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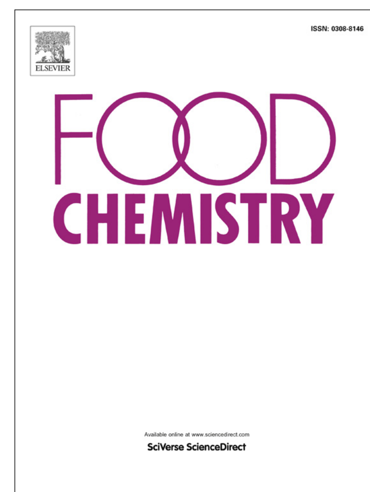

Antioxidants and α-glucosidase inhibitors from "Liucha" (young leaves and shoots of *Sibiraea laevigata*)

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1 Antioxidants and α-glucosidase inhibitors from "Liucha" (young
2 leaves and shoots of *Sibiraea laevigata*)

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20 **Abstract**

21 The young leaves and shoots of *Sibiraea laevigata*, known as "Liucha", are used as tea by Tibetans to
22 improve digestion after meals. Long-term consumption of "Liucha" will cause weight loss. In present
23 work, we reported on the isolation and NMR and chemical analysis-based elucidation of seven new
24 sorbitol *O*-caffeic acid ester derivatives named sorbitol ester A–G (**1–7**) and eighteen known phenolic
25 compounds from *S. laevigata*. All of the isolates were evaluated for their antioxidant and
26 *α*-glucosidase inhibitory activities. Among them sorbitol ester A (**1**), sorbitol ester D (**4**), sorbitol ester
27 F (**6**), sorbitol ester G (**7**), isoferulic acid (**15**), methyl caffeate (**18**), trans-*p*-hydroxycinnamic acid
28 (**19**), and kaempferol 3-*O*-*β*-D-(6"-*E*-*p*-coumaroyl)-glucopyranoside (**25**) showed more potent
29 *α*-glucosidase inhibitory activity than the clinical drug acarbose.

30 **Keywords:** *Sibiraea laevigata*, Sorbitol *O*-caffeic acid ester derivatives, Phenolic compounds,
31 Antioxidants, *α*-Glucosidase inhibitors

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32 **1. Introduction**

33 In recent years, a growing awareness of the relationship between functional foods and health has
34 led to more and more attention being paid to the development of physiological functional plants due to
35 their potential health benefits. “Liucha” is a kind of tea consumed by local people on the Qinghai-Tibet
36 Plateau. Anecdotally the consumption “Liucha” has some beneficial effects such as improving
37 digestion and protecting stomach. “Liucha” has long been used as Tibetan folk medicine to treat
38 indigestion and upset stomach. However, mixing “Luchia” into sheep feed is avoided since it has been
39 practically known to cause sheep weight-loss (Ito, et al., 2009). “Liucha” is made of the young leaves
40 and shoots of two *Sibiraea* species, *S. leavigata* and *S. angustata* (Duan, Li, Liu, & Yang, 2010).
41 Previous researches of “Liucha” have mainly focused on *S. angustata* which revealed the chemical
42 components of *S. angustata* (Ito et al., 2009; Wang, et al., 2013; Li, et al., 2010) and showed that the
43 extracts of *S. angustata* exhibited hypolipidemic, antitumor, antidiabetic and anti-obesity effects (Xie,
44 et al. 2014; Wei, Yang, Li, Duan, & Li, 2011; Ito, et al., 2009). However, studies about *S. leavigata* are
45 quite few (Yu, Shao, & Tao, 2014).

46 The free radicals and reactive oxygen species are considered to be harmful to human health and
47 trigger many diseases, such as cancer, coronary heart disease, arteriosclerosis, inflammatory disorders,
48 and aging processes (Wang, Yang, & Zhang, 2007). Phenolic components including tocopherols,
49 flavonoids, and polyphenolic compounds are typical natural antioxidants that can potentially provide
50 protection against the development of certain oxidation-linked chronic diseases (Hwang, Yoon, Lee,
51 Cha, & Kim, 2014; Spínola, Pinto, & Castilho, 2015). On the other hand, phenolic compounds had
52 been reported as glucosidase inhibitors used to reduce postprandial hyperglycemia induced by the
53 digestion of starch in the small intestine (Wan, Yuan, Cirello, & Seeram, 2012; Manzano &

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54 Williamson, 2010; Benalla, Bellahcen, & Bnouham, 2010). Previous researches showed that a series of
55 unique phenolic compounds were obtained from *S. angustata*. (Zhang, Li, Feng, Zhao & Wang, 1993;
56 Li, et al., 2015) *S. leavigata* bears extensive similarity to *S. angustata* and both of them were used as
57 the materials of "Liucha". Thus, the main objective of this work was to clarify the chemical
58 constituents of "Liucha" (*S. leavigata*) which has a variety of pharmaceutical functions and search for
59 new natural antioxidants and *α*-glucosidase inhibitors from "Liucha" (*S. leavigata*). In this work, we
60 isolated and identified the phenolic components of *S. leavigata* and evaluated their antioxidant and
61 *α*-glucosidase inhibitory activities.

