-sitosterol and daucosterol from some *Zygophyllum* plants, all had the anticancer effect.

We could presume that the hypoglycemic or anticancer effect was a synergetic process depending on a series of the above substances, but further research is required due to the compatibility and complexity of traditional Chinese medicine (TCM). The effective constituents of TCM are the basis for their clinical efficacy. Therefore, we believe that the active ingredients or parts of the TCM have specific pharmacological effects as "Chinese medicine molecule".

The isolation or determination of active ingredients is necessary. Most of compounds in the *Zygophyllum* genus listed in Table 1-3 were only isolated and identified, but seldom associated with the pharmacological action of *Zygophyllum* plants. The pharmacological action was studied usually by using the total extract with polar solvents or a few fractions with simple solvent/solvent extraction from the total extract, but seldom associated with the isolated single compound by activity guided methods. The pharmacological effects of total extract and some fractions of *Zygophyllum* species were significant, but with very high dosage.

It is possible that the contents of the main active compounds are different among species. Activity guided separation and chromatographic fingerprint construction are necessary for study. The disease related target gene is the most essential role of plant medicine indicators. *Zygophyllum* species have the effective components for diabetes, hypertension, hyperlipemia and other disease models. The effective compounds and the detection methods are necessary to investigate and elucidate the molecular mechanisms. Further studies with experiments *in vitro* or *in vivo* to isolate the active ingredients are required for *Zygophyllum* plants for a good understanding on their mechanisms of action[17].

[**References**]

[1] Beier B A, Chase M W, Thulin M. Phylogenetic relationships and taxonomy of subfamily

Zygophylloideae (Zygophyllaceae) based on molecular and morphological data[J]. Plant Syst Evolut, 2003, 240(1/4):11-39.

[2] Institute of Botany The Chinese Academy of Sciences. *Flora of China*[M]. Beijing: The Science Press, 1998: 126-141.

[3] Feriani A, Hachani R, Kaabi B, et al. Protective effects of *Zygophyllum album* extract against deltamethrin-induced hyperglycemia and hepato-pancreatic disorders in rats[J]. Can J Physiol Pharmacol, 2016, 94(11): 1202-1210.

[4] El Ghoul J, Boughattas N A, Ben-Attia M. Antihyperglycemic and antihyperlipidemic activities of ethanolic extract of *Zygophyllum album* in streptozotocin-induced diabetic mice [J]. Toxicol Ind Health, 2013, 29(1):43-51.

[5] Mnafgui K, Kchaou M, Ben S H, et al. Essential oil of *Zygophyllum album* inhibits key-digestive enzymes related to diabetes and hypertension and attenuates symptoms of diarrhea in alloxan-induced diabetic rats [J]. Pharmaceutical Biology, 2016, 54(8): 1326-1333.

[6] Yuldasheva N K, Sasmakov S A, Khushbaktova Z A, et al. A total triterpene glycosides preparation from *Zygophyllum oxianum* as a potential hypoglycemic agent[J]. Pharmaceut Chem J, 2013, 47(8):433-436.

[7] Jiangsu Institute of Botany, Chinese Academy of Medical Sciences, Kunming Institute of Botany. *Xinhua Bencao Gangyao*[M]. Shanghai: Shanghai Science and Technology Press, 1988:272.

[8] HE J H, NIU Y F, LI J X, et al. Studies on terpenoids from *Zygophyllum fabago* [J]. China J Chin Mater Med, 2015, 40(23):4634-4638.

[9] HE J B, LYU X M, NIU Y F, et al. Four new compounds from *Zygophyllum fabago* L[J]. Phytochem Lett, 2016, 15:116-120.

[10] FENG Y L, XIE B, LI H R, et al. A new sulfated triterpenoid from the bark of *Zygophyllum fabago* L [J]. Chin Chem Lett, 2010, 21(9):1100-1102.

[11] Mnafgui K, Kchaou M, Hamden K, et al. Inhibition of carbohydrate and lipid digestive enzymes activities by *Zygophyllum album* extracts: effect on blood and pancreas inflammatory biomarkers in alloxan-induced diabetic rats[J]. J Physiol Biochem, 2014, 70(1): 93-106.

[12] Medjdoub H, Tabti B. Antidiabetic effect of the aerial part ethanolic extracts of *Zygophyllum geslini* Coss. In streptozotocin induced-diabetic rats[J]. Metab Funct Res Diabetes, 2012, 5:17-20.

[13] Gibbons S, Oriowo M. Antihypertensive effect of an aqueous extract of *Zygophyllum coccineum* L in rats [J]. Phytother Res, 2001, 15(5):452-455.

[14] Mnafgui K, Hamden K, Ben Salah H, et al. Inhibitory activities of *Zygophyllum album*: a natural weight-lowering plant on key enzymes in high-fat diet-fed rats [J]. Evid Based Complement Alternat Med, 2012, doi: 10.1155/2012/620384.

