The genus *Liriope*: Phytochemistry and pharmacology

SHANG Zhan-Peng\(^1\Delta\), WANG Fei\(^1\Delta\), ZHANG Jia-Yu\(^2\ast\), WANG Zi-Jian\(^2\), LU Jian-Qiu\(^3\), WANG Huai-You\(^4\), LI Ning\(^4\ast\)

\(^1\) School of Chinese Pharmacy, Beijing University of Chinese Medicine, Beijing 100102, China; \(^2\) Beijing Research Institute of Chinese Medicine, Beijing University of Chinese Medicine, Beijing 100029, China; \(^3\) Library of Beijing University of Chinese Medicine, Beijing University of Chinese Medicine, Beijing 100029, China; \(^4\) Shenzhen Research Institute, Hong Kong University of Science and Technology, Shenzhen 518057, China

Available online 20 Nov., 2017

**[ABSTRACT]** *Liriope* (Liliaceae) species have been used as folk medicines in Asian countries since ancient times. From *Liriope* plants (8 species), a total of 132 compounds (except polysaccharides) have been isolated and identified, including steroidal saponins, flavonoids, phenols, and eudesmane sesquiterpenoids. The crude extracts or monomeric compounds from this genus have been shown to exhibit anti-tumor, anti-diabetic, anti-inflammatory, and neuroprotective activities. The present review summarizes the results on phytochemical and biological studies on *Liriope* plants. The chemotaxonomy of this genus is also discussed.

**[KEY WORDS]** *Liriope*; Liliaceae; Chemical constituents; Biological activities

**[CLC Number]** R284, R96

**[Document code]** A

**[Article ID]** 2095-6975(2017)11-0801-15

**Introduction**

There has been a long history in the discovery, cultivation and utilization of medicinal plants in most developing countries. Even nowadays, the people there still rely on medicinal plants for primary health care directly or indirectly. Among the well-known medicinal plants and herbs, species from genus *Liriope* play an important role in protecting the well-being of Asian people. According to ‘Flora of China’, genus *Liriope* (Liliaceae) mainly consists of 8 species that are distributed in subtropical and temperate zones, such as China, Japan, Vietnam, and Philippines \(^{[1-3]}\).

Various species of genus *Liriope* have been used as traditional medicines for treating various diseases. As perennial plants, *L. platyphylla* is a well-known herbal medicine for the treatment of asthma and bronchia and lung inflammation \(^{[4-5]}\).

The effects of its root extracts in preventing obesity, diabetes, and neurodegenerative diseases have also been proven recently \(^{[6-9]}\). As substitutes for *Ophiopogon japonicus*, *L. muscari* (Duanting Shanmaidong) and *L. spicata* (Hubei Maidong) are widely used as remedies for various inflammation-related diseases, such as pharyngitis, bronchiectasis, pneumonia, and cough, and cardiovascular diseases \(^{[4,9-12]}\). *L. graminifolia* has been used as a popular remedy for the treatment of cancer \(^{[13]}\). Besides, modern pharmacological studies have demonstrated the biological activities of *Liriope* plants for the treatment of gastrelcosis \(^{[14]}\), as well as neuroprotective \(^{[14]}\), hepatoprotective \(^{[14]}\), anti-inflammatory \(^{[15]}\), antibacterial \(^{[16]}\) effects. Therefore, the documented information on medicinal use of *Liriope* plants provides valuable clues for the further bio-prospecting and clinical applications \(^{[17]}\).

As an effort to facilitate the related therapeutic and pharmacological research of *Liriope* plants, this review comprehensively describes their chemical compositions and pharmacological and biological activities. The chemotaxonomic significance and further research prospects are also discussed.

**Chemical Constituents of *Liriope* Plants**

A total of 132 compounds (except polysaccharides \(^{[7]}\) have...
been isolated and identified from various *Liriope* plants so far. These constituents are of five categories, namely, steroidal saponins, flavonoids, phenols, eudesmane sesquiterpenoids and the other components (Figs. 1, 2, 3, 4, and 5 and Tables 1, 2, 3, 4, and 5). Among them, steroidal saponins are the dominant constituent in *Liriope* plants.

![Structures of steroidal saponins from genus Liriope](image)

Fig. 1 Structures of steroidal saponins from genus *Liriope*

Phytochemical studies on *Liriope* plants have led to the isolation and structural characterization of 46 steroidal saponins (Table 1). From the subterranean part of *L. platyphylla*, 10 steroidal saponins have been isolated (compounds 5 and 6 were mixed steroidal saponins) [18]. In addition, 21 steroidal saponins have been isolated from *L. musacari*. To our surprise, there are three furanostanol saponins (8, 36 and 44) in *L. platyphylla* which are previously reported to be abundant in *Ophiopogon* plants.
Besides, 37 flavonoids, including homoisoflavones, anthocyanidins, chalcones, flavones, iso flavanones, and flavonols, have been isolated and identified from *Liriope* plants. Among them, there are 16 homoiso flavanones (50−61, 70 and 81−83) which exhibit remarkable pharmacological activities. Among them, compounds 54−59 are identified for the first time from *L. platyphylla* [35]. Besides, 19 phenols have been isolated from *L. muscari*. Absolute configuration of compounds 92−94 are comprehensively determined by 1D, 2D NMR, CD and MS spectral data analysis [40]. In addition, 6 eudesmane sesquiterpenes have been isolated from *Liriope* plants. Of them, two new *cis*-eudesmane sesquiterpene

---

**Fig. 2** Structures of flavonoids from genus *Liriope*
glycosides from tubers of *L. muscari* (104 and 107) are isolated and identified via NMR and HR-ESI-MS analysis whereas compound 108 is characterized by NOSEY, ROESY and CD spectral analysis. And 24 other constituents, including amides, fatty acids, alkaloids, dihydrobenzofuroisocoumarins, have been identified from *Liriope* plants. Among them, compounds 130 and 131 are isolated for the first time from the *L. muscari* and exhibit significant antioxidant activity.

