



# A critical review on chemical constituents and pharmacological effects of *Lilium*

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## ABSTRACT

Genus *Lilium* is famous for edible and medicinal function which is related to its chemical constituents and pharmacological effects. Chemical researches showed that genus *Lilium* genus mainly contains steroidal saponins, polysaccharides, alkaloids and flavonoids. Pharmacological effects of *Lilium* include anti-tumor, hypoglycemic, antibacterial, anti-oxidation, anti-depression and anti-inflammatory. This paper summarized chemical constituents and pharmacological effects of *Lilium*.

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## 1. Introduction

The plants of *Lilium* in the Liliaceae family are distributed in China and they are cultivated as ornamental plants throughout the world, as well as used as important edible plants and biological medicinal products. *Lilium* has the effects of nourishing yin to moisten the lung, clearing away heart fire and tranquilizing the mind. It is also used for yin deficiency lasted cough, hemoptysis, anxiety, insomnia, dreaminess, and spirit trance [1]. The bulbs of genus *Lilium* plants have a quite high medicinal value, such as *L. pumilum* and *L. lancifolium*. Many studies have been conducted the chemical constituents of genus *Lilium* genus involving saponins, sterols, alkaloids, polysaccharides, glycerol glycerides, phenylpropanoids and flavonoids, which illustrated their pharmacological effects of anti-tumor, hypoglycemic,

antibacterial, anti-inflammatory, hypolipidemic, reducing blood lipid, anti-depression, anti-fatigue and hypoxia tolerance. In this paper, we summarized recent studies concerning the phytochemistry and pharmacology of the genus *Lilium*, which can provide references for further research and for the application of these species (Figs. 1–5).

## 2. Chemical constituents

### 2.1. Steroidal saponins

To date, more than 32 compounds (1–32) have been obtained from 10 species of the genus *Lilium* (*L. lancifolium*, *L. brownii* F.E.Brown var. *viridulum* Baker, *L. pumilum*, *L. longiflorum* Thunb, *L. brownii* var. *colchesteri*, *L. candidum*, *L. speciosum*, *L. tenuifolium*, *L. callosum* Sieb. et Zucc) (Table 1) [2–12]. Compounds 9, 12, 19, and 22 to 30 were identified as new compounds from 9 species of the genus *Lilium* (*L. lancifolium*, *L. pumilum*, *L. brownii* var. *colchesteri*, *L. candidum*, *L. speciosum*, *L. tenuifolium*, *L. brownii* F.E.Brown var. *viridulum* Baker, *L. callosum*) [4,5,7–11].

### 2.2. Sterols

Compounds 34 and 35 were isolated from *L. lancifolium* and *L. brownii* F. E. Brown var. *viridulum* Baker [3,12,13].