[15] Kchaou M, Salah H B, Mhiri R, et al. Anti-oxidant and anti-acetylcholinesterase activities of *Zygophyllum album*[J]. Bangladesh J Pharmacol, 2015, 11(1): 54-62.

[16] Belguidoum M, Dendougui H, Kendour Z, et al. Antioxidant activities, phenolic, flavonoid and tannin contents of endemic *Zygophyllum cornutum* Coss. from algerian sahara[J]. Der Pharmacutical Chem, 2015, 7(11):312-317.

[17] Ait E C M, Makram S, Ansare M, et al. Anti-inflammatory activity of aqueous and ethanolic extracts of *Zygophyllum gaetulum*[J]. Ann Pharm Fr, 2012, 70(2):113-116.

[18] Kumar H, Kakrani N, Kakrani P H, et al. Evaluation of analgesic and anti-inflammatory activity of ethyl acetate extract of *Zygophyllum simplex* Linn. herb[J]. Int J Pharmacognosy Phytochem Res, 2011, 1(3):180-183.

[19] Sasmakov S A, Gazizov F Y, Putieva Z M, et al. Neutral lipids, phospholipids, and biological activity of extracts from *Zygophyllum oxianum* [J]. Chem Nat Compd, 2012, 48(1):11-15.

[20] Ksouri W M, Medini F, Mkadmini K, et al. LC-ESI-TOF-MS identification of bioactive secondary metabolites involved in the antioxidant, anti-inflammatory and anticancer activities of the edible halophyte *Zygophyllum album* Desf. [J]. Food Chem, 2013, 139(1):1073-1080.

[21] Larhsini M, Markouk M, Jaouhari J, et al. The antipyretic activity of some moroccan medicinal plants [J]. Phytother Res, 2002, 16(S1):97-98.

[22] Maïza K, Hammiche V, Bra dlPRA. Traditional saharian pharmacopoeia[J]. Acta Horticulturae, 1993(332): 37-42.

[23] Smati D, Hammiche V, Nehari H, et al. *Zygophyllum geslini* Coss.: Chemical investigation hypoglycemic activity[J]. Acta Horticulturae, 1993(332):243-248.

[24] Eskander E F, Won J H, Ibrahim K A, et al. Hypoglycemic effect of a herbal formulation in alloxan induced diabetic rats[J]. Egypt J Pharmaceut Sci,

1995,36(1/6):253-270.

[25] Alaga, Guller G, Sulei C, et al. Mongolian medicinal plant resource investigation in he lan mountain[J]. J Med Pharmacy Chin Minorities, 2014, 20(8):35-48.

[26] Baytop T. *Therapy with medicinal plants in turkey (past and present)*[M]. Istanbul: Nobel Tip Kitapevi, 1999.

[27] Zargari A. *Medicinal Herbs*[M]. Tehran: University of Tehran Press, 1995.

[28] Yaripour S, Delnavazi M R, Asgharian P, et al. A survey on phytochemical composition and biological activity of *Zygophyllum fabago* from iran [J]. Adv Pharmaceut Bull, 2017, 7(1):109-114.

[29] Bellakhdar J, Claisse R, Fleurentin J, et al. Repertory of standard herbal drugs in the moroccan pharmacopoea [J]. J Ethnopharmacol, 1991, 35(2):123-143.

[30] Tahraoui A, El-Hilaly J, Israili Z H, et al. Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in south-eastern morocco (errachidia province)[J]. J Ethnopharmacol, 2007, 110(1):105-117.

[31] World Health Organization Regional Office for the Western Pacific. *Medicinal Plants in Mongolia*[M]. Geneva: World Health Organization Press, 2013: 230-232.

[32] Taha A, Alsayed H. Brine shrimp bioassay of ethanol extracts of *Sesuvium verrucosum*, *Salsola baryosma* and *Zygophyllum quatarense* medicinal plants from bahrain [J]. Phytother Res, 2000, 14(1):48-50.

[33] Alhaddad H, Fadhil A A, Ismael S H. Estimation of LD_{50} and acute toxicity of *Zygophyllum fabago* in mice [J]. J Dentistry, 2015, 15(6):94-97.

[34] El Ghoul J, Smiri M, Ghrab S, et al. Antihyperglycemic, antihyperlipidemic and antioxidant activities of traditional aqueous extract of *Zygophyllum album* in streptozotocin diabetic mice [J]. Pathophysiology, 2012, 19(1):35-42.

[35] Berzou S, Taleb-Senouci D, Guenzet A, et al. *Zygophyllum gaetulum* attenuates hypercholesterolemia and protects against oxidative stress in rats fed a high-cholesterol diet[J]. J Exp Integr Med, 2014, 4(4): 1-6.

[36] Houria M, Boufeldja T, Malika B, et al. Antihyperglycemic effect of *Zygophyllum geslini* aqueous extract in streptozotocin-induced diabetic wistar rats[J]. J Life Sci, 2012(6):652-656.