**Biological Activities of Liriope Plants**

**Antitumor activity**

Anti-tumor activities of extracts and monomeric compounds from *Liriope* plants have been investigated. The results form the basis of further study on the cellular and molecular impacts of *L. platyphylla* root extract on human cancer cell lines. For example, a study has shown that the fractions extracted from the *L. platyphylla* root part (LPRP-9) might inhibit proliferation of tumor lines MCF-7 and Huh-7 and down-regulate the phosphorylation of AKT. The results have demonstrated that LPRP-9 could be developed as an anti-tumor adjuvant.

Cytotoxicities of compounds isolated from *Liriope* plants have been tested on various cancer cell lines. For instance, DT-13 (mixture of 16 and 30 from *L. muscari*) exhibit...
significant in vitro and in vivo anti-tumor effects [49]. The study on the ability of Ophiopogonin B (Op-B) to suppress in non-small cell lung cancer (NSCLC) lines NCL-H167 and NCL-H460 [50] have demonstrated that Op-B might be a prospective inhibitor of PI3K/Akt to induce autophagy in cells. Meanwhile, many steroidal saponins and flavonoids exhibit remarkable bioactivities against lung cancer, cervical cancer, and liver cancer cell lines, etc. Table 6 shows the effects of different constituents from Liriope plants on various cancer cell lines [26, 30, 34, 49-52]. It has been revealed that the introduction of a hydroxyl group to C-17 on the aglycone moiety does not significantly influence their activities, whereas the attachment of a C-14 a hydroxyl group to the aglycone moiety considerably reduces the cytotoxicity [53]. Although it may be useful for exploring the structure-activity relationship of some steroidal saponins, more information remains to be needed for further studies.