62 **2. Materials and methods**

63 *2.1. General experimental procedure*

64 Optical rotations were acquired on a Jasco P-1020 digital polarimeter (JASCO Corporation, Tokyo,
65 Japan). Ultraviolet-visible (UV) spectra were measured on a Shimadzu UV2401A ultraviolet-visible
66 spectrophotometer (Shimadzu Corporation, Tokyo, Japan). Circular dichroism (CD) spectra were tested
67 on a Chirascan Circular Dichroism spectrometer (Applied Photophysics Ltd., Surrey, UK). Infrared (IR)
68 spectra were recorded on a Bruker Tensor-27 FI-IR spectrometer (Bruker, Germany) with KBr pellets.
69 Nuclear magnetic resonance (NMR) spectra measured on a Bruker Avance III-600 spectrometer
70 (Bruker, Rheinstetten, Germany), using tetramethylsilane as an internal standard. Chemical shifts were
71 reported in units of δ (ppm) and coupling constants (J) were expressed in Hz. HRESIMS were run on
72 an API QSTAR Pulsar-1 spectrometer and an Agilent 6230 Accurate-Mass spectrometer (Agilent
73 Technologies, Santa Clara, California, USA), respectively. Column chromatography (CC) were carried
74 out over silica gel (200–300 mesh, Qingdao Haiyang Chemical Co., Shandong, China) and MCI gel

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75 CHP 20P (75–150 μm, Mitsubishi Chemical Corporation, Tokyo, Japan). Pre-coated silica gel plates
76 (Qingdao Haiyang Chemical Co., Shandong, China) were used for thin-layer chromatography (TLC).
77 Detection was done under UV light (254 nm and 365 nm) and by spraying the plates with 10% sulfuric
78 acid followed by heating. An Agilent series 1200 (Agilent Technologies, Palo Alto, California, USA)
79 were used for analysis high performance liquid chromatography (HPLC). Semi-preparative HPLC was
80 done on a Hanbon series NP7005C (Hanbon Sci & Tech, Jiangsu, China), the columns used were
81 XCharge C18, XAqua C18, and XAmide (10 μm, 100 Å, 250 mm × 20 mm, Acchrom, Beijing, China).
82 Preparative HPLC was done on a Hanbon series NP7010C equipped with a dynamic axial compression
83 column DAC-HB50 C18 (10 μm, 100 Å, 400 mm × 50 mm, Hanbon Sci & Tech, Jiangsu, China)

84 *2.2. Plant material*

85 The young leaves and shoots of *S. leavigata* were collected in Huzhu City, Qinghai Province,
86 People's Republic of China, in August 2011, and identified by Professor Lijuan Mei (Northwest
87 Institute of Plateau Biology, Chinese Academy of Science). A voucher specimen (No. 0317608) was
88 deposited in the Key Laboratory of Tibetan Medicine Research.

89 *2.3. Preparation of n-BuOH fraction and isolation of compounds*

90 The air-dried *S. leavigata* young leaves and shoots (9.5 kg) were powdered and extracted with 95%
91 ethanol under reflux. After removal of the organic solvent, the ethanol extract was suspended in water
92 and then extracted successively with EtOAc and *n*-BuOH to obtain the *n*-BuOH fraction (300 g). The
93 *n*-BuOH fraction was chromatographed over a silica gel column chromatography (CC), eluting with a
94 $CHCl_3$-MeOH-H_2O gradient system (9:1:0.1–6:4:1, v/v/v), to give four fractions (Fr.1–4).

95 Fr.1 (80 g) was separated into thirteen sub-fractions Fr.11–13 on a MCI gel CHP 20P CC using

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96 gradient aqueous MeOH (10%–90%) eluent. Fr.11 (4.7 g) was further separated by semi prep-HPLC
97 (XAmide column, 90% MeCN with 0.2% formic acid (FA), flow rate: 15 mL/min) to give compounds
98 **22** (35 mg) and **23** (57 mg). Fr.12 (12.3 g) was subjected to semi prep-HPLC (XCharge C18 column,
99 23% MeCN with 0.2% FA, flow rate: 15 mL/min) to give compounds **13** (56 mg), **14** (78 mg), and
100 Fr.121 (101 mg). Compounds **21** (23 mg) and **24** (23 mg) were purified from Fr.13 (7.9 g) using the
101 same method. Fr.121 was further chromatographed over semi prep-HPLC (XAqua C18 column, 25%
102 MeCN with 0.2% FA, flow rate: 15 mL/min) to give compound **16** (33 mg).

103 Fr.2 (54 g) was submitted to MCI gel CHP 20P CC eluted with 90% aqueous MeOH to give Fr.21
104 (27 g), followed by prep-HPLC (DAC-HB50 C18 column, 30%–50% MeOH with 0.2% FA, over 60
105 min, flow rate: 60 mL/min) to afford Fr.211 (3.4 g). Compound **10** (2.0 g) was acquired by
106 re-precipitation from Fr.211 and the filtrate was subjected to semi prep-HPLC (XCharge C18 column,
107 30%–50% MeCN with 0.2% FA, over 60 min, flow rate: 15 mL/min) to yield compound **9** (78 mg).

108 Fr.3 (37 g) was subjected to prep-HPLC (DAC-HB50 C18 column, 30%–60% MeOH with 0.2%
109 FA, over 60 min, flow rate: 60 mL/min) to give nine fractions (Fr.31–39). Compound **25** (1.2 g) was
110 obtained by re-precipitation from Fr.31. The filtrate of Fr.31 was purified through semi prep-HPLC
111 (XCharge C18 column, 15% MeCN with 0.2% FA, flow rate: 15 mL/min) to yield compounds **20** (33
112 mg) and **11** (101 mg). Fr.34 (2.0 g) was purified by semi prep-HPLC (XCharge C18 column, 15%
113 MeCN with 0.2% FA, flow rate: 15 mL/min) to yield compounds **12** (198 mg) and **2** (12 mg). Fr.35
114 (3.1 g) was separated by semi prep-HPLC (XCharge C18 column, 20% MeCN with 0.2% FA, flow rate:
115 15 mL/min) to get compound **5** (15 mg). Fr.39 (900 mg) was purified by semi prep-HPLC (XCharge
116 C18 column, 25% MeCN with 0.2% FA, flow rate: 15 mL/min) to yield compound **7** (21 mg).

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117 Fr.4 (21 g) was subjected to semi prep-HPLC (XAqua C18 column, 10%–30% MeCN with 0.2%
118 FA, over 60 min, flow rate: 15 mL/min) to give compound **15** (13 mg) and two sub-fractions (Fr.41 and
119 42). Fr.41 (5.1 g) was purified trough semi prep-HPLC (XCharge C18 column, 10%–30% MeCN with
120 0.2% FA, over 60 min, flow rate: 15 mL/min) to yield compounds **17** (23 mg), **1** (12 mg), **8** (340 mg),
121 **4** (13 mg), and **18** (56 mg). Fr.42 (7.0 g) was purified on semi prep-HPLC (XCharge C18 column,
122 10%–30% MeCN with 0.2% FA, over 80 min, flow rate: 15 mL/min) to yield compounds **19** (123 mg),
123 **3** (10 mg), and **6** (96 mg).