[37] Amin E, El-Hawary S S, Fathy M M, et al. Triterpenoidal saponins: bioactive secondary metabolites from *Zygophyllum coccineum*[J]. Planta Med, 2011, 77(5):488-491.

[38] Perveen K. Potential of *Zygophyllum coccineum* extracts in inhibiting the growth of plant pathogenic fungi[J]. J Pure Appl Microbiol, 2014, 8(2):1715-1720.

[39] Elbadry M A, Elaasser M M, Elshiekh H H. Evaluation of antimicrobial, cytotoxic and larvicidal activity of *Zygophyllum coccineum* north sinai, Egypt[J]. Med Aromat Plants, 2015, doi: 10.4172/2167-0412.1000214.

[40] El Cadi M A, Khabbal Y, Alaoui K, et al. Antidiarrhoeal activity of *Zygophyllum gaetulum*[J]. Phytotherapie, 2008, 6(1):2-4.

[41] Al-Salihi A K, Al-Ramhay K A. Diarrhea associated with ingestion of *Zygophyllum coccineum* (tartir) in camels in the al-najaf desert in Iraq[J]. Int J Poisonous Plant Res, 2014, 3(1):1-6.

[42] Smati D, Mitaine-Offer A C, Miyamoto T, et al. Ursane-type triterpene saponins from *Zygophyllum geslini*[J]. Helv Chim Acta, 2007, 90(4):712-719.

[43] FENG Y L, LI H R, XU L Z, et al. 27-nor-triterpenoid glycosides from the barks of *Zygophyllum* fabago L[J]. J Asian Nat Prod Res, 2007, 9(6/8):505-510.

[44] Ahmad V U, Ghazala, Uddin S, et al. Saponins from *Zygophyllum propinquum*[J]. Phytochemistry, 1993, 53(5):1193-1197.

[45] Amin E, WANG Y H, Avula B, et al. Simultaneous determination of saponins and a flavonoid from aerial parts of *Zygophyllum coccineum* L[J]. J AOAC Int, 2012, 95(3):757-762.

[46] Elgamal H A M, Shaker H K, Pöllmann K, et al. Triterpenoid saponins from *Zygophyllum* species [J]. Phytochemistry, 1995, 40(4):1233-1236.

[47] Ganbaatar C, Gruner M, Tunsag J, et al. Chemical constituents isolated from *Zygophyllum melongena* bunge growing in mongolia[J]. Nat Prod Res, 2016, 30(14):1661-1664.

[48] Mostafa M, Nahar N, Mosihuzzaman M, et al. Phosphodiesterase-i inhibitor quinovic acid glycosides from bridelia ndellensis [J]. Nat Prod Res, 2006, 20(7):686-692.

[49] Hassanean H A, Desoky E K. An acylated isorhamnetin glucoside from *Zygophyllum simplex* [J]. Phytochemistry, 1992, 31(9):3293-3294.

[50] Ahmad V U, Ghazala, Uddin S. A triterpenoid saponin from *Zygophyllum propinquum* [J]. Phytochemistry, 1992, 31(2):1051-1054.

[51] Attia A A. Triterpenoidal saponins from the aerial parts of *Zygophyllum coccineum* L and *Zygophyllum fabago* L