**Fig. 5** Structures of other compounds from genus Liriope

**Hypoglycemic activity**

The great hypoglycemic effect has been reported from L. platyphylla and L. spicata. Their roots are usually adopted as a popular Chinese folk medicine for the treatment of diabetes. For example, to compare the hypoglycemic effect of different L. spicata extracts, systematic experiments have been carried out on diabetic animals [54]. Rats were orally administrated with polysaccharide extract, steroidal saponin extract, total extract, diamicron (a common hypoglycemic agent) and equivalent normal saline (control group). There was a significant difference between four drug groups and control group. Furthermore, it was demonstrated that L. platyphylla could stimulate insulin secretion, decrease lipid in serum and inhibit fatty liver formation by regulating fatty acid oxidation [55]. Related studies have been also carried out to confirm it [56-58]. In-depth studies, especially at the molecular level, are in urgent need in order to clarify their mechanisms.
<table>
<thead>
<tr>
<th>No.</th>
<th>Names</th>
<th>Type(s)</th>
<th>Plant</th>
<th>Part</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25(R)-Ruscogenin-3-O-α-L-Rhamnopyranoside</td>
<td>A</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18]</td>
</tr>
<tr>
<td>2</td>
<td>25(S)-Ruscogenin-1-O-β-D-Fucopyranosyl-3-O-α-L-Rhamnopyranoside</td>
<td>B</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18–21]</td>
</tr>
<tr>
<td>3</td>
<td>25(R)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>A</td>
<td><em>L. spicata</em></td>
<td>Root Tuber</td>
<td>[22, 24]</td>
</tr>
<tr>
<td>4</td>
<td>25(R)-Ruscogenin-3-O-[β-D-Glucopyranosyl(1→3)]-α-L-Rhamnopyranoside</td>
<td>A</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18]</td>
</tr>
<tr>
<td>5</td>
<td>3-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranosyl(1→3)-β-D-Glucopyranosides of Diosgenin and Yamogenin</td>
<td>G</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18]</td>
</tr>
<tr>
<td>6</td>
<td>3-O-[β-Chacotrioside of Diosgenin and Yamogenin]</td>
<td>G</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18]</td>
</tr>
<tr>
<td>7</td>
<td>25(S)-Ruscogenin-1-sulfate-3-O-α-L-Rhamnopyranoside</td>
<td>A</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18, 23]</td>
</tr>
<tr>
<td>8</td>
<td>26-O-[β-D-Glucopyranosyl-22-O-Methyl-Furost-5-ene-3β,26-diol-3-O-β-Chacotrioside</td>
<td>E</td>
<td><em>L. platyphylla</em></td>
<td>Subterranean</td>
<td>[18]</td>
</tr>
<tr>
<td>9</td>
<td>25(S)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranoside</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Root Tuber</td>
<td>[20–21, 24–25]</td>
</tr>
<tr>
<td>10</td>
<td>25(S)-Ruscogenin-1-O-[β-D-Xylopyranosyl-3-O-α-L-Rhamnopyranoside]</td>
<td>B</td>
<td><em>L. spicata, L. graminifolia</em></td>
<td>Root Tuber</td>
<td>[19, 26]</td>
</tr>
<tr>
<td>11</td>
<td>25(S)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranoside</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Root Tuber</td>
<td>[19, 21, 24]</td>
</tr>
<tr>
<td>12</td>
<td>25(S)-Ruscogenin-1-O-[2-O-acetyl]-α-L-Rhamnopyranosyl(1→2)-β-D-Fucopyranoside</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Subterranean</td>
<td>[19]</td>
</tr>
<tr>
<td>13</td>
<td>25(S)-Ruscogenin-1-O-[3-O-acetyl]-α-L-Rhamnopyranosyl(1→2)-β-D-Fucopyranoside</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Root Tuber</td>
<td>[19, 24]</td>
</tr>
<tr>
<td>14</td>
<td>Yamogenin-3-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranosyl(1→3)-β-D-Fucopyranoside</td>
<td>C</td>
<td><em>L. spicata</em></td>
<td>Subterranean</td>
<td>[19]</td>
</tr>
<tr>
<td>15</td>
<td>25(R)-Ruscogenin-1-O-[β-D-Glucopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>A</td>
<td><em>L. musacari</em></td>
<td>Subterranean</td>
<td>[19, 27–28]</td>
</tr>
<tr>
<td>16</td>
<td>25(S)-Ruscogenin-1-O-[β-D-Xylopyranosyl(1→3)]-β-D-Fucopyranoside (Spicatoside A)</td>
<td>B</td>
<td><em>L. spicata, L. platyphylla</em></td>
<td>Root Tuber</td>
<td>[19, 22, 27–29]</td>
</tr>
<tr>
<td>17</td>
<td>25(S)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranosyl(1→3)-β-D-Fucopyranosyl-3-O-α-L-Rhamnopyranoside (Lirioproliside A)</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Root Tuber</td>
<td>[19, 25, 28, 30]</td>
</tr>
<tr>
<td>18</td>
<td>25(S)-Ruscogenin-1-O-[3-O-acetyl]-α-L-Rhamnopyranosyl(1→2)-β-D-Fucopyranoside (Lirioproliside B)</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Root Tuber</td>
<td>[19, 24–25]</td>
</tr>
<tr>
<td>19</td>
<td>25(S)-Ruscogenin-1-O-[2-O-acetyl]-α-L-Rhamnopyranosyl(1→2)-β-D-Fucopyranoside (Lirioproliside C)</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Subterranean</td>
<td>[19, 25]</td>
</tr>
<tr>
<td>20</td>
<td>25(R)-Ruscogenin-1-O-[2-O-acetyl]-α-L-Rhamnopyranosyl(1→2)-β-D-Fucopyranoside</td>
<td>A</td>
<td><em>L. spicata</em></td>
<td>Subterranean</td>
<td>[19, 25]</td>
</tr>
<tr>
<td>22</td>
<td>Pennogenin-3-O-[4'-O-acetyl]-α-L-Rhamnopyranosyl(1→3)-β-D-Xylopyranosyl(1→4)-β-D-Glucopyranoside</td>
<td>D</td>
<td><em>L. musacari</em></td>
<td>Root Tuber</td>
<td>[31]</td>
</tr>
<tr>
<td>23</td>
<td>25(R)-Ruscogenin-1-O-[β-D-Xylopyranosyl(1→3)]-β-D-Fucopyranoside</td>
<td>A</td>
<td><em>L. musacari</em></td>
<td>Root Tuber</td>
<td>[27–28]</td>
</tr>
<tr>
<td>24</td>
<td>25(R)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranoside</td>
<td>A</td>
<td><em>L. graminifolia</em></td>
<td>Subterranean</td>
<td>[26]</td>
</tr>
<tr>
<td>25</td>
<td>25(S)-Spirost-5-ene-3β,17α-diol-3-O-[β-D-Xylopyranosyl(1→3)]-[α-L-Arabino furanosyl(1→2)] [α-L-Rhamnopyranosyl(1→4)]-β-D-Glucopyranoside (Lirioprolisides A)</td>
<td>D</td>
<td><em>L. graminifolia</em></td>
<td>Subterranean</td>
<td>[26]</td>
</tr>
<tr>
<td>26</td>
<td>Ophiopogon A</td>
<td>B</td>
<td><em>L. spicata</em></td>
<td>Subterranean</td>
<td>[25]</td>
</tr>
<tr>
<td>27</td>
<td>25(R)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranosyl(1→4)-β-D-Glucopyranoside</td>
<td>A</td>
<td><em>L. musacari</em></td>
<td>Root Tuber</td>
<td>[28]</td>
</tr>
<tr>
<td>28</td>
<td>25(R)-Pennogenin-3-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Xylopyranosyl(1→3)-β-D-Glucopyranoside</td>
<td>A</td>
<td><em>L. musacari</em></td>
<td>Root Tuber</td>
<td>[28]</td>
</tr>
<tr>
<td>No.</td>
<td>Names</td>
<td>Type&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>Plant</td>
<td>Part</td>
<td>References</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------------------------------------------</td>
<td>-------------------</td>
<td>------------</td>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td>29</td>
<td>25(R)-Ruscogenin-1-O-[β-D-Glucopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Fucopyranoside</td>
<td>A</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[27–28]</td>
</tr>
<tr>
<td>30</td>
<td>25(S)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Fucopyranosyl-3-O-α-L-Rhamnopyranoside</td>
<td>A</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[26]</td>
</tr>
<tr>
<td>31</td>
<td>25(S)-Ruscogenin-1-O-[β-D-Fucopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Fucopyranoside</td>
<td>B</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[28, 30, 32]</td>
</tr>
<tr>
<td>32</td>
<td>25(S)-Ruscogenin-1-O-[β-D-Xylopyranosyl(1→3)]-β-D-Fucopyranoside</td>
<td>B</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[28]</td>
</tr>
<tr>
<td>33</td>
<td>25(R)-Ruscogenin-1-O-[β-D-Fucopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Glucopyranoside</td>
<td>B</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[30]</td>
</tr>
<tr>
<td>34</td>
<td>25(S)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Glucopyranoside</td>
<td>B</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[30]</td>
</tr>
<tr>
<td>35</td>
<td>25(R)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Fucopyranoside</td>
<td>A</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[30]</td>
</tr>
<tr>
<td>36</td>
<td>26-O-β-D-Glucopyranosyl-25(S)-Furost-5(6)-ene-1β-3β-22-26-Tetraol-1-O-[β-D-D-Glucopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Fucopyranoside (Spicatosides B)</td>
<td>E</td>
<td>L. platyphylla</td>
<td>Root Tuber</td>
<td>[33]</td>
</tr>
<tr>
<td>37</td>
<td>25(S)-Ruscogenin-1-O-[β-D-Glucopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>B</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[22]</td>
</tr>
<tr>
<td>38</td>
<td>Neoruscogenin</td>
<td>F</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[24]</td>
</tr>
<tr>
<td>39</td>
<td>Neoruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>F</td>
<td>L. spicata</td>
<td>Root Tuber</td>
<td>[24]</td>
</tr>
<tr>
<td>40</td>
<td>Yamogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Glucopyranoside</td>
<td>C</td>
<td>L. spicata</td>
<td>Root Tuber</td>
<td>[24]</td>
</tr>
<tr>
<td>41</td>
<td>25(S)-Ruscogenin1-O-2,3,5-tri-O-acetyl-[α-L-Rhamnopyranosyl(1→2)]β-D-Xylopyranosyl(1→3)-β-D-Fucopyranoside</td>
<td>B</td>
<td>L. spicata</td>
<td>Root Tuber</td>
<td>[24]</td>
</tr>
<tr>
<td>42</td>
<td>Neoruscogenin-1-O-3-acetyl-[α-L-Rhamnopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>F</td>
<td>L. spicata</td>
<td>Root Tuber</td>
<td>[24]</td>
</tr>
<tr>
<td>43</td>
<td>Neoruscogenin-1-O-2,5,6-tri-O-acetyl-[α-L-Rhamnopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>F</td>
<td>L. spicata</td>
<td>Root Tuber</td>
<td>[24]</td>
</tr>
<tr>
<td>45</td>
<td>25(R)-Ruscogenin-1-O-[β-D-Xylopyranosyl(1→3)]β-D-Glucopyranosyl(1→2)-β-D-Fucopyranoside</td>
<td>A</td>
<td>L. spicata</td>
<td>Root Tuber</td>
<td>[29]</td>
</tr>
<tr>
<td>46</td>
<td>25(S)-Ruscogenin-1-O-[α-L-Rhamnopyranosyl(1→2)]-β-D-Fucopyranoside</td>
<td>B</td>
<td>L. muscari</td>
<td>Root Tuber</td>
<td>[22]</td>
</tr>
</tbody>
</table>