124 *2.4. Assay of DPPH and $ABTS^+$ radical-scavenging*

125 DPPH assay was performed as described in previous paper (Brand-Williams, Cuvelier, & Berset,
126 1995), Radical scavenging activity against $ABTS^+$ was performed according to a previously reported
127 protocol (Re, et al., 1999). Ascorbic acid used as positive control was purchased from Sigma-Aldrich
128 (St. Louis, MO, USA). In DPPH radical scavenging assay, 1,1-Diphenyl-2-picrylhydrazyl radical
129 (DPPH, Sigma-Aldrich, St. Louis, MO, USA) was dissolved in ethanol to a concentration of 250 μM
130 and allowed the mixture to stand in the dark at room temperature for 12–16 h. The DPPH stock
131 solution was diluted with ethanol to an absorbance of 0.700 (± 0.020) at 517 nm before use. The
132 inhibitory activity was determined by following equation: inhibitory activity (%) = $[A_{blank} -$
133 $A_{sample}]/A_{blank} \times 100$. A_{sample} is the absorbance of diluted DPPH radical solution mixed with the test
134 compound measured at 517 nm, and A_{blank} is the absorbance of DPPH radical solution mixed with
135 ethanol solution measured at 517 nm. The IC_{50} values were obtained through GraphPad Prism 6.02 and
136 denoted the concentration of sample required to inhibit 50% of DPPH radicals. In $ABTS^+$ radical
137 scavenging assay, 2,2'-Azino-di(3-ethyl-benzthiazoline sulphonic acid (ABTS, Sigma-Aldrich, St.
138 Louis, MO, USA) was dissolved in water to a 7 mM concentration, and then add potassium persulfate

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139 to a final concentration of 2.45 mM, allowing the mixture to stand in the dark at room temperature for
140 12–16 h to obtain ABTS radical cation ($ABTS^{+}$). The $ABTS^{+}$ solution was diluted with ethanol to an
141 absorbance of 0.700 (± 0.020) at 734 nm. $ABTS^{+}$ inhibitory activity (%) = $[A_{blank} - A_{sample}]/A_{blank} \times 100$,
142 and A_{sample} is the absorbance of diluted $ABTS^{+}$ solution mixed with the test compound measured at 734
143 nm, and A_{blank} is the absorbance of $ABTS^{+}$ radical solution mixed with ethanol solution measured at
144 734 nm. The percentage inhibition and IC_{50} value was calculated.

145 *2.5. α-Glucosidase assay*

146 The *α*-glucosidase inhibition assay was adapted as described previously (Collins, Ng, Fong, Wan,
147 & Yeung, 1997). 0.26 U of *α*-glucosidase from *Saccharomyes cerevisiae* purchased from
148 Sigma-Aldrich (St. Louis, MO, USA) were diluted to 0.1 M phosphate buffer consisting of Na_2HPO_4
149 and KH_2PO_4 (pH 6.5). The 25 *μ*L test compound and 25 *μ*L *α*-glucosidase were preincubated in 96-well
150 plates at 37 °C for 15 min. The reaction was initiated by adding 50 *μ*L of 0.3125 mM pNPG
151 (4-nitrophenyl *α*-D-glucopyranoside, Aladdin, Shanghai, China) as substrate. The plate was incubated
152 for an additional 15 min at 37 °C, followed by the addition of 50 *μ*L of 0.2 M Na_2CO_3 to stop the
153 reaction. All test compounds were prepared in DMSO then diluted with the buffer. The final
154 concentrations of tested compounds were between 0.03 and 250 *μ*g/mL. The reaction was monitored by
155 change of absorbance at 405 nm using a Dimension RxL Max clinical chemistry system Enspire
156 MP150 (Siemens Healthineers, Germany).

157 *2.6. Alkaloid hydrolysis and polyol analysis of compounds **1**–7*

158 Alkaloid hydrolysis and polyol analysis of compounds **1–7** was performed as described previously
159 (Li, et al., 2015). Each of compounds **1–7** (each 5 mg) was refluxed in 2 M KOH (2 mL) at 100 °C for

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160 1 h and neutralized with HCl. The polyhydric alcohol was obtained through polyamide column
161 chromatography and identified as sorbitol by TLC comparison with the reference as well as
162 comparison of NMR with data the reference values.

163 *2.7. Statistical analysis*

164 All experiments were conducted in triplicates and the inhibitory rates and IC_{50} values were
165 expressed as mean ± standard deviation (SD). Data process and analysis were performed on Microsoft
166 excel 2010 and GraphPad Prism 6.02 (GraphPad Software Inc., San Diego, CA, USA).

167 *2.8. Spectroscopic data of compounds **1**–**7***

168 Sorbitol ester A (**1**). Colorless gum. $[\alpha]_D^{25.7}$ –47.9 (*c* 0.08, MeOH); UV (MeOH) λ_{max} nm (log ε):
169 204 (3.71), 244 (3.48), 332 (3.56); CD (MeOH, c = 2.3×10^{-4} mol L^{-1}); λ_{max} nm ($\Delta\varepsilon$): 203 (–2.3), 299
170 (2.5), 348 (–1.7); IR (KBr) ν_{max}: 3397, 2969, 1691, 1604, 1519, 1445, 1279, 1178 cm^{-1}; NMR
171 spectroscopic data see Tables 1 and 2; HRESIMS *m/z*: 507.1510 $[M+H]^+$ (calculated for $C_{24}H_{27}O_{12}$
172 507.1497).