[J]. Pharmazie, 1999, 54(12): 931-934.
[52] FENG Y L, WU B, LI H R, et al. Triterpenoidal saponins from the barks of *Zygophyllum fabago* L[J]. Chem Pharmaceut Bull, 2008, 56(6): 858-860.
[53] Hassanean H A, El-Hamouly M M A, El-Moghazy S A, et al. 14-Decarboxyquinovic and quinovic acid glycosides from *Zygophyllum album* [J]. Phytochemistry, 1993, 33(3): 667-670.
[54] Ahmad V U, Ghazala, Uddin S, et al. Saponins from *Zygophyllum propinquum*[J]. Phytochemistry, 1993, 33(2): 453-455.
[55] Tapondjou L A, Lontsi D, Sondengam B L, et al. Structure-activity relationship of triterpenoids isolated from mitragyna stipulosa on cytotoxicity [J]. Arch Pharmacal Res, 2002, 25(3): 270-274.
[56] Khan S S, Khan A, Khan A, et al. Urease inhibitory activity of ursane type sulfated saponins from the aerial parts of *Zygophyllum fabago* Linn[J]. Phytomedicine, 2014, 21(3): 379-382.
[57] Aquino R, Tortora S, Fkih-Tetouani S, et al. Saponins from the roots of *Zygophyllum gaetulum* and their effects on electrically-stimulated guinea-pig ileum [J]. Phytochemistry, 2001, 56(4): 393-398.
[58] Safir O, Fkihtetouani S, De T N, et al. Saponins from *Zygophyllum gaetulum*[J]. J Nat Prod, 1998, 61(1): 130-134.
[59] Smati D, Mitaine-Offer A C, Miyamoto T, et al. Phytochemical study of the aerial parts of *Zygophyllum geslini*[J]. Planta Med, 2007, 73(9): 416.
[60] Ahmad V U, Iqbal S, Kousar F, et al. Two new saponins from *Zygophyllum atriplicoides* [J]. Cheminform, 2006, 37(8): 1126-1130.
[61] Pöllmann K, Gagel S, Elgamal M H A, et al. Triterpenoid saponins from the roots of *Zygophyllum* species[J]. Phytochemistry, 1997, 44(3): 485-489.
[62] Teponno R B, Tapondjou A L, Gatsing D, et al. Bafoudiosbulbins a and b, two anti-salmonellal clerodane diterpenoids from *Dioscorea bulbifera* L. var *sativa*[J]. Phytochemistry, 2006, 67(17): 1957-1963.
[63] Mitaine-Offer A-C, William H, Michel S, et al. Triterpenes and phytosterols as human leucocyte elastase iinhibitors[J]. Planta Med Int, 2002, 68(10): 930-932.
[64] Hassanean H H, Desoky E K, El-Hamouly M M A. Quinovic acid glycosides from *Zygophyllum album*[J]. Phytochemistry, 1993, 33(3): 663-666.
[65] Pöllmann K, Schaller K, Schweizer U, et al. Triterpenoid saponins from *Zygophyllum decumbens* [J]. Phytochemistry, 1998, 48(5): 875-880.
[66] Capasso A, Omar S, Fkihtetouani S, et al. Properties and effects on isolated guinea-pig ileum of *Zygophyllum gaetulum* species endemic in moroccan sahara [J]. Pharm Biol, 1998, 36(5): 320-326.
[67] Khan S S, Khan A, Ahmed A, et al. Two new disulfated triterpenoids from *Zygophyllum fabago*[J]. Helv Chim Acta, 2010, 93(10): 2070-2074.
[68] Capasso A, Aquino R P. Pharmacochemical investigation on extracts from some Moroccan Sahara medicinal plants. Section title: plant biochemistry[J]. Recent Res Dev Plant Sci, 2004, 2: 85-116.
[69] Sasmakov S A, Putieva Z M, Saatov Z, et al. Triterpene glycosides of *Zygophyllum eichwaldii* c. A. M [J]. Chem Nat Comp, 2001, 37(1): 91-92.
[70] Sasmakov S A, Putieva Z M, Kachala V V, et al. Triterpene glycosides of *Zygophyllum eichwaldii*. Ii. structure of zygoeichwaloside i[J]. Chem Nat Comp, 2001, 37(4): 347-350.
[71] Sasmakov S A, Putieva J M, Saatov Z, et al. A new triterpene glycoside from *Zygophyllum eichwaldii*[J]. Pharmazie, 2003, 58(8): 602-603.
[72] Ahmad V U, Khan S S, Ahmed A, et al. Sulfated triterpene glyscosides from *Zygophyllum fabago*[J]. Nat Prod Commun, 2007, 2(11): 1085-1088.
[73] Sasmakov S A, Putieva Z M, Lindequist U. New pomolic acid triterpene glycosides from *Zygophyllum eichwaldii* [J]. Die Pharmazie, 2008, 62(12): 957-959.
[74] FENG Y L, WU B, HE M Z, et al. Study on triterpenoids in the stem of *Zygophyllum fabago*[J]. Chin Tradit Herbal Drugs, 2009, 40(9): 1369-1372.
[75] Iqbal S, Khan A, Ahmad V U, et al. Two new triterpenoids from *Zygophyllum eurypterum* [J]. Nat Prod Commun, 2011, 6(2): 179-182.
[76] Saleha S, Khan, Khan A, et al. A new ursane type sulfated saponin from *Zygophyllum fabago* Linn[J]. Rec Nat Prod, 2014, 8(21): 354-359.
[77] Saleh A H A M, El-Hadidi M N. An approach to the chemosystematics of the Zygophyllaceae[J]. Biochem Syst Ecol, 1977, 5(2): 121-128.
[78] Sahebkar A. Effects of quercetin supplementation on lipid profile: A systematic review and meta-analysis of randomized controlled trials[J]. Criti Rev Food Sci Nutr, 2017, 57(4): 666-676.
[79] Fischer C, Speth V, Fleig-Eberenz S, et al. Induction of zygotic polyembryos in wheat: influence of auxin polar transport [J]. Plant Cell, 2002, 9(10): 1767-1780.
[80] Lee K H, Park E, Lee H J, et al. Effects of daily

quercetin-rich supplementation on cardiometabolic risks in male smokers[J]. Nutr Res Pract, 2011, 5(1): 28-33.

[81] Russo G L, Russo M, Spagnuolo C, et al. Quercetin: a pleiotropic kinase inhibitor against cancer [J]. Cancer Tr Res, 2014, 159: 185-205.