Notes: (1) A, 25(R)-Ruscogenin; B, 25(S)-Ruscogenin; C, Yamogenin; D, Pennogenin; E, Furost; F, Neoruscogenin; G, Other types.
Table 2  Flavonoids from genus *Liriope*

<table>
<thead>
<tr>
<th>No.</th>
<th>Names</th>
<th>Plants</th>
<th>Part</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>Hesperidin</td>
<td><em>L. graminifolia</em></td>
<td>Root tuber</td>
<td>[26]</td>
</tr>
<tr>
<td>48</td>
<td>7,4′-dihydroxy-5-methoxy-flavanol</td>
<td><em>L. graminifolia</em></td>
<td>Root tuber</td>
<td>[26]</td>
</tr>
<tr>
<td>49</td>
<td>5,7-dihydroxy-8-mthoxy-flavone</td>
<td><em>L. graminifolia</em></td>
<td>Root tuber</td>
<td>[34]</td>
</tr>
<tr>
<td>50</td>
<td>(3S)-3,5,4′-trihydroxy-7-methoxy-6-methyl-homoisoflavanone</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[34]</td>
</tr>
<tr>
<td>51</td>
<td>5,7-dihydroxy-3-(4-methoxybenzyl)-6-methyl-chroman-4-one (Ophiogonanone B)</td>
<td><em>L. graminifolia</em></td>
<td>Subterranean</td>
<td>[26]</td>
</tr>
<tr>
<td>52</td>
<td>(3R)-5,4′-dihydroxy-7-methoxy-6-methyl-chroman-4-one (Liriopein A)</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>53</td>
<td>(3R)-5,2′,4′-trihydroxy-7-methoxy-6-methyl-chroman-4-one (Liriopein B)</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>54</td>
<td>(3R)-3-(4′-hydroxybenzyl)-5,7-dihydroxy-6-methyl-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>55</td>
<td>(3R)-3-(4′-hydroxybenzyl)-3,5-dihydroxy-7-methoxy-6-methyl-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>56</td>
<td>(3R)-3-(4′-hydroxybenzyl)-3,5-dihydroxy-7-methoxy-6-methyl-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>57</td>
<td>3-(4′-hydroxybenzylidene)-5,7-dihydroxy-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[36]</td>
</tr>
<tr>
<td>58</td>
<td>3,5-dihydroxy-7-methoxy-3-(4-hydroxybenzy)-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[36]</td>
</tr>
<tr>
<td>59</td>
<td>3,5-dihydroxy-7-methoxy-6-methyl-3-(4-hydroxybenzy)-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[36]</td>
</tr>
<tr>
<td>60</td>
<td>Isoliquiritigenin</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>61</td>
<td>Kaempferol</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[37]</td>
</tr>
<tr>
<td>62</td>
<td>3-O-methylquercetin</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[37]</td>
</tr>
<tr>
<td>63</td>
<td>3,3′-O-dimethylquercetin</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>64</td>
<td>3,4′-O-dimethylquercetin</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>65</td>
<td>Kaempferol-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>66</td>
<td>Quercetin-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>67</td>
<td>Isorhamnetin-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>68</td>
<td>3-(2′,4′-dihydroxybenzyl)-5,7-dihydroxy-6-methyl-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>69</td>
<td>Isorhamnetin-3-O-glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>70</td>
<td>7,4′-dihydroxy-5-methoxy-flavanonol</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>71</td>
<td>Liquiritigenin</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>72</td>
<td>Diosmetin</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>73</td>
<td>Delphinidin-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>74</td>
<td>Delphinidin-3-O-Rutinoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>75</td>
<td>Cyanidin-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>76</td>
<td>Petunidin-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>77</td>
<td>Petunidin-3-O-Rutinoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>78</td>
<td>Malvidin-3-O-Glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>79</td>
<td>Malvidin-3-O-Rutinoside</td>
<td><em>L. platyhylla</em></td>
<td>Fruit</td>
<td>[38]</td>
</tr>
<tr>
<td>80</td>
<td>6-C-methylquercetin-3-methylether</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>81</td>
<td>Disporopsin</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>82</td>
<td>3-(2′,4′-dihydroxy-benzyl)-5,7-dihydroxy-6-methyl-chroman-4-one</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>83</td>
<td>Methylophiopogonanone B</td>
<td><em>L. graminifolia</em></td>
<td>Root tuber</td>
<td>[26]</td>
</tr>
</tbody>
</table>
Table 3  Phenols from genus *Liriope*