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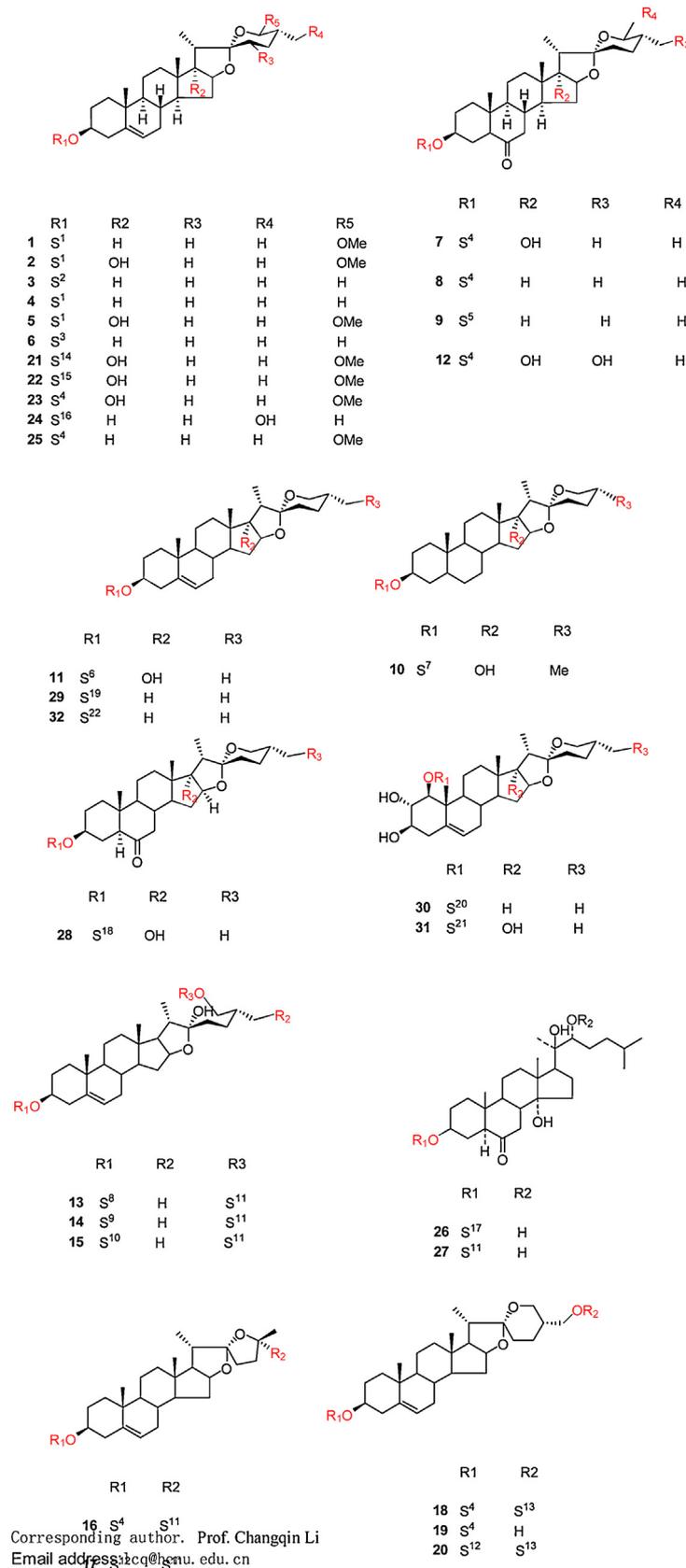


Fig. 1. Saponins isolated from the family Liliaceae.