[82] Hubbard G P, Stevens J M, Cicmil M, et al. Quercetin inhibits collagen-stimulated platelet activation through inhibition of multiple components of the glycoprotein vi signaling pathway[J]. J Thromb Hemost, 2003, 1(5): 1079-1088.

[83] Chirumbolo S. Quercetin as a potential anti-allergic drug: Which perspectives? [J]. Iran J Allergy Asthma Immunol, 2011, 10(2): 139-140.

[84] Alam M M, Meerza D, Naseem I. Protective effect of quercetin on hyperglycemia, oxidative stress and DNA damage in alloxan induced type 2 diabetic mice[J]. Life Sci, 2014, 109(1): 8-14.

[85] Nabavi S F, Russo G L, Daglia M, et al. Role of quercetin as an alternative for obesity treatment: you are what you eat! [J]. Food Chem, 2015, 179(305): 305-310.

[86] Chirumbolo S. The role of quercetin, flavonols and flavones in modulating inflammatory cell function[J]. Inflamm Allergy Drug Targets, 2010, 9(4): 263-285.

[87] Kleemann R, Verschuren L, Morrison M, et al. Anti-inflammatory, anti-proliferative and anti-atherosclerotic effects of quercetin in human *in vitro* and *in vivo* models [J]. Atherosclerosis, 2011, 218(1): 44-52.

[88] Moustafa A M Y, Khodair A I, Hammouda F M, et al. Phytochemical and toxicological studies of *Zygophyllum album* L. F[J]. J Pharmacol Toxicol, 2007, 2(3): 220-237.

[89] Hussein S R, Marzouk M M, Ibrahim L F, et al. Flavonoids of *Zygophyllum album* L. F. And *Zygophyllum simplex* L. (Zygophyllaceae) [J]. Biochem Syst Ecol, 2011, 39(4/6): 778-780.

[90] Yalda S, Maryam R, Leila H, et al. Quercetin-3-*O*-β-*D*-glucopyranoside, a dietary flavonoid, protects PC_{12} cells from H_2O_2-induced cytotoxicity through inhibition of reactive oxygen species[J]. Food Chem, 2015, 167: 162-167.

[91] Lee J W, Lee J S, Kim S J, et al. Quercetin-3-*O*-glucoside suppresses pancreatic cancer cell migration induced by tumor-deteriorated growth factors *in vitro* [J]. Oncol Rep, 2016, 35(4): 2473-2479.

[92] Olszewska M A, Michel P. Activity-guided isolation and identification of free radical-scavenging components from various leaf extracts of *Sorbus aria* (L.) Crantz [J]. Nat Prod Res, 2012, 26(3): 243-254.

[93] Samanta S K, Bhattacharya K, Mandal C, et al. Identification and quantification of the active component quercetin 3-*O*-rutinoside from *Barringtonia racemosa*, targets mitochondrial apoptotic pathway in acute lymphoblastic leukemia [J]. J Asian Nat Prod Res, 2010, 12(8): 639-648.

[94] Fuentes O, Fuentes M, Badilla S, et al. Maqui (aristotelia chilensis) and rutin (quercetin-3-*O*-rutinoside) protects against the functional impairment of the endotheliumdependent vasorelaxation caused by a reduction of nitric oxide availability in diabetes[J]. Bol Latinoam Caribe Planta Med Aromáticas, 2013, 12(3): 220-229.

[95] Bansal P, Paul P, Kunwar A, et al. Radioprotection by quercetin-3-*O*-rutinoside, a flavonoid glycoside-a cellular and mechanistic approach [J]. J Funct Foods, 2012, 4(4): 924-932.

[96] Rani N, Vijayakumar S, PTV L, et al. Allosteric site-mediated active site inhibition of pbp2a using quercetin 3-*O*-rutinoside and its combination [J]. J Biomol Struct Dyn, 2016, 34(8): 1778-1796.

[97] Abdel-Hamid R A, Ross S A, Abilov Z A, et al. Flavonoids and sterols from *Zygophyllum fabago*[J]. Chem Nat Compd, 2016, 52(2): 318-319.

[98] TENG B S, LU Y H, WANG Z T, et al. *In vitro* anti-tumor activity of isorhamnetin isolated from *Hippophae rhamnoides* L. against BEL-7402 cells [J]. Pharmacol Res, 2006, 54(3): 186-194.

[99] WANG Y, TANG C Y, ZHANG H. Hepatoprotective effects of kaempferol 3-*O*-rutinoside and kaempferol 3-*O*-glucoside from *Carthamus tinctorius* L. on CCl_4-induced oxidative liver injury in mice[J]. J Food Drug Anal, 2015, 23(2): 310-317.

[100] Habtemariam S. A-glucosidase inhibitory activity of kaempferol-3-*O*-rutinoside [J]. Nat Prod Commun, 2011, 6(2): 201-203.