173 Sorbitol ester B (**2**). Colorless gum. $[\alpha]_D^{25.3}$ –29.7 (*c* 0.29, MeOH); UV (MeOH) λ_{max} nm (log ε):
174 204 (3.46), 211 (3.46), 241 (3.32), 300 (3.36), 326 (3.40); CD (MeOH, c = 3.0×10^{-4} mol L^{-1}); λ_{max} nm
175 ($\Delta\varepsilon$): 199 (-1.1), 299 (1.4), 340 (-1.7); IR (KBr) ν_{max}: 3411, 2937, 2842, 1692, 1608, 1513, 1442, 1266,
176 1161 cm^{-1}; NMR spectroscopic data see Tables 1 and 2; HRESIMS *m/z* 521.1678 $[M+H]^+$ (calculated
177 for $C_{25}H_{29}O_{12}$ 521.1654).

178 Sorbitol ester C (**3**). Colorless gum. $[\alpha]_D^{25.7}$ +7.1 (*c* 0.15, MeOH); UV (MeOH) λ_{max} nm (log ε): 204
179 (3.57), 213 (3.56), 242 (3.38), 333 (3.50); CD (MeOH, c = 3.0×10^{-4} mol L^{-1}); λ_{max} nm ($\Delta\varepsilon$): 209 (–2.5),
180 289 (–2.2), 345 (3.7); IR (KBr) ν_{max}: 3397, 2969, 1692, 1602, 1520, 1445, 1280, 1160 cm^{-1}; NMR

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181 spectroscopic data see Tables 1 and 2; HRESIMS *m/z* 507.1519 $[M+H]^+$ (calculated for $C_{24}H_{27}O_{12}$
182 507.1497).

183 Sorbitol ester D (**4**). Colorless gum. $[\alpha]_D^{25.7}$ -38.0 (*c* 0.10, MeOH); UV (MeOH) λ_{max} nm (log ε):
184 205 (3.56), 333 (3.36); CD (MeOH, *c* = 3.0×10^{-4} mol L^{-1}); λ_{max} nm ($\Delta\varepsilon$): 200 (–2.4), 290 (1.1), 343
185 (–0.9); IR (KBr) ν_{max}: 3412, 2970, 1694, 1604, 1519, 1445, 1279, 1166 cm^{-1}; NMR spectroscopic data
186 see Tables 1 and 2; HRESIMS *m/z* 507.1501 $[M+H]^+$ (calculated for $C_{24}H_{27}O_{12}$ 507.1497).

187 Sorbitol ester E (**5**). Colorless gum. $[\alpha]_D^{25.4}$ –15.8 (*c* 0.24, MeOH); UV (MeOH) λ_{max} nm (log ε):
188 204 (3.62), 213 (3.61), 241 (3.48), 303 (3.51), 327 (3.56); IR (KBr) ν_{max}: 3384, 2950, 2844, 1682, 1605,
189 1514, 1442, 1266, 1165 cm^{-1}; NMR spectroscopic data see Tables 1 and 2; HRESIMS *m/z* 521.1665
190 $[M+H]^+$ (calculated for $C_{25}H_{29}O_{12}$ 521.1654).

191 Sorbitol ester F (**6**). Colorless gum. $[\alpha]_D^{25.8}$ –25.8 (*c* 0.12, MeOH); UV (MeOH) λ_{max} nm (log ε):
192 203 (3.67), 215 (3.65), 242 (3.49), 306 (3.56), 331 (3.66); IR (KBr) ν_{max}: 3421, 2959, 1689, 1603, 1517,
193 1444, 1278, 1162 cm^{-1}; NMR spectroscopic data see Tables 1 and 2; HRESIMS *m/z* 669.1828 $[M+H]^+$
194 (calculated for $C_{33}H_{33}O_{15}$ 669.1814).

195 Sorbitol ester G (**7**). Colorless gum. $[\alpha]_D^{24.5}$ -28.6 (*c* 0.17, MeOH); UV (MeOH) λ_{max} nm (log ε):
196 203 (3.68), 215 (3.65), 249 (3.48), 307 (3.52), 333 (3.56); IR (KBr) ν_{max}: 3422, 2937, 1688, 1607, 1513,
197 1442, 1267, 1160 cm^{-1}; NMR spectroscopic data see Tables 1 and 2; HRESIMS *m/z* 683.1980 $[M+H]^+$
198 (calculated for $C_{34}H_{35}O_{15}$ 683.1970).

199 3. Results and discussion

200 *3.1. Structure elucidation of compounds*

201 The *n*-BuOH fraction of *S. leavigata* was subjected to the column chromatography over silica gel,

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202 MCI gel CHP 20P, preparative and semi-preparative HPLC to afford compounds **1–25** including seven
203 new sorbitol *O*-caffeic acid ester derivatives, sorbitol ester A–G (**1–7**) (Figure 1) and eighteen known
204 phenolic compounds. The known compounds were each identified as 1,6-sorbitol-*O*-dicaffeic acid ester
205 (**8**) (Li, et al. 2015), icariside H_1 (**9**) (Matsushita, Miyase, & Ueno, 1991),
206 9-*O*-*β*-D-glucopyranosyl-3,4-dimethoxy-cinnamic acid (**10**) (Hu, Shi, & Chen, 2012),
207 1-feruloyl-*β*-D-glucopyranoside (**11**) (Takaya, Kondo, Furukawa, & Niwa, 2003),
208 9-*O*-*β*-D-glucopyranosyl-4-methoxy-cinnamic acid (**12**) (Hu, et al. 2012), (*E*)-ferulic acid (**13**) (Chung,
209 et al., 2011), 3-(3,4-dimethoxyphenyl)prop-2-enoic acid (**14**) (Chakraborti, et al., 2011), isoferulic acid
210 (**15**) (Souliman, Barakat, El-Mousallamy, Marzouk, & Nawwa, 1991), 4-methoxy cinnamic acid (**16**)
211 (Vishnoi, Agrawal, & Kasana, 2009), caffeic acid (**17**) (Chung, et al., 2011), methyl caffeate (**18**)
212 (Chung, et al., 2011), trans-*p*-hydroxycinnamic acid (**19**) (Chung, et al., 2011),
213 4-hydroxy-3-methoxybenzeneethanol (**20**) (Cardinal, Azelmat, Grenier, & Voyer, 2016), 3,4-dihyroxy
214 benzaldehyde (**21**) (Fu, Meng, Li, & Wu, 1992), *p*-vanillin (**22**) (Chung, et al., 2011),
215 4-hydroxybenzoic acid (**23**) (Chung, et al., 2011), vanillic acid (**24**) (Chung, et al., 2011), and
216 kaempferol 3-*O*-*β*-D-(6''-*E*-*p*-coumaroyl)-glucopyranoside (**25**) (Refaat, et al., 2015) by comparison of
217 their ^{1}H, ^{13}C NMR, and MS data with those reported in the literatures. It was noted that except **15** and
218 **16** all compounds were isolated from this plant for the first time.