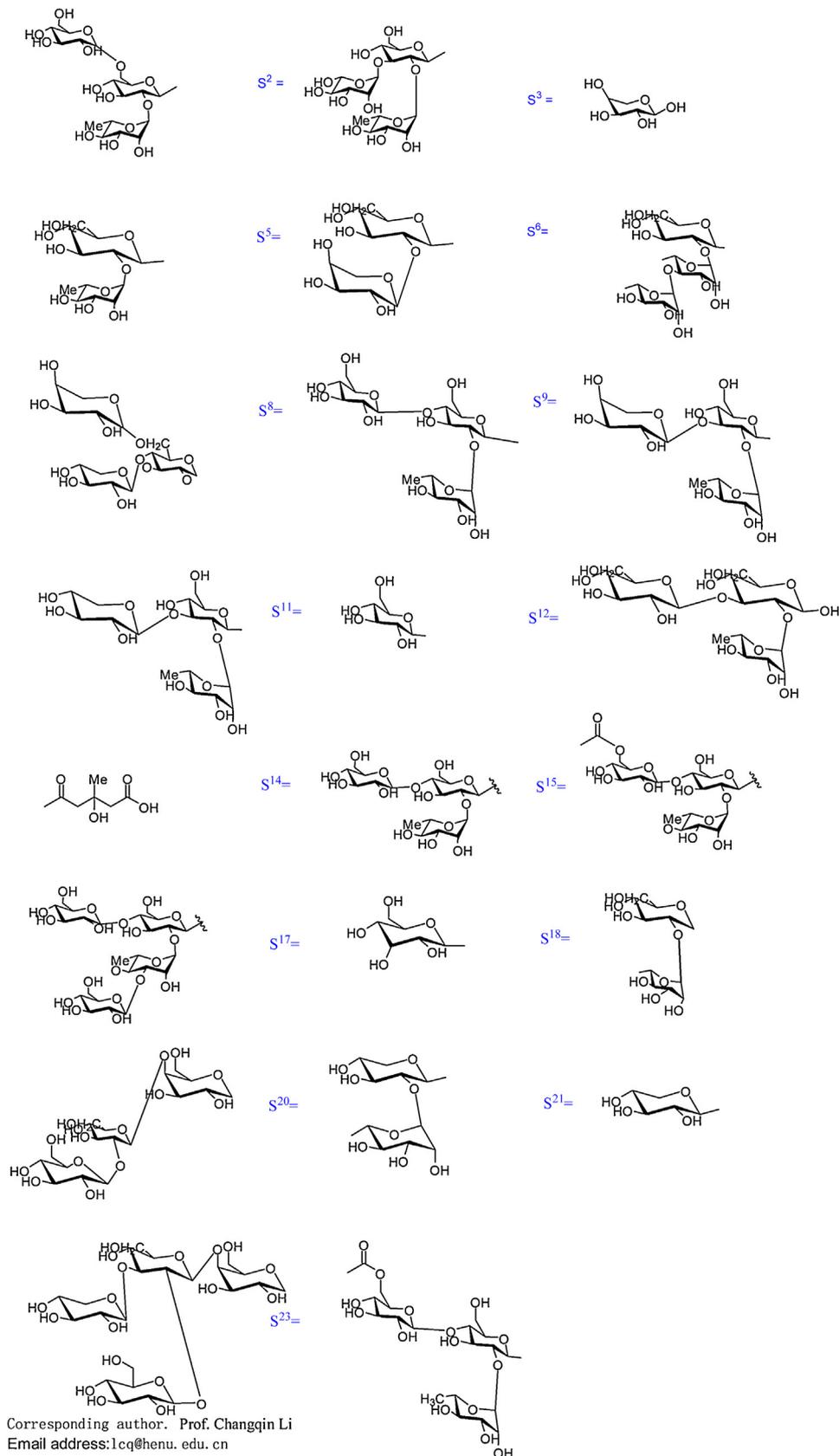


Fig. 5. The sugar residues isolated from the family *Lilium*.

galacturonic acid [18]. Another polysaccharide from *L. lancifolium* through further purified exhibited a homogeneous fraction and the average molecular weight were  $8.52 \times 10^3$  kDa. The fraction was

composed of rhamnose, arabinose, glucose and galactose residues with the molar ratio of 15:17:8:20. According to infrared spectrum and NMR, it was conjectured that the fraction was consisted of