[101] Ahmad M, Gilani A U H, Aftab K, et al. Effects of kaempferol-3-*O*-rutinoside on rat blood pressure[J]. Phytother Res, 2010, 7(4): 314-316.

[102] Lal Shyaula S, Abbas G, Siddiqui H, et al. Synthesis and antiglycation activity of kaempferol-3-*O*-rutinoside (nicotiflorin)[J]. Med Chem, 2012, 8(3): 415-420.

[103] Petpiroon N, Suktap C, Pongsamart S, et al. Kaempferol-3-*O*-rutinoside from afgekia mahidoliae promotes keratinocyte migration through fak and rac1 activation [J]. J Nat Med, 2015, 69(3): 340-348.

[104] Jang Y S, WANG Z Q, Lee J M, et al. Screening of korean natural products for anti-adipogenesis properties and isolation of kaempferol-3-*O*-rutinoside as a potent anti-adipogenetic compound from *Solidago virgaurea* [J]. Molecules, 2016, 21(2): 226.

[105] Fathy N A, Rasha E L, Reham M M A, et al. Green reduction of oxidized graphite to reduced graphene oxide using *Zygophyllum album* if: Comparative adsorption studies on p-nitrophenol [J]. Recent Innov Chem Eng, 2015, 8(2): 87-102.

[106] Ouf S A, Hady F K A, Elgamal M H, et al. Isolation of antifungal compounds from some *Zygophyllum* species and their bioassay against two soil-borne plant pathogens[J]. Folia Microbiol, 1994, 39(3): 215-221.

[107] Ahmad V U, Iqbal S, Nawaz S A, et al. Isolation of four new pterocarpans from *Zygophyllum eurypterum* (Syn. *Z. Atriplicoides*) with enzyme-inhibition properties [J]. Chem Biodivers, 2006, 3(9): 996-1003.

[108] Roth A, Schaffner W, Hertel C. Phytoestrogen kaempferol (3, 4′, 5, 7-tetrahydroxyflavone) protects PC12 and T47D cells from beta-amyloid-induced toxicity [J]. J Neurosci Res, 1999, 57(3): 399-404.

[109] Kim J K, Choi S J, Cho H Y, et al. Protective effects of kaempferol (3, 4′, 5, 7-tetrahydroxyflavone) against amyloid beta peptide (aβ)-iinduced neurotoxicity in icr mice[J]. Biosci Biotechnol Biochem, 2010, 74(2): 397-401.

[110] HU C, CAI X, HU T, et al. Mechanism of growth inhibition effect of 3′, 4′, 5, 7-tetrahydroxyflavone on A549 cells [J]. China J Chin Mater Med, 2012, 37(9): 1259-1264.

[111] Kim S H, Choi K C. Anti-cancer effect and underlying mechanism (s) of kaempferol, a phytoestrogen, on the regulation of apoptosis in diverse cancer cell models [J]. Toxicol Res, 2013, 29(4): 229-234.

[112] Khalil M, Sulaiman S. The potential role of honey and its polyphenols in preventing heart disease: A review [J]. Afr J Tradit Complem Altern Med, 2010, 7(4): 315-321.

[113] LI CJ, Elgamal MH, Sharker KH, et al. A new sulfated flavonoid from *Zygophyllum dumosum* [J]. Nat Prod Lett, 1996, 8(4): 281-284.

[114] Smati D, Longeon A, Guyot M. 3β-(3, 4-Dihydroxycinnamoyl)-erythrodiol, a cytotoxic constituent of *Zygophyllum geslini* collected in the algerian sahara[J]. J Ethnopharmacol, 2004, 95(2): 405-407.

[115] Razavi S M, Zahri S, Zarrini G, et al. Biological activity of quercetin-3-*O*-glucoside, a known plant flavonoid [J]. Russ J Bioorg Chem, 2009, 35(3): 376-378.

[116] Süntar I P, Akkol E K, Yalçln F N, et al. Wound healing potential of *Sambucus ebulus* L. Leaves and isolation of an active component, quercetin 3-*O*-glucoside [J]. J Ethnopharmacol, 2010, 129(1): 106-114.

[117] Panda S, Kar A. Antidiabetic and antioxidative effects of *Annona squamosa* leaves are possibly mediated through quercetin-3-*O*-glucoside[J]. Biofactors, 2007, 31(3/4): 201-210.

[118] Makino T, Kanemaru M, Okuyama S, et al. Anti-allergic effects of enzymatically modified isoquercitrin (α-oligoglucosyl quercetin 3-*O*-glucoside), quercetin 3-*O*-glucoside, α-oligoglucosyl rutin, and quercetin, when administered orally to mice [J]. J Nat Med, 2013, 67(4): 881-886.