<table>
<thead>
<tr>
<th>No.</th>
<th>Names</th>
<th>Plants</th>
<th>Part</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>84</td>
<td>Emodin</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[36]</td>
</tr>
<tr>
<td>85</td>
<td>Syringaresinol</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35, 37]</td>
</tr>
<tr>
<td>86</td>
<td>4-Allylpyrocatenol</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[39]</td>
</tr>
<tr>
<td>87</td>
<td>2,6-Dimethoxy-4-nitrophenol</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[39]</td>
</tr>
<tr>
<td>88</td>
<td>Vanillic acid</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[27, 39]</td>
</tr>
<tr>
<td>89</td>
<td><em>trans</em>-p-Hydroxycinnamic acid</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[39]</td>
</tr>
<tr>
<td>90</td>
<td>Syringic acid</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[39]</td>
</tr>
<tr>
<td>91</td>
<td>4-Hydroxy-benzaldehyde</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35, 39]</td>
</tr>
<tr>
<td>92</td>
<td>(−)-Pinoresinol</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[35, 40]</td>
</tr>
<tr>
<td>93</td>
<td>(2S,3R)-Methyl-7-hydroxy-2-(4-hydroxy-3-methoxyphenyl)-3-(hydroxymethyl)-2,3-dihydrobenzofuran-5-carboxylate</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[39, 40]</td>
</tr>
<tr>
<td>94</td>
<td>(4R,5S)-5-(3-Hydroxy-2,6-dimethylphenyl)-4-isopropylidihydrofuran-2-one</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[39, 40]</td>
</tr>
<tr>
<td>95</td>
<td>2-(4'-Hydroxybenzyl)-5,6-methylenedioxy-benzofuran</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[39]</td>
</tr>
<tr>
<td>96</td>
<td>(−)-Platyphyllarin A</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35, 37]</td>
</tr>
<tr>
<td>97</td>
<td>(−)-Platyphyllarin B</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35, 37]</td>
</tr>
<tr>
<td>98</td>
<td>(2R)-(2',4'-Dihydroxybenzyl)-6,7-methylenedioxy-2,3-dihydrobenzofuran</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>99</td>
<td>(−)-Platyphyllarin C</td>
<td><em>L. platyhylla</em></td>
<td>Aerial part</td>
<td>[37]</td>
</tr>
<tr>
<td>100</td>
<td>Ophiopogonoside A</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[42, 43]</td>
</tr>
<tr>
<td>101</td>
<td>Ophiopogonoside B</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[42, 43]</td>
</tr>
</tbody>
</table>

Table 4  Eudesmane sesquiterpene glucoside from genus *Liriope*

<table>
<thead>
<tr>
<th>No.</th>
<th>Names</th>
<th>Plants</th>
<th>Part</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>1,4-epoxy-cis-Eudesm-6-O-β-D-glucopyranoside</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[41]</td>
</tr>
<tr>
<td>104</td>
<td>1β, 6β-Dihydroxy-cis-eudesm-3-ene-6-O-β-D-glucopyranoside (<em>Liriopeoside A</em>)</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[41]</td>
</tr>
<tr>
<td>105</td>
<td>1β,6β-Dihydroxy-cis-eudesm-3-ene-6-O-β-D-glucopyranoside</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[41, 42]</td>
</tr>
<tr>
<td>106</td>
<td>1α,6β-Dihydroxy-5,10-bis-epi-eudesm-4(15)-ene-6-O-β-D-glucopyranoside</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[41]</td>
</tr>
<tr>
<td>107</td>
<td>Ophiopogonoside A</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[42, 43]</td>
</tr>
<tr>
<td>108</td>
<td>Ophiopogonoside B</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[43]</td>
</tr>
</tbody>
</table>