**Table 1**  
Steroidal saponin of *Lilium L.* plants.

NO.	Compounds	Ref.
1	(25R,26R)-26-methoxyspirooxane-5-ene-3 $\beta$ -O- $\alpha$ -L-rhamnose-(1 $\rightarrow$ 2)-[ $\beta$ -D-glucose-(1 $\rightarrow$ 6)]- $\beta$ -D-glucoside	[2]
2	(25R,26R)-3 $\beta$ ,17 $\alpha$ -hydroxy-26-methoxyspirooxane-5-ene-3 $\beta$ -O- $\alpha$ -L-rhamnose-(1 $\rightarrow$ 2)-[ $\beta$ -D-glucose-(1 $\rightarrow$ 6)]- $\beta$ -D-glucoside	[2]
3	Diosgenin 3-O-{O- $\alpha$ -L-rhamnosyl-(1 $\rightarrow$ 2)-O-[ $\beta$ -D-xylosyl (1 $\rightarrow$ 3)]- $\beta$ -D-glucoside}	[2]
4	(25R)-spirooxane-5-ene-3 $\beta$ -O- $\alpha$ -L-pyran rhamnose-(1 $\rightarrow$ 2)-[ $\beta$ -D-glucopyranose-(1 $\rightarrow$ 6)]- $\beta$ -D-glucopyranoside	[2,3]
5	(25R,26R)-17 $\alpha$ -hydroxy-26-methoxyspirooxane-5-ene-3 $\beta$ -O- $\alpha$ -L-pyranrhamnose-(1 $\rightarrow$ 2)-[ $\beta$ -D-pyran Glucose-(1 $\rightarrow$ 6)]- $\beta$ -D-glucopyranoside	[3]
6	Diosgenin 3-O-{O- $\alpha$ -L-rhamnosyl-(1 $\rightarrow$ 2)-O-[ $\alpha$ -L-arabinosyl (1 $\rightarrow$ 3)]- $\beta$ -D-glucoside	[4]
7	(25R)-3 $\beta$ ,17 $\alpha$ -diol-5 $\alpha$ -spirostan-6-one 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside	[5]
8	(25R)-3 $\beta$ -hydroxyl-5 $\alpha$ -spirostan-6-one-3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside	[5]
9	(25R)-3 $\beta$ -hydroxy-5 $\alpha$ -spirostan-6-one-3-O- $\alpha$ -L-arabinopyranosyl-(1 $\rightarrow$ 6)- $\beta$ -D-glucopyranoside	[5]
10	(25R)-5 $\alpha$ -spirostan-3 $\beta$ ,17 $\alpha$ -diol 3-O- $\beta$ -D-xylopyranosyl-(1 $\rightarrow$ 4)-[ $\alpha$ -L-arabinopyranosyl-(1 $\rightarrow$ 6)]- $\beta$ -D-glucopyranoside	[5]
11	Dioscin	[5]
12	(25R)-3 $\beta$ ,17 $\alpha$ ,27-triol-spirostan-6-one 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside	[5]
13	(25R)-26-O-( $\beta$ -D-glucopyranosyl)furost-5-ene-3 $\beta$ ,22 $\alpha$ ,26-triol 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 4)- $\beta$ -D-glucopyranoside	[6]
14	(25R)-26-O-( $\beta$ -D-glucopyranosyl)furost-5-ene-3 $\beta$ ,22R,26-triol 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\alpha$ -L-arabinopyranosyl-(1 $\rightarrow$ 3)- $\beta$ -D-glucopyranoside	[6]
15	(25R)-26-O-( $\beta$ -D-glucopyranosyl)furost-5-ene-3 $\beta$ ,22R,26-triol 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\alpha$ -L-xylopyranosyl-(1 $\rightarrow$ 3)- $\beta$ -D-glucopyranoside	[6]
16	26-O- $\beta$ -D-glucopyranosylnuatigenin 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside	[7]
17	26-O- $\beta$ -D-glucopyranosylnuatigenin 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O-[ $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 4)]- $\beta$ -D-glucopyranoside	[7]
18	brownioside	[7]
19	deacylbrownioside	[7]
20	27-O-(3-hydroxy-3-methylglutaryl)isonarthogenin 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O-[ $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 4)]- $\beta$ -D-glucopyranoside	[7]
21	(25R,26R)-26-methoxyspirost-5-ene-3 $\beta$ ,17 $\alpha$ -diol 3-O-{O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O-[ $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 4)]- $\beta$ -D-glucopyranoside}	[8]
22	(25R,26R)-26-methoxyspirost-5-ene-3 $\beta$ ,17 $\alpha$ -diol 3-O-{O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O-[6-O-acetyl- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 4)]- $\beta$ -D-glucopyranoside}	[8]
23	(25R,26R)-26-methoxyspirost-5-ene-3 $\beta$ ,17 $\alpha$ -diol 3-O-{O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O- $\beta$ -D-glucopyranoside}	[8]
24	Isonarthogenin 3-O-{O- $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 3)-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O-[ $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 4)]- $\beta$ -D-glucopyranoside}	[8]
25	(25R,26R)-26-methoxyspirost-5-en-3 $\beta$ -ol-3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside	[9]
26	(20R,22R)-3 $\beta$ ,14 $\alpha$ ,20,22-tetrahydroxy-5 $\alpha$ -cholestan-6-one 3-O- $\beta$ -D-allopyranoside	[10]
27	(20R,22R)-3 $\beta$ ,20,22-tetrahydroxy-5 $\alpha$ -cholestan-6-one 3-O- $\beta$ -D-glucopyranoside	[10]
28	(25R)-3 $\beta$ ,17 $\alpha$ ,27-trihydroxy-spirostan-6-one-3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-[ $\beta$ -D-glucopyranosyl-(1 $\rightarrow$ 6)]- $\beta$ -D-glucopyranoside	[11]
29	funkioside D	[11]
30	Atropurosida A	[11]
31	Atropurosida C	[11]
32	aspidistrin	[11]

$\rightarrow$ 4)- $\alpha$ -D-GalA-(1 $\rightarrow$ ,  $\rightarrow$ 2)- $\alpha$ -Rhap-(1 $\rightarrow$  as the backbone and  $\rightarrow$ 4)- $\alpha$ -Rhap-(1 $\rightarrow$ ,  $\rightarrow$ 3)- $\alpha$ -Araf-(1 $\rightarrow$ ,  $\rightarrow$ 4)- $\beta$ -Galp-(1 $\rightarrow$ , 4 $\rightarrow$ )- $\beta$ -Glc-(1 $\rightarrow$  as side chains [19].

### 2.5. Others

There are also other constituents in the family *Lilium*, such as flavonoids (41, 42), organic acids (43,44), etc. [20–24].

## 3. Biological activities

### 3.1. Antitumor activity

The bulbs of *Lilium* plants including *L. brownii*, and *L. lancifolium* are used as antitumor herbs in Chinese medicine. The antitumor activities of the genus *Lilium* have been confirmed in HepG2, K562, SGC-7901, A549, HGC-27 and SPCA-1 cells, and in mouse models of S180, H22, B16 [15,25–31].