[119] Sekhon-Loodu S, Ziaullah Z, Rupasinghe H P V, et al. Novel quercetin-3-*O*-glucoside eicosapentaenoic acid ester ameliorates inflammation and hyperlipidemia[J]. Inflammopharmacology, 2015, 23(4): 173-185.

[120] Warnakulasuriya S, Ziaullah, Rupasinghe H. Long chain fatty acid acylated derivatives of quercetin-3-*O*-glucoside as antioxidants to prevent lipid oxidation[J]. Biomolecules, 2014, 4(4): 980-993.

[121] Pavan B, Capuzzo A, Forlani G. Quercetin and quercetin-3-*O*-glucoside interact with different components of the camp signaling cascade in human retinal pigment epithelial cells[J]. Life Sci, 2015, 121: 166-173.

[122] Hamouda N N, Qureshi M A, Alkaabi J M, et al. Reduction in the amplitude of shortening and Ca^{2+} transient by phlorizin and quercetin-3-*O*-glucoside in ventricular myocytes from streptozotocin-induced diabetic rats[J]. Physiol Res, 2016, 65(2): 239-250.

[123] YE L, LI G Q, FENG Y L. Studies on the chemical constituents of *Zygophyllum fabag* [J]. Lishizhen Med Mater Med Res, 2008, 19(6): 1414-1415.

[124] FENG Y L, WU B, LI Y Q, et al. Study on chemical constituents of stem of *Zygophyllum fabago* [J]. Chin Trad Herbal Drugs, 2009, 40(4): 536-538.

[125] Tigrinekordjani N, Meklati B Y, Chemat F. Contribution of microwave accelerated distillation in the extraction of the essential oil of *Zygophyllum album* L [J]. Phytochem Anal, 2010, 22(1): 1-9.

[126] Ayad R, Rahai M, Azouzi S, et al. Phytochemical investigation of the endemic plant *Zygophyllum cornutum* [J]. Chem Nat Compd, 2012, 48(2):

313-314.

[127] Amin E, El-Hawary S S, Fathy M M, et al. A phytochemical study of *Zygophyllum simplex* L[J]. Planta Med, 2011, 77(5): 40.

[128] Dorsch W, Stuppner H, Wagner H, et al. Antiasthmatic effects of picrorhiza kurroa: androsin prevents allergen- and paf-induced bronchial obstruction in guinea pigs [J]. Int Arch Allergy Immunol, 1991, 95(2/3): 128-133.

[129] Masuda Y, Kadokura T, Ishii M, et al. Hinesol, a compound isolated from the essential oils of *Atractylodes lancea* rhizome, inhibits cell growth and induces apoptosis in human leukemia HL-60 cells [J]. J Nat Med, 2015, 69(3): 332-339.

[130] Kato-Noguchi H, Tamura K, Sasaki H, et al. Identification of two phytotoxins, blumenol a and grasshopper ketone, in the allelopathic Japanese rice variety *Awaakamai*[J]. J Plant Physiol, 2012, 169(7): 682-685.

[131] LIU X X, TIAN F F, ZHANG H B, et al. Biologically active blumenol a from the leaves of *Annona glabra* [J]. Nat Prod Lett, 1999, 14(1): 77-81.

[132] Abdallah H M, Esmat A. Antioxidant and anti-inflammatory activities of the major phenolics from *Zygophyllum simplex* L[J]. J Ethnopharmacol, 2017, 205: 51-56.

[133] MA Y, Wink M. The beta-carboline alkaloid harmine inhibits bcrp and can reverse resistance to the anticancer drugs mitoxantrone and camptothecin in breast cancer cells[J]. Phytother Res, 2009, 24(1): 146-149.

[134] Abbassi K, Atay-Kadiri Z, Ghaout S. Biological effects of alkaloïds extracted from three plants of moroccan arid areas on the desert locust [J]. Physiol Entomol, 2003, 28(3): 232-236.

[135] Narayanan C, Joshi D, Mujumdar A, et al. Pinitol-a new anti-diabetic compound from the leaves of bougainvillea spectabilis[J]. Curr Sci, 1987, 56(3): 139-141.

[136] Singh R, Pandey B, Tripathi M, et al. Anti-inflammatory effect of (+)-pinitol [J]. Fitoterapia, 2001, 72(2): 168-170.

[137] Albishri H M, Almaghrabi O A, Moussa T A. Characterization and chemical composition of fatty acids content of watermelon and muskmelon cultivars in saudi arabia using gas chromatography/mass spectroscopy [J]. Pharmacogn Mag, 2013, 9(33): 58-66.

[138] Ododo M M, Choudhury M K, Dekebo A H. Structure elucidation of β-sitosterol with antibacterial activity from the root bark of malva parviflora[J]. Springer Plus, 2016, 5(1): 1210.

[139] Dighe S B, Kuchekar B S, Wankhede S B. Analgesic and anti-inflammatory activity of β-sitosterol isolated from leaves of *Oxalis corniculata* [J]. Int J Pharmacol Res, 2016, 6(3): 109-113.