219 Compound **1** was isolated as a colorless gum. Its molecular formula was determined as
220 $C_{24}H_{26}O_{12}$, on the basis of HRESIMS spectrum. The ^{1}H and ^{13}C NMR spectra of **1** (Tables 1
221 and 2) revealed the presence of two *trans*-configuration double bonds [δ_H 7.59, (1H, d, J =
222 15.9), 6.29, (1H, d, J = 15.9), 7.56, (1H, d, J = 15.9), and 6.26, (1H, d, J = 15.9); δ_C 114.9,
223 147.2, 115.1, and 147.4], two carbonyl carbons (δ_C 169.2 and 168.8) as well as two

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224 1,3,4-trisubstituted benzene rings [δ_H 7.02, (2H, brs), 6.73, (2H, d, J = 8.1), and 6.87, (2H, m);
225 δ_C 115.3, 116.6, 123.0, 127.7, 146.8, and 149.6]. All of these signals indicated that there were
226 two caffeoyl groups in the molecular. In addition, four oxygenated methines and two
227 oxymethylenes were also observed in the ^{1}H NMR spectrum. All above mentioned data were
228 similar to the signals of 1,6-sorbitol-*O*-dicaffeic acid ester (**8**) (Li, et al., 2015). And the UV and
229 IR spectroscopic features of **1** were similar to those of **8** indicating that **1** was an isomer of **8**. The
230 ^{1}H-^{1}H COSY correlations (Figure 2) showed the existence of a sorbitol chain, which was further
231 confirmed by the alkaloid hydrolysis of compound **1**. A polyhydric alcohol was obtained and
232 identified as sorbitol by TLC and NMR comparison with the reference (Li, et al., 2015). Two
233 caffeoyl moieties were attached to C-1 and C-5 or C-2 and C-6 of the sorbitol, respectively, which was
234 verified by HMBC cross-peaks (Figure 2) from H-1 or H-6 (δ_H 4.32, m) and H-5 or H-2 (δ_H 5.08, m) to
235 the corresponding carbonyl carbons of the caffeoyl groups, respectively. The locations of the caffeoyl
236 groups were further determined according to the CD exciton chirality method (Figure 3) reported by
237 Weckerle, Schreier, & Humpf, (2001). In compound **1**, the exciton coupling between the two transition
238 dipoles of the chromophores results in a negative split CD curve with a first Cotton effect (CE) at 348
239 nm ($\Delta\varepsilon$ = –1.7) and a positive second CE at 299 nm ($\Delta\varepsilon$ = +2.5). Thus, two caffeoyl moieties should
240 be attached to C-1 (δ_C 66.6) and C-5 (δ_C 75.6), respectively. This was also confirmed by shielded signal
241 of C-5 and deshielded signal of C-6 (δ_C 75.6 and 61.7 for compound **1**) compared with the
242 corresponding carbon (δ_C 70.8 and 66.7) reported in the reference (Li, et al., 2015). Thus, the structure
243 of **1** was determined and named as sorbitol ester A.

244 Compound **2** had the molecular formula of $C_{25}H_{28}O_{12}$ as established by the protonated molecular
245 ion at *m/z* 521.1678 $[M + H]^+$ and ^{13}C NMR data. The ^{1}H and ^{13}C NMR data (Tables 1 and 2) of **2**

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246 showed similarities to those of compound **1** except for an additional methoxy group [δ_H (3H, 3.84, s),
247 δ_C 56.3] in compound **2**. According to ^{1}H-^{1}H COSY and HMBC correlations (Figure 2) as well as the
248 similar CD spectroscopic features, the acyl groups were proved to be located at C-1 (δ_C 66.3) and C-5
249 (δ_C 75.4). The methoxy was located at C-4' by the HMBC cross-peaks from protons of methoxy [δ_H
250 3.84 (3H, s)] to C-4' (δ_C 151.4) (Figure 2). The structure of compound **2** was defined (Figure 1) and
251 named sorbitol ester B.

252 Compound **3** was a colorless gum and had a molecular formula of $C_{24}H_{26}O_{12}$ as assigned by the
253 protonated molecular ion at *m/z* 507.1519 $[M + H]^+$ and ^{13}C NMR data. The UV, IR, and NMR
254 spectroscopic features of **3** were similar to those of **1** indicating that **3** could be an isomer of **1**.
255 Inspection of its 1D and 2D NMR signals revealed the existence of sorbitol chain and two caffeoyl
256 moieties. And the caffeoyl moieties could be attached to C-1 and C-2 or C-5 and C-6, respectively,
257 which was verified by HMBC correlations (Figure 2) from H-1 or H-6 (δ_H 4.42 and 4.75) and H-2 or
258 H-5 (δ_H 5.35) to the carbonyl carbons. The CD spectrum of **3** exhibited opposite CEs at 345 nm ($\Delta\varepsilon$ =
259 +3.7) and 289 nm ($\Delta\varepsilon$ = –2.2) to those of **1**. Based on the ^{1}H-^{1}H COSY and HMBC correlations
260 (Figure 2) combined with the CD exciton chirality method (Figure 3) (Weckerle, et al., 2001), two
261 caffeoyl moieties should be located at C-1 (δ_C 64.1) and C-2 (δ_C 72.8), respectively. Thus, the structure
262 of **3** was determined and named as sorbitol ester C.