Table 5  Other types of constituents from genus *Liriope*

<table>
<thead>
<tr>
<th>No.</th>
<th>Names</th>
<th>Plants</th>
<th>Part</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>β-Sitosterol</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[21, 39, 44]</td>
</tr>
<tr>
<td>110</td>
<td>β-Sitosteryl palmitate</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>111</td>
<td>β-Sitosteryl-β-D-glucopyranoside</td>
<td><em>L. musacari, L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35, 43, 45]</td>
</tr>
<tr>
<td>112</td>
<td>Stigmasterol</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[36]</td>
</tr>
<tr>
<td>113</td>
<td>Stigmasteryl palmitic</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>114</td>
<td>Stigmasterol-β-D-glucoside</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>115</td>
<td>Campesterol glucoside</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>116</td>
<td>Pentacosane</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>117</td>
<td>Hentriacontane</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>118</td>
<td>Oleaonic acid</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>119</td>
<td>Ursolic acid</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[27, 44]</td>
</tr>
<tr>
<td>No.</td>
<td>Names</td>
<td>Plants</td>
<td>Part</td>
<td>References</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------------------</td>
<td>-------------</td>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>120</td>
<td>Glutaminsäure anhydride</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[27]</td>
</tr>
<tr>
<td>121</td>
<td>Lupenone</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[44]</td>
</tr>
<tr>
<td>122</td>
<td>Lupeol</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[45]</td>
</tr>
<tr>
<td>123</td>
<td><em>N</em>-Pentyl benzoate</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[28]</td>
</tr>
<tr>
<td>124</td>
<td>Palmitic acid glyceride</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[43]</td>
</tr>
<tr>
<td>125</td>
<td>Ethyltributanoate</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>126</td>
<td>Palmitic acid</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[43, 44, 45]</td>
</tr>
<tr>
<td>127</td>
<td>4-Hydroxy-methyl benzoate</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
<tr>
<td>128</td>
<td>5-Hydroxymethyl-2-furaldehyde</td>
<td><em>L. spicata</em></td>
<td>Root tuber</td>
<td>[39]</td>
</tr>
<tr>
<td>129</td>
<td><em>N</em>-trans-Coumaroyltyramine</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[34-36]</td>
</tr>
<tr>
<td>130</td>
<td><em>N</em>-trans-Feruloyltyramine</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[34, 35]</td>
</tr>
<tr>
<td>131</td>
<td><em>N</em>-trans-Feruloyloctopamine</td>
<td><em>L. musacari</em></td>
<td>Root tuber</td>
<td>[34, 35]</td>
</tr>
<tr>
<td>132</td>
<td>Fatty acid derivative</td>
<td><em>L. platyhylla</em></td>
<td>Root tuber</td>
<td>[35]</td>
</tr>
</tbody>
</table>

Table 6  Anti-tumor activity of constituents from *Liriope* plants against tumor cell lines

<table>
<thead>
<tr>
<th>Source</th>
<th>Compound or extract</th>
<th>Cell lines</th>
<th>Result (μg·mL⁻¹)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. graminifolia</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Subterranean)</td>
<td>25</td>
<td>SMMC-7721</td>
<td>IC₅₀ 76.4 ± 6.6</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>SMMC-7721</td>
<td>IC₅₀ &gt; 100</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>SMMC-7721</td>
<td>IC₅₀ 45.8 ± 5.4</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>SMMC-7721</td>
<td>IC₅₀ &gt; 100</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>83</td>
<td>SMMC-7721</td>
<td>IC₅₀ 34.6 ± 5.4</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>SMMC-7721</td>
<td>IC₅₀ &gt; 100</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Hela</td>
<td>IC₅₀ 26.1 ± 4.4</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>Hela</td>
<td>IC₅₀ 18.6 ± 3.6</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Hela</td>
<td>IC₅₀ 13.3 ± 3.0</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Hela</td>
<td>IC₅₀ 40.6 ± 6.4</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>83</td>
<td>Hela</td>
<td>IC₅₀ 6.0 ± 2.4</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>Hela</td>
<td>IC₅₀ 14.0 ± 3.2</td>
<td>[26]</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>H157</td>
<td>IC₅₀ 2.86</td>
<td>[50]</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>H460</td>
<td>IC₅₀ 4.61</td>
<td>[50]</td>
</tr>
<tr>
<td><em>L. platyhylla</em></td>
<td>Extract (70% ethanol)</td>
<td>A549</td>
<td>IC₅₀ &gt; 100</td>
<td>[48]</td>
</tr>
<tr>
<td>(Root part)</td>
<td></td>
<td>Huh-7</td>
<td>IC₅₀ &gt; 100</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hep 3B</td>
<td>IC₅₀ 84.3 ± 1.0</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MCF-7</td>
<td>IC₅₀ 67.7 ± 0.8</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MDA-MB-231</td>
<td>IC₅₀ 57.6 ± 1.8</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td>Extract</td>
<td>A549</td>
<td>IC₅₀ 77.9 ± 1.9</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Huh-7</td>
<td>IC₅₀ 36.0 ± 0.2</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hep 3B</td>
<td>IC₅₀ 52.1 ± 2.2</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MCF-7</td>
<td>IC₅₀ 23.1 ± 1.3</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MDA-MB-231</td>
<td>IC₅₀ 72.2 ± 1.4</td>
<td>[48]</td>
</tr>
<tr>
<td><em>L. musacari</em></td>
<td>DT-13 (16, 30)</td>
<td>SMMC-7721</td>
<td>IC₅₀ 17</td>
<td>[47]</td>
</tr>
<tr>
<td>(Root part)</td>
<td></td>
<td>Hela</td>
<td>IC₅₀ 38</td>
<td>[47]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A549</td>
<td>IC₅₀ 67</td>
<td>[47]</td>
</tr>
</tbody>
</table>
Anti-inflammatory activity

Previous studies have demonstrated that extracts and constituents from *Liriope* plants exhibit distinct anti-inflammatory abilities [59]. For example, xylene-induced ear swelling and paw edema mice were adopted to evaluate the anti-inflammatory activities of aqueous extract from *L. muscari* [60]. It showed remarkable anti-inflammatory effects in such two animal models at a single oral dose of 23.2 and 4.6 mg·kg⁻¹, respectively. The therapeutic effect of aqueous extract of *L. platyphylla* on atopic dermatitis has also been confirmed by using the luciferase report system in IL-4/Luc/CNS-1 transgenic mice [61]. An inhaled treatment of *L. platyphylla* extract could weaken airway hyper responsiveness (AHR) in an ovalbumin-induced asthmatic mouse model [15]. Similar studies about inflammatory pulmonary diseases [5, 62-63] have also been conducted to confirm this pharmacology property.