Polysaccharides of *L. brownii* could inhibit the growth of S180 and H22 tumor-bearing mice, but the inhibitory effect was not obvious [15,26]. When treated with 0.1, 0.15 g/L of the methanol extract of lily and 1.1, 1.4 g/L of the lily extract alkaloid, the proliferation of SGC-7901 (human gastric cancer cell) was inhibited and the SGC-7901 cell was blocked in the G<sub>2</sub>/M period [27]. The p-coumaric acid, gallic acid, rutin from the bulbs of *L. lancifolium* could inhibit the proliferation of A549, SGC-7901 and HGC-27 cells [28]. Moreover, water extraction, alcohol extraction, alkaloids extraction, and saponins extraction from *L. lancifolium* could inhibit the proliferation of A549 cell [30,31]. Compound 28 isolated from *L. callosum* showed strong anticancer cytotoxic activities against SGC7901, K562, SPCA-1 cells [11].

From these findings, it can be seen that the crude extracts and some active constituents from *L. brownii*, *L. lancifolium*, *L. callosum* exhibited potential antitumor effects. These *in vivo* and *in vitro*

experiments suggested different underlying mechanisms summarized as follows: (i) improve immune function to kill tumor cells. (ii) inhibit the proliferation of cells and make the cells block in the G<sub>2</sub>/M period.

### 3.2. Anti-inflammatory activities

The root extract of *L. lancifolium* inhibited the numbers of macrophages and neutrophils in cigarette smoke-exposed mouse model and reduced the protein secretion levels of TNF- $\alpha$ , IL-6, IL-1 $\beta$  and MCP-1 [32]. Kwon et al. [33] demonstrated that the methanol extracts of the root of *L. lancifolium* had anti-inflammatory effects as it significantly inhibited the content of lipopolysaccharide-induced NO, PGE<sub>2</sub>, IL-6 and TNF- $\alpha$  induced by lipopolysaccharide, and inhibited the expression of iNOS and COX-2 in RAW264.7 cells to exert anti-inflammatory effect. The two phenylpropanoid acylglycerols were obtained and identified from the chloroform fraction of *L. brownii* significantly decreased the production of PGE2 and several other pro-inflammatory cytokines, such as IL-1, IL-6 and TNF- $\alpha$ . They also down-regulated the protein levels of iNOS and COX-2. Moreover, they also inhibited the nuclear translocation of NF- $\kappa$ B p65 subunit and suppressed MAPKs pathway. So the anti-inflammatory mechanisms were the inhibitory effect of inflammatory factors production to show the effect of anti-inflammation [34]. These data suggested that *Lilium* plants may be potential therapeutic candidates for the treatment of inflammatory diseases. However, the possible major bioactive components, and mechanisms of these bulbs' extracts should be defined.

### 3.3. Anti-oxidant activity

Polysaccharides from *L. brownii* (200,400 mg/kg) had obvious *in vivo* anti-oxidant activity in mice by decreasing the content of MDA in serum and tissues, enhancing the activity of SOD,

and improving the activity of CAT in liver and serum [35]. The crude polysaccharides from *L. brownii* (1.0 mg/mL) exhibited the strongest scavenging capability on hydroxyl and nitrite [36]. Besides, phenolic compounds extracted from bulbs of *L. lancifolium* showed strong anti-oxidant capacity and free radical scavenging capacity *in vitro* against DPPH, ABTS and hydroxyl [23]. The bulb extracts of *L. lancifolium* had significant antioxidant capacity and could be a potential nature source of antioxidants.

### 3.4. Effect on the immune system

Hu et al. [35] proved that *L. brownii* polysaccharide middle and heavy dose groups (200,400 mg/kg) could improve the clearance rate of charcoal particles and the weight index of immune organs, indicated that *L. brownii* polysaccharide could promote the phagocytic function of reticuloendothelial system in mice and strengthen non-specific immune function. Furthermore, *L. brownii* polysaccharide could improve the level of serum hemolysin in mice. These results indicated that *L. brownii* polysaccharide had certain enhancement to the humoral immunity function of the mice.

### 3.5. Hypoglycemic effects

The polysaccharides from *L. brownii* had obvious hypoglycemic effect on hypoglycemic mice induced by alloxan [37]. Xiao et al. [38] investigated the effect of alkali washing *L. brownii* polysaccharide on blood glucose in type I diabetic rats induced by streptozotocin. Polysaccharide from *L. brownii* had a positive effect on the hypoglycemic mechanisms exertion through enhancing the activities of antioxidant enzymes, improving antioxidant function and inhibiting oxygen free radical damage to pancreatic  $\beta$  cells resulting in increasing insulin secretion. Furthermore, Zhu et al. [39] found that steroidal glycoside rich fraction (SGL) could increase glucose consumption in HepG2 cells and 3T3-L1 adipocytes, and enhance 3T3-L1 preadipocyte differentiation.