263 The molecular formula of compound **4** was determined to be $C_{24}H_{26}O_{12}$ on the basis of its
264 HRESIMS and ^{13}C NMR spectra. ^{1}H and ^{13}C NMR spectroscopic data and coupling patterns of the
265 aromatic area protons (Tables 1 and 2) suggested that there are two caffeoyl groups in compound **4**.
266 NMR data (Tables 1 and 2), UV, and IR spectra of **4** resembled those of **3**. However, **4** exhibited
267 opposite Cotton effects at 343 nm ($\Delta\varepsilon$ = –0.9) and 290 nm ($\Delta\varepsilon$ = +1.1) to those of **3**. On the basis of

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268 ^{1}H-^{1}H COSY and HMBC correlations (Figure 2) and the CD exciton chirality method (Figure 3)
269 (Weckerle, et al., 2001), the two caffeoyl groups were located at C-5 (δ_C 74.8) and C-6 (δ_C 64.2). The
270 structure of compound **4** was therefore elucidated and named as sorbitol ester D.

271 Compound **5** was isolated as a colorless gum. Its molecular formula was determined to be
272 $C_{25}H_{28}O_{12}$ on the basis of NMR and HRESIMS spectra. Its IR spectrum showed absorption bands at
273 3384, 2950, 2844, 1682, 1605, 1514, 1442, 1266, and 1165 cm^{-1} ascribable to hydroxyl groups, alkyl
274 groups, ester groups, and aromatic rings. The spectroscopic data of compound **5** also showed high
275 resemblance to that of **8** (Li, et al., 2015). Whereas, the molecular weight of **5** was 14 mass
276 units larger than that of **8**, which indicated that one hydroxy in **8** was replaced by a methoxy in
277 compound **5**. Based on the ^{1}H-^{1}H COSY, HMBC, and NOE correlations (Figure 2), an
278 isoferuloyl group and a caffeoyl group were attached to the head or tail of sorbitol of **5** by ester
279 linkages, respectively. Because of the high symmetry of the sorbitol, we didn't find any
280 effective method to determine the locations of the acyl groups. Thus, we reported the planar
281 structure of **5** as shown in Figure 1 and named as sorbitol ester E.

282 Compound **6** was colorless gum with a molecular formula of $C_{33}H_{32}O_{15}$ deduced by HRESIMS
283 spectrum, indicating 18 degrees of unsaturation. The ^{1}H and ^{13}C NMR spectra of **6** (Tables 1 and 2)
284 displayed the presence of six trans olefinic bonds [δ_H 6.25 (3H, d, J = 15.9) and δ_H 7.51–7.53 (3H, d, J
285 = 15.9) and δ_C 147.6 (C-7'), 148.0 (C-7''), 147.5 (C-7''), and 114.8 (C-8', 8'', 8''')], three
286 1,3,4-trisubstituted benzene rings, and three carbonyl carbons at δ_C 169.2 (C-9'), 168.5 (C-9''), and
287 169.0 (C-9'''). All of these signals revealed three caffeoyl moieties in **6**. In addition to three caffeoyl
288 moieties, four oxygenated methines and two oxymethylenes resulting from the sorbitol moiety could be
289 found in the NMR spectra of **6** which were confirmed through 2D NMR spectroscopic method (Figure

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290 2). Furthermore, comparing the spectroscopic data of compounds **6** with those of **8** showed their
291 structural similarities, except that the deshielded carbon signal of C-5 or C-2 of the sorbitol and an
292 additional caffeoyl moiety in **6**, revealing that the hydroxyl of C-5 or C-2 in compound **6** was also
293 substituted with caffeoyl moiety. Although the additional caffeoyl moiety as a chromophore was
294 located at a chiral carbon, no obvious cotton effect was observed in the CD spectrum of **6**. Thus, we
295 can only report the planar structure of **6** and named as sorbitol ester F (Figure 1).

296 The molecular formula of compound **7** was deduced to be $C_{34}H_{34}O_{15}$ according to HRESIMS and
297 NMR spectra. The ^{1}H and ^{13}C NMR spectroscopic data of compound **7** (Tables 1 and 2) resembled
298 those of **6**, except for a methoxy group in compound **7** instead of a hydroxyl group in **6,** which was also
299 confirmed by 1D and 2D NMR spectra (Figure 2). Furthermore, the HMBC correlations from protons
300 of methoxy, H-2''' and H-6''' to C-4''' at δ_C 151.4 conformed that methoxy was located at C-4''' (Figure
301 2). And the HMBC correlations (Figure 2) from H-7''' to C-6''' and C-9''' and from H-6 [δ_H 4.37 (1H, dd,
302 *J* = 11.5, 3.8 Hz) and 4.43 (1H, dd, *J* = 12.3, 6.4 Hz)] to C-9''' conformed the isoferuloyl group attached
303 to C-6 (δ_C 64.1). The planar structure of compound **7** was therefore elucidated as shown in Figure 1 and
304 named as sorbitol ester G.

305 *3.2. Antioxidant properties of the compounds*

306 Phenolic compounds, a kind of natural antioxidant, can potentially provide protection against the
307 development of certain oxidation-linked chronic diseases (Škerget, et al., 2005). The antioxidant
308 activities of compounds **1**–**25** isolated from *S. laevigata* were determined though DPPH and $ABTS^{+}$
309 radical scavenging assay. The results of these experiments have been shown in Table 3. Comparing
310 with the positive control ascorbic acid, compounds **1**–**8**, **13**, **17**, **18**, **21**, and **23** showed stronger or
311 similar DPPH radical inhibitory activity (2.8–18.3 μg/mL). The results of the $ABTS^{+}$ radical

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312 scavenging assay showed that compounds **6**, **8**, **13**, **17**, **18**, **21**, and **23** displayed more potent
313 antioxidant activity than ascorbic acid. Above results suggested that these phenolic compounds could
314 be considered as main antioxidant components of “Liucha”.