[140] Choi S, Kim K W, Choi J S, et al. Angiogenic activity of β-sitosterol in the ischaemia/reperfusion-damaged brain of mongolian gerbil [J]. Planta Med, 2002, 68(4): 330-335.

[141] Dehpour A A. Antioxidant activity andi isolation of β-sitosterol from ethyl acetate extract of aerial parts of *consolida orientalis*[J]. Preprints, 2016, doi: 20944/preprints201609.0037.v1.

[142] Panggua D M, Johannes E, Natsir H, et al. Bioactivity and antioxidant test of hexadecanoic acid and β-sitosterol isolated from hydroid aglaophenia *Cupressina lamoureoux*[J]. Int J Eng Sci Appl, 2016, 2(2): 175-182.

[143] Desai F, Ramanathan M, Fink C S, et al. Comparison of the immunomodulatory effects of the plant sterol β-sitosterol to simvastatin in peripheral blood cells from multiple sclerosis patients[J]. Int Immunopharmacol, 2008, 9(1): 153-157.

[144] Talabani N S, Tofiq D I. Citrullus colocynthis as a bioavailable source of β-sitosterol, antihyperlipidemic effect of oil in rabbits [J]. Middle East J Int Med, 2013, 6(1): 12-16.

[145] Rosenblat M, Volkova N, Aviram M. Pomegranate phytosterol (β-sitosterol) and polyphenolic antioxidant (punicalagin) addition to statin, significantly protected against macrophage foam cells formation [J]. Atherosclerosis, 2013, 226(1): 110-117.

[146] Nasution R, Bahi M, Saidi N, et al. B-sitosterol from bark of artocarpus camansi and its antidiabetic activity [J]. Proc Annu Int Conference, Syiah Kuala Univ Life Sci Eng Chapter, 2015: 5.

[147] Sitorus P, Harahap U, Pandapotan M, et al. Isolation of β-sitosterol from n-hexane extract of *Picria felterrae* Lour. leave and study of its antidiabetic effect in alloxan induced diabetic mice[J]. Int J Pharm Tech Res, 2014, 6(1): 137-141.

[148] Lee J H, Lee J Y, Park J H, et al. Immunoregulatory activity by daucosterol, a β-sitosterol glycoside, induces protective th1 immune response against disseminated candidiasis in mice [J]. Vaccine, 2007, 25(19): 3834-3840.

[149] JIANG L H, YANG N Y, YUAN X L, et al. Daucosterol

promotes the proliferation of neural stem cells[J]. J Steroid Biochem Mol Biol, 2014, 140: 90-99.

[150] Sultana N, Afolayan A. A novel daucosterol derivative and antibacterial activity of compounds from *Arctotis arctotoides*[J]. Nat Prod Res, 2007, 21(10): 889-896.

[151] Esmaeili M A, Farimani M M. Inactivation of pi3k/AKt pathway and upregulation of pten gene are involved in daucosterol, isolated from salvia sahendica, induced apoptosis in human breast adenocarcinoma cells[J]. South Afr J Bot, 2014, 93: 37-47.

[152] JIANG L H, YUAN X L, YANG N Y, et al. Daucosterol protects neurons against oxygen-glucose deprivation/reperfusion-mediated injury by activating IGF1 signaling pathway[J]. J Steroid Biochem Mol Biol, 2015, 152: 45-52.

[153] GAO X, SU Y, LI F. The effect of daucosterol in achyranthes bidentata bl. On proliferation of umr106 osteoblast like cells and itsdetermination[J]. J Chengde Med College, 2003, 20(1): 1-4.

[154] WANG G Q, GU J F, GAO Y C, et al. Daucosterol inhibits colon cancer growth by inducing apoptosis, inhibiting cell migration and invasion and targeting caspase signalling pathway[J]. Bangladesh J Pharmacol, 2016, 11(2): 395-401.

[155] JI Z H, XU Z Q, ZHAO H, et al. Neuroprotective effect and mechanism of daucosterol palmitate in ameliorating learning and memory impairment in a rat model of Alzheimer's disease[J]. Steroids, 2017, 119: 31-35.

[156] YANG J, LI J X, SONG Z, et al. Daucosterol derived from cordyceps (a traditional chinese medicine) as a possible lead compound for allergic transfusion reactions[J]. Bangladesh J Pharmacol, 2015, 10(1): 35-39.

[157] Zaki A A, Ali Z, El-Amier Y A, et al. A new lignan from *Zygophyllum aegyptium*[J]. Magn Reson Chem, 2016, 54(9): 771-773.

[158] Jaouhari J, Lazrek H, Jana M. The hypoglycemic activity of *Zygophyllum gaetulum* extracts in alloxan-induced hyperglycemic rats[J]. J Ethnopharmacol, 2000, 69(1): 17-20.

[责任编辑 顾雪竹]