### 3.6. Antibacterial activity

The antibacterial activity of the bulbs of *L. davidii*, *L. leucanthum*, *L. regale*, *L. brownii*, *L. lancifolium* were related with effective substances, such as alkaloids, flavanoids and saponins [40,41]. There existed a significant dose-effect relation between the antibacterial activity and the contents of lily bulb extracts. The antibacterial activity increased proportionally along with the increasing of the contents of lily bulb extracts [41].

### 3.7. Antidepressant effect

The rats' depression model by chronic psychological stimulation was used to observe the influence of *L. brownii* saponins on the blood COR, ACTH [42]. In the study, saponins from *L. brownii* could reduce the elevated COR and ACTH of depression model rats, indicated that there existed a significant dose-effect relation between the anti-depressant effect and the contents of *L. brownii* saponins. Wang et al. [43] studied the duration of immobility within 4 min which recorded in tail suspended experiment and forced swimming experiment. The suspended experiment and forced swimming experiment showed that compared with normal control group, the duration of immobility within 4 h in tail suspended experiment and force swimming experiment was decreased in *L. brownii* saponins extract medium-dose and low-dose groups. The *L. brownii* saponins have certain anti-depressant activity in mice. Gao et al. [44] reported that total saponins fraction possessed anti-depression combined with IBS action of rat by filling stomach with different dosage and showed certain dose-effect relationship.

### 3.8. Anti-fatigue and anti-hypoxia

He et al. [45] observed the anti-fatigue pharmacological effect of *L. lancifolium* polysaccharide in mice, and found that lily polysaccharide could lengthen the mice's swimming time and enhance the activity of SOD and reduce the content of MDA. So polysaccharide from lily could enhance mice's anti-fatigue capability.

## 4. Future perspectives and conclusion

The literatures indicate that saponins, flavonoids and polysaccharides are the main and active ingredients in the genus *Lilium*. Recently, more and more researchers were interested in pharmacological effects of the *Lilium*. The research on chemical constituents is mainly concentrated on the bulbs of *Lilium*, few studies on their flower. The pharmacological effects of compounds isolated from *Lilium* are less researched, and the mechanism is not clearly.

In view of this, in the future research and rational development of *Lilium*, we could start from the following points: (i) identify chemical components in *Lilium* by new techniques, such as UPLC-Q-TOF-MS; (ii) systematic study of the pharmacological effects and mechanisms of the chemical constituents of *Lilium*, including the flower parts of *Lilium* and the mechanism should be explored further; (iii) it is significance for its in-depth research and development in food, health care products and related drugs.