In additional, the ability of DT-13 to inhibit carrageenan or histamine-induced acute inflammation has been investigated [61]. The reported results have demonstrated that DT-13 could suppress acute inflammation and inhibit the adhesion of HL-60 to ECV304 cells *in vitro*. In another study, at doses of 10 and 20 mg·kg⁻¹, DT-13 might resist ear swelling significantly [64]. Compound 16 might increase PMA-induced mucin secretion and stimulate basal mucin production, which indicated the ability to relieve pulmonary inflammation with the mechanism of directly affecting airway epithelial cells [65]. The neutrophil respiratory inhibitory activities of compounds 3, 9, 11, 16, 17, 21, 38, and 39 from *L. spicata* [24] were conducted (Table 7).

Anti-oxidant activity

The dried leaf powders of *Liriope* plants are frequently used as tea drinks in Taiwan [66]. Different extracts, including hexane-soluble, ethylacetate-soluble and water-soluble of *Liriope* plants, have been tested for their DPPH scavenging activities using spectrophotometry [67]. The results have demonstrated that ethylacetate-soluble fraction possessed the highest DPPH scavenging activity with IC₅₀ of SL, BL, and TL for DPPH radical scavenging activity at 41.55, 24.55, and 53.33 μg·mL⁻¹, respectively. In addition, the acidic methanol extract also exhibited 83.9% DPPH and 92.5% ABTS scavenging activities at a dose of 0.5 mg·mL⁻¹ [39]. Furthermore, the anti-oxidant activity of 7 types of anthocyanin (73-80) isolated from *L. platyphylla* fruits have been tested. Among them, Compounds 77 and 79 showed the highest activity. The DPPH scavenging effects of 5 compounds and references were investigated and they decreased according to the following order: VC > 131 > 130 > BHT > 49 > 129 > 50 [66, 67].

Table 7 Anti-inflammation activity of constituents from *Liriope* plants

<table>
<thead>
<tr>
<th>Source</th>
<th>Compound or extract</th>
<th>Cell lines</th>
<th>Result (μg·mL⁻¹)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. spicata</em></td>
<td>β-Sitosterol (109)</td>
<td>SGC-7901</td>
<td>IC₅₀ 154.02</td>
<td>[51, 52]</td>
</tr>
<tr>
<td>(Root part)</td>
<td></td>
<td>HO-8910</td>
<td>IC₅₀ 55.32</td>
<td>[51, 52]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HCT-116</td>
<td>—</td>
<td>[51, 52]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BEL-7402</td>
<td>IC₅₀ 17.81</td>
<td>[51, 52]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SMMC-7721</td>
<td>IC₅₀ 40.09</td>
<td>[51, 52]</td>
</tr>
<tr>
<td><em>L. muscari</em></td>
<td>A mixture of 33 and 34</td>
<td>MDA-MB-435</td>
<td>IC₅₀ 0.58 ± 0.8</td>
<td>[30]</td>
</tr>
<tr>
<td>(Root part)</td>
<td></td>
<td>MDA-MB-435</td>
<td>IC₅₀ 0.05 ± 0.1</td>
<td>[30]</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>MDA-MB-435</td>
<td>IC₅₀ &gt; 100</td>
<td>[30]</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>MDA-MB-435</td>
<td>IC₅₀ 0.15</td>
<td>[30]</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>MDA-MB-435</td>
<td>IC₅₀ 18.6</td>
<td>[23]</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>K562</td>
<td>IC₅₀ 16.5</td>
<td>[23]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HL60</td>
<td>IC₅₀ —</td>
<td>—</td>
</tr>
</tbody>
</table>

Neuroprotective activity

The effects of 70% ethanol extract of *L. platyphylla* roots have been investigated using behavioral and immunohistochemical methods in mice [68], which have demonstrated it has good ability to improve learning and memory and enhance BDNF or NGF expression. Besides, butanol extract of *L. platyphylla* might activate astroglial nerve growth factor through a PKC-dependent pathway which contributed to the induction of neurite outgrowth of PC12 cells [14].

Total saponins extract of *Liriope* plants might affect the spontaneous activity of mice at a dose of 600 mg·kg⁻¹, and significantly reduce the caffeine sodium benzoate-induced...
excitable activity \[69\]. Current finding indicates that \textit{L. platyphylla} extract exhibit neuroprotective effects against H$_2$O$_2$-induced apoptotic cell death through modulating p38 activation in SH-SY5Y cells. Another research has shown that total saponins extract of \textit{L. platyphylla} could improve the memory of senile mice induced by D-galactose, increase their body weight, thymus and spleen indexes while the levels of methane dicarboxylic aldehyde (MDA) and lipofuscin are decreased \[70\].

\textbf{Laxative activity}

\textit{L. platyphylla} has been used as a valid medicine in China and Korea for the treatment of gastrointestinal (GI) disorders which are related to constipation and abnormal GI motility \[70\].

The laxative effect of aqueous extract of \textit{L. platyphylla} has been tested on constipated SD rats \[72\]. The reported results have demonstrated that the amounts of stool and urine excretion are significantly higher than those of control group while the food consumption and water intake remain at the same level. Furthermore, RT-PCR and Western blot experiments have revealed a dramatic reduction of key factors level on the muscarinic acetylcholine receptors (mAChRs) signaling pathway \[73\].