315 *3.3. α-Glucosidase inhibitory activity of the compounds*

316 Type 2 diabetes mellitus is a chronic metabolic disease, which affects millions of people worldwide.
317 The disease is characterized by chronically elevated blood glucose concentrations (hyperglycaemia),
318 which result in comorbidities and multi-organ dysfunction (Gaitonde, et al., 2016). Controlling the
319 blood glucose concentration is an effective therapy for diabetes and many antidiabetic therapies focus
320 on decreasing the level of blood glucose (Blonde, 2012; Yki-Järvinen, 2002). *α*-Glucosidase inhibitors
321 can reduce postprandial hyperglycemia by slowing the digestion of carbohydrates in the intestines
322 (Bolen, et al., 2007). For example, acarbose, a well-known and efficacious *α*-glucosidase inhibitor, is a
323 post-prandial acting antidiabetic drug (Singla, Singh, & Dubey, 2016). Although a number of medicines
324 are available, diet therapy as adjuvant treatment or prevention of diabetes also aroused great interest. In
325 order to explore the hypoglycemic function of “Liucha”, all isolated compounds were evaluated for
326 their *α*-glucosidase inhibitory activity (Table 3). Overall, among all the isolates, four sorbitol *O*-caffeic
327 acid ester derivatives (**3**, **4**, **6**, and **7**), two phenylpropanoids (**15** and **18**), a benzaldehyde (**21**) and a
328 flavonoid glycoside (**25**) showed stronger *α*-glucosidase inhibitory activity than the positive control
329 acarbose. According to the *α*-glucosidase inhibitory activity results, we find that the caffeoyl
330 substituent in sorbitol *O*-caffeic acid ester derivatives could enhancing the *α*-glucosidase inhibitory
331 activity and the *α*-glucosidase activity will decline a lot when the hydroxy of the caffeoyl was replaced
332 by methoxy group.

333 **4. Conclusions**

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334 Considering the various functions and values of "Liucha" (young leaves and shoots of *S. laevigata*),
335 it is clearly important to figure out its chemical constituents. Phytochemical study of "Liucha" resulted
336 in seven new sorbitol *O*-caffeic acid ester derivatives (**1–7**) together with 18 known phenolic
337 compounds. To our knowledge, all compounds were reported from this plant for the first time except **15**
338 and **16**. Phenolics have been extensively studied for their human health benefit (Crozier, Jaganath, &
339 Clifford, 2009). In our study, a series of phenolic compounds with strong antioxidant and *α*-glucosidase
340 inhibitory activities was identified through isolation, structural elucidation and in vitro bioactive tests.
341 It is worth noting that a sorbitol *O*-tricaffeic acid ester, compounds **6**, showed very strong
342 *α*-glucosidase inhibitory activity with the IC_{50} value of 0.2 ± 0.1 *μ*g/mL. A large body of data
343 supporting the health benefits of phenolics and our current bioassay data suggest that "Liucha" may be
344 a potential resource for developing antioxidants and diabetic agents. However, further research on the
345 toxicity of antioxidant and *α*-glucosidase inhibitory phenolic compounds and in vivo physiological
346 functions of these phenolics should be carried out.

347 **Notes**

348 The authors declare no competing financial interest.

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352 Compounds, Strategic Biological Resources Service Network Programme of Chinese Academy of
353 Sciences (ZSTH-027).

354 **Appendix A. Supplementary data**

355 Supplementary data associated with this article can be found, in the online version.

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Figure captions

Fig. 1. Chemical structures of compounds **1–7**.

Fig. 2. Key HMBC, ^{1}H-^{1}H COSY and NOE correlations of **1–7**.

Fig. 3. CD spectra, preferred conformation, and the predicted sign of the first Cotton effect of **1–4**. (bold lines indicate transition dipoles).

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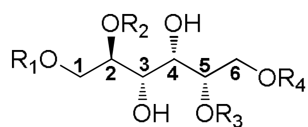
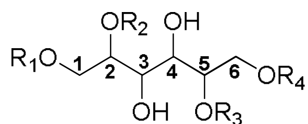
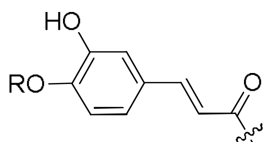
Fig. 1.



1 R_1 = *E*-caffeoyl, R_2 = H, R_3 = *E*-caffeoyl, R_4 = H
2 R_1 = *E*-isoferuloyl, R_2 = H, R_3 = *E*-caffeoyl, R_4 = H
3 R_1 = *E*-caffeoyl, R_2 = *E*-caffeoyl, R_3 = H, R_4 = H
4 R_1 =H , R_2 = H, R_3 = *E*-caffeoyl, R_4 = *E*-caffeoyl



5 R_1 = *E*-s-isoferuloyl, R_2 = H, R_3 = H, R_4 = *E*-caffeoyl
6 R_1 = *E*-caffeoyl, R_2 = *E*-caffeoyl, R_3 = H, R_4 = *E*-caffeoyl
7 R_1 = *E*-caffeoyl, R_2 = *E*-caffeoyl, R_3 = H, R_4 = *E*-isoferuloyl



E-caffeoyl R = H
E-isoferuloyl R = CH_3

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Fig. 2.