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## References

- [1] People's Republic of China Pharmacopoeia, Chemical Industry Press, Beijing, China, 2005.
- [2] Z.L. Zhou, R.B. Shi, B. Liu, et al., Steroidal saponins and phenolic constituents from *Lilium lancifolium* and their anti-oxidant activities, *Chin. Tradit. Herbal Drugs* 42 (1) (2011) 21–24.
- [3] W.Y. Hu, J.A. Duan, D.W. Qian, et al., Studies on chemical constituents in fresh fleshy scaleleaf of *Lilium lancifolium*, *China J. Chin. Mater. Med.* 32 (16) (2007) 1656–1659.
- [4] X.W. Yang, Y.S. Wu, Y.X. Cui, et al., A new steroidal saponin from the bulbs of *Lilium lancifolium*, *Acta Pharm. Sin.* B 37 (11) (2002) 863–866.
- [5] Z.L. Zhou, Z.C. Feng, C.Y. Fu, et al., Steroidal and phenolic glycosides from the bulbs of *Lilium pumilum* DC and their potential  $\text{Na}^+/\text{K}^+$  ATPase inhibitory activity, *Molecules* 17 (9) (2012) 10494–10502.
- [6] J.M. Jr, T.J. Gianfagna, Quantitative analysis of steroidal glycosides in different organs of easter lily (*Lilium longiflorum* Thunb.) by LC-MS/MS, *J. Agric. Food Chem.* 59 (3) (2011) 995–1004.
- [7] Y. Mimaki, Y. Sashida, Steroidal saponins from the bulbs of *Lilium brownii*, *Phytochemistry* 29 (7) (1990) 2267–2271.
- [8] Y. Mimaki, T. Satou, M. Kuroda, et al., New steroidal constituents from the bulbs of *Lilium candidum*, *Chem. Pharm. Bull.* 46 (11) (1998) 1829–1832.
- [9] Y. Mimaki, Y. Sashida, Steroidal and phenolic constituents of *Lilium speciosum*, *Phytochemistry* 30 (3) (1991) 937–940.
- [10] Y. Mimaki, Y. Sashida, H. Shimomura, Lipid and steroidal constituents of *Lilium auratum*, var. *Platyphyllum*, and *L. tenuifolium*, *Phytochemistry* 28 (12) (1989) 3453–3458.
- [11] X. Wang, G.Q. Wu, A new steroidal glycoside and potential anticancer cytotoxic activity of compounds isolated from the bulbs of *Lilium callosum*, *Cheminform* 46 (20) (2015) 577–579.
- [12] X.Y. Hou, F.K. Chen, Isolation and structural elucidation of chemical constituents of *Lilium brownii*, *Acta Pharm. Sin.* B 12 (1998) 923–926.
- [13] Z.L. Zhou, R.B. Shi, B. Liu, et al., Chemical constituents of Juandan (*Lilium lancifolium* Thunb.), *J. Beijing Univ. Tradit. Chin. Med.* 33 (1) (2010) 57–61.
- [14] I. Erdogan, B. Sener, A. Rahman, Etioline, a steroidal alkaloid from *Lilium candidum* L, *Biochem. Syst. Ecol.* 29 (5) (2001) 535–536.
- [15] J.P. Munafó, A. Ramanathan, L.S. Jimenez, et al., Isolation and structural determination of steroidal glycosides from the bulbs of easter lily (*Lilium longiflorum* Thunb.), *J. Agric. Food Chem.* 58 (15) (2010) 8806–8813.
- [16] C.M. Liu, G.M. Fu, H. You, et al., Isolation and Purification of Polysaccharides from Lily, *Food Sci.* 23 (5) (2002) 114–117.