\textbf{Immunoregulatory activity}

Polysaccharide extract of \textit{Liriope} plants \[74\] could relieve the damage of cyclophosphamide-induced immune organ at a dose of 1 600 mg·kg$^{-1}$ and increase the weight of immune organ. Systematic experiments showed polysaccharide extracts of \textit{L. muscari} could significant enhance splenic index, macrophage phagocytosis capacity, serum hemolysin, cytokines (IL-2, TNF-α), NK cell activity and lymphocyte transformation ability \[75-77\]. Besides, another research has been conducted in the lipopolysaccharide-induced cultured RAW 264.7 mouse macrophages \[78\]. The results have demonstrated that water extract of \textit{L. platyphylla} has the immunomodulatory activity to reduce excessive immune reactions via activating macrophages.

Meanwhile, different extracts of \textit{L. platyphylla}, including methanol, ethanol and aqueous extracts, have been tested on hematology and innate immune response in olive flounder, \textit{Paralichthys olivaceus} \[79\]. All of these extracts could enhance the leucocytes activities against \textit{Flexibacter maritimus}.

\textbf{Cardiovascular activities}

Extracts of \textit{Liriope} plants have been shown to have obvious cardiovascular effects, mainly by inhibiting platelet aggregation \[35\], anti- myocardial ischemia \[80\], anti-arrhythmia \[81\], anti-ischemic \[82\] and anti-hypertensive activities \[83\].

Water-alcohol extract of \textit{L. spicata} has been investigated in normal rats to confirm its anti-arrhythmia effects \[81\]. The results have demonstrated that it might improve chloroform epinephrine-induced, acoline-induced and BaCl$_2$-induced arrhythmia at a dose of 2.5 g·kg$^{-1}$ with no effect on ouabain-induced arrhythmia rats \[84\]. The total saponins extract of \textit{Liriope} plants could reduce brain infarcted area and prolong the bleeding time and clotting time \[82\]. Besides, Compounds 52, 53, 56, 57, 58, 97, 98, 125, and 130 have been undergone anti-platelet aggregation tests. Compounds 57 and 58 attributed to homoioflavonoids have shown greater anti-platelet potency than 52, 53, 55 and 58, suggesting a positive role for the C-2′ hydroxy moiety in enhancing the inhibitory effect on platelet aggregation induced by collagen \[35\].

\textbf{Other activities}

When given DT-13 to ICR mice, the liver injury decreased significantly \[85\]. The essential oil of \textit{L. muscari} exhibited potent insecticidal activities against \textit{ Tribolium castaneum}, \textit{Lasioderma serricorne} and \textit{ Liposcelis bostrychophila} adults, with LD$_{50}$ values of 13.36, 11.28 μg/adult and 21.37 μg/cm$^2$ \[86\], respectively. Besides, \textit{L. platyphylla} is also used as estrogen-receptor agonists \[37\]. Compounds 63, 64, 68, 80, and 97 exhibit significant binding activity to estrogen-receptor α and/or β, as demonstrated by the SEAP reporter assay system in MCF-7 cells. What is more, polysaccharides extract of \textit{Liriope} plants could significantly increase the amount of salivary secretion, spleen, thymus and submandibular glands index to against sjogren syndrome \[87\].

\textbf{Conclusions and Research Prospects}

The abundant ingredients in \textit{Liriope} plants have displayed extensive biological and pharmacological functions, providing a scientific basis for their traditional therapeutic effects. Herein we propose a few future investigations to better understand its mechanisms of action and better its clinical use in the future.

First, biological availabilities of steroidal saponins are relatively limited due to their large molecular weight \[88-89\]. Consequently, it is crucial to exploit new formulations to increase their oral absorption. To a certain extent, \textit{L. muscari} and \textit{L. spicata} can be adopted as \textit{O. japonicus} in clinic due to their similar pharmacological activities according to Chinese Pharmacopoeia. However, some distinct discrimination still exists. On the one hand, \textit{Liriope} plants contain much more 25(S)-ruscogenin compounds than \textit{O. japonicas} in terms of number and contents. On the other hand, more furostanol saponins could be found in \textit{O. japonicus}. What is more, diosgenin-type saponins have been only reported to exist in \textit{O. japonicus} so far.

Second, great efforts have been devoted to exploring the activities of crude extracts. However, only limited compounds from \textit{Liriope} plants have been tested in pharmacological studies, such as DT-13, Op-B, etc. \[24, 47\]. High structural similarity, low contents as well as absence of overwhelming production in \textit{Liriope} plants have made the isolation, purification and stereochemistry determination challenging, resulting in difficulties to obtain enough amounts for pharmacological assays, especially for \textit{in vivo} testing. This is probably one of the major reasons that most of the bio-prospective experiments of isolated compounds have been conducted only \textit{in vitro}. For \textit{Liriope} steroidal saponins, to take full advantage of their anti-tumor effects, great efforts should be made in chem-
Liriope known that homoisoflavonoids could be used to distinguish Liriope plants from Ophiopogon [90-92]. But as we have summarized, a few homoflavonoids have been identified from Liriope plants [34-37]. For a rigorous academic attitude, we took a rather skeptical attitude to the reports. On the one hand, the raw material used in the experiments might be much more than ever before, or they were randomly mixed with the other folk medicines such as O. japonicus. On the other hand, with the rapid development of extractive and analytical technologies, the existence of homoisoflavonoids in Liriope plants as well as its chemotaxonomic significance will be revealed.

Overall, Liriope emerges as a treasure of the folk medicines in China and other Asian countries. Owing to various traditional uses and extensive therapeutic applications, it plays an important role for the indigenous health care. Ethnopharmacological, phytochemical and molecular pharmacological studies have revealed a variety of biological activities and pharmacological effects. These results provide remarkable evidences for the traditional application of Liriope plants. With the ever increasing interest in traditional medicines and botanical drugs worldwide, Liriope plants will capture more and more attentions among chemists and pharmacologists in the near future.

References
[27] Cheng ZH, Wu T, Yu BY, et al. Study on the chemical constituents of Liriope muscari [J]. China Tradit Herb Drugs,