- [17] G.H. Zhao, L.I. Z.X., Z.D. Chen, Chemical structure and antitumor activity of polysaccharide from *Lilium brownii*, *J. Food Sci. Biotechnol.* 21 (1) (2002) 62–66.
- [18] Q. Zhu, Isolation, Purification, Structure Determination and Biological Activities of Polysaccharides From Bulb of Lily (*Lilium Lancifolium* Thunb), Nanjing Agriculture University, 2012.
- [19] T. Zhang, Separation, Purification, Structure Identification and Hypoglycemic Activity of Polysaccharides From *Lilium lancifolium*, Hefei University of Technology, 2014.
- [20] H.Q. Zhang, H. Yan, D.W. Qian, et al., Analysis and evaluation of eight active ingredients in *Lilium lancifolium* from different regions, China *J. Chin. Mater. Med.* 42 (2) (2017) 311–318.
- [21] L. Jin, Y.L. Zhang, L.X. Niu, et al., Antioxidant activity of polyphenolic compounds in bulbs of three *Lilium* species, *Acta Botanica Boreali-Occidentalia Sinica* 34 (5) (2014) 995–1001.
- [22] H.L. Jiao, Y.L. Zhang, L.X. Niu, Phenolic composition and antioxidant activity of polyphenols from bulbs of *Lilium lancifolium* Thunb., *J. Northwest A & F Univ. (Nat. Sci. Ed.)* 43 (7) (2015) 150–154.
- [23] L. Jin, Y.L. Zhang, L.M. Yan, et al., Phenolic compounds and antioxidant activity of bulb extracts of six *Lilium* species native to China, *Molecules* 17 (8) (2012) 9361–9378.
- [24] W. T. T., H.H. Huang, Y. Zhang, et al., Role of effective composition on antioxidant, anti-inflammatory, sedative-hypnotic capacities of 6 common edible *Lilium* varieties, *J. Food Sci.* 80 (4) (2015) H857–H868.
- [25] F. Li, B.X. Yuan, M. Mi, et al., Effects of purified polysaccharides from Lily on tumor growth and immune functions of tumor-bearing mice, *J. Mod. Oncol.* 16 (2) (2008) 188–189.
- [26] Y. Yang, F. Li, Effects of neutral polysaccharide from lily on enhancing efficacy and reducing toxicity of 5-FU and proliferation of gastric carcinoma cell line SGC-7901 in vitro, *J. Yan'an Univ. (Med. Sci.)* 11 (2) (2013) 8–11.
- [27] L. Jia, Lily Proliferation Inhibition on Human Gastric Cancer cell Lines SGC-7901 and Discussion of Functional Mechanism, Yan'an University, 2015.
- [28] L. Li, X.D. Liu, J.H. Zhan, et al., A study on the antitumor activity of chemical constituents from *Lilium lancifolium* thunb., *J. Hunan Univ. Chin. Med.* 38 (10) (2018) 46–49.
- [29] Q.Y. Ai, Y.F. Zhao, A.H. Wang, et al., Depressant effects of *Lilium lancifolium* on human pulmonary adenocarcinoma cell line A549 in vitro, *Shanxi J. Tradit. Chin. Med.* 36 (4) (2015) 497–499.
- [30] L.H. Lei, Antioxidant Capacity and Lung Cancer Cell Rejection Characteristic of *Lilium lancifolium* Bulbs From Different Populations, Northwest A&F University, 2015.
- [31] Z.Y. Yuan, L.M. Luo, N.H. Chen, et al., Rapid analysis of chemical constituents of Lily Bulbil by UPLC-Q-TOF-MS and the antitumor activity of diosgenin, *Nat. Prod. Res. Dev.* 31 (5) (2019) 809–814.
- [32] E. Lee, N. Yun, Y.P. Jang, et al., *Lilium lancifolium* Thunb. extract attenuates pulmonary inflammation and air space enlargement in a cigarette smoke-exposed mouse model, *J. Ethnopharmacol.* 149 (1) (2013) 148–156.
- [33] O.K. Kwon, M.Y. Lee, J.E. Yuk, et al., Anti-inflammatory effects of methanol extracts of the root of *Lilium lancifolium*, on LPS-stimulated Raw264.7 cells, *J. Ethnopharmacol.* 130 (1) (2010) 28–34.
- [34] T. Ma, Z. Wang, Y.M. Zhang, et al., Bioassay-guided isolation of anti-inflammatory components from the bulbs of *Lilium brownii* var. *viridulum* and identifying the underlying mechanism through acting on the NF- $\kappa$ B/MAPKs pathway, *Molecules* 22 (4) (2017) 506.
- [35] M.M. Hu, B.C. Cai, Z.J. Zhang, et al., Pharmacodynamics research of *Lilium brownii* polysaccharide, *Tradit. Chin. Drug Res. Clin. Pharmacol.* 18 (2) (2007) 107–109.
- [36] L.H. Li, Determination of polysaccharide of lily and its antioxidant activity, *Hubei Agric. Sci.* 50 (14) (2011) 2954–2957.
- [37] C.M. Liu, G.M. Fu, Z.C. Tu, et al., Study on the function lily-polysaccharides to lower the blood glucose, *J. Food Sci.* 23 (6) (2002) 113–114.
- [38] X. Xiao, X. Wu, C.L. He, Hypoglycemic effect of lily polysaccharides in Type I diabetic rats, *J. Food Sci.* 35 (1) (2014) 209–213.
- [39] M.D. Zhu, J.G. Luo, L.H. et al., Determination of anti-hyperglycaemic activity in steroidal glycoside rich fraction of lily bulbs and characterization of the chemical profiles by LC-Q-TOF-MS/MS, *J. Funct. Foods* 6 (1) (2014) 585–597.
- [40] H.J. Li, Study on the Nutrients nioactive Materials and Cultivation Characteristics of *Lilium lancifolium* Thunb, Northwest A&F University, 2007.
- [41] M. Tang, Research on Extraction, Purification and Bacteriostatic Activity of Polysaccharides in *Lilium*, Hunan Agricultural University, 2010.
- [42] Q.P. Guo, Study on Quality Standard and Antidepression Effect of *Lilium brownii*, Guangzhou University of Chinese Medicine, 2009.
- [43] Y. Wang, Extraction technology and anti-depression activity of saponins from *Lilium brownii*, *China Pharm.* 7 (2014) 602–604.
- [44] S.Y. Gao, Quality Standard Research of the Total Saponins of Lily and Discussing on Anti-depression Accompanied With IBS, Guangzhou University of Chinese Medicine, 2013.
- [45] He C L, X.H. Yang, H. Huang, et al., Anti-weary pharmacological action of lily polysaccharide, *J. Hunan Normal Univ. (Med. Sci.)* 6 (3) (2009) 9–11.