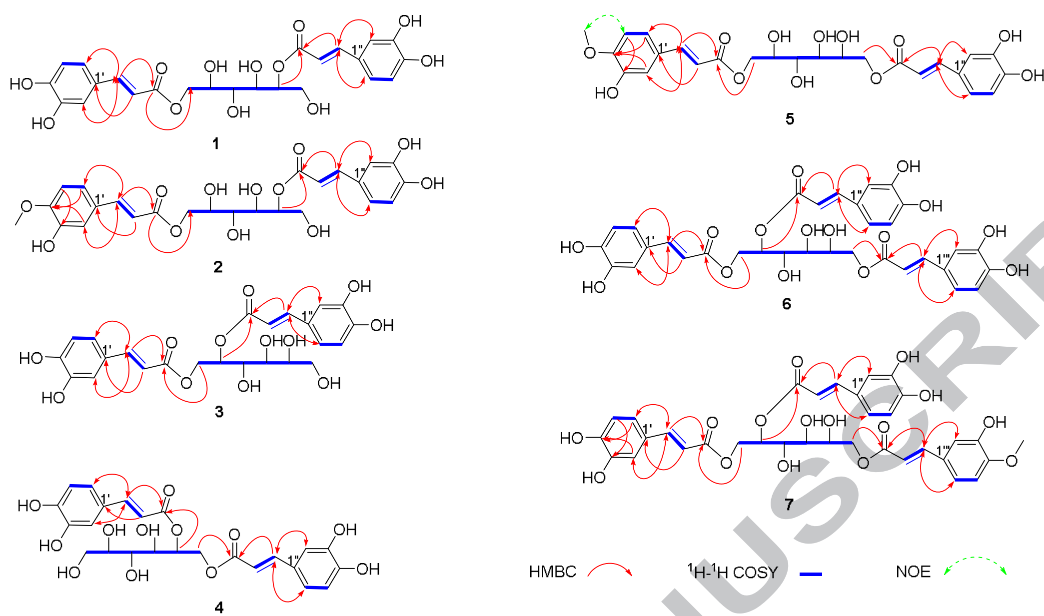

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Fig. 3.

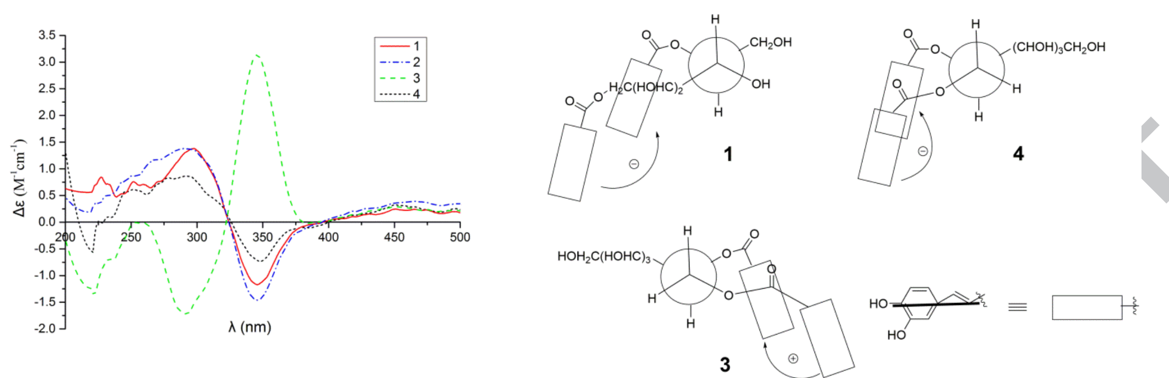

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Table 1

^{1}H NMR spectroscopic data of compounds **1**–**7** at 600 MHz (δ in ppm, J in Hz)

Pos.	**1**^{a}	**2**^{a}	**3**^{a}	**4**^{a}	**5**^{b}	**6**^{a}	**7**^{a}
1a	4.32, m	4.32, m	4.42, dd (12.1, 5.8)	3.65, overlapped	4.11, dd (11.4, 7.4)	4.49, dd (12.4, 5.6)	4.46, dd (12.4, 5.8)
1b			4.75, d (12.1)	3.81, dd (11.2, 3.1)	4.21, dd (11.4, 3.8)	4.81, d (10.8)	4.79, d (10.1)
2	4.04, overlapped	4.05, overlapped	5.35, t (5.6)	3.73, m	3.85, m	5.42, brs	5.39, m
3	3.71, m	3.73, brs	4.05, d (7.6)	3.64, overlapped	3.74, m	4.17,overlapped	4.12, overlapped
4	4.02, overlapped	4.02, overlapped	3.75, overlapped	4.17, d (5.8)	3.50, d (8.3)	3.84, overlapped	3.80, overlapped
5	5.08, m	5.09, brs	3.83, m	5.44, td (6.4, 2.7)	3.77, m	4.17, overlapped	4.12, overlapped
6a	3.88, m	3.88, m	3.66, dd (11.3, 5.70)	4.40, dd (12.2, 6.8)	4.04, dd (11.3, 6.8)	4.39, d (8.8)	4.37, dd (11.5, 3.8)
6b	3.95, m	3.95, d (10.9)	3.73, overlapped	4.61, dd (12.2, 2.7)	4.33, dd (11.3, 2.5)	4.45, m	4.43, dd (12.3, 6.4)
2'	7.02, brs	7.00,brs	7.05, brs	7.05, brs	7.07, d (2.1)	7.03, brs	7.01, brs
5'	6.73, d (8.1)	6.74, d (7.8)	6.78, d (7.9)	6.75, d (8.1)	6.93, d (8.4)	6.73,overlapped	6.71, d (8.1)
6'	6.87, m	6.86, d (7.8)	6.94, overlapped	6.93, d (8.1)	7.09, d (8.4, 2.1)	6.87, d (7.9)	6.84, overlapped
7'	7.56, d (15.9)	7.54, d (15.9)	7.60, d (15.9)	7.54, d (15.8)	7.51, d (15.9)	7.55, d (15.9)	7.55, d (15.9)
8'	6.26, d (15.9)	6.25, d (15.9)	6.31, d (15.9)	6.25, d (15.8)	6.31, d (15.9)	6.25, d (15.9)	6.28, d (15.9)
2''	7.02, brs	7.00, brs	7.05, brs	7.02, brs	7.02, d (1.9)	7.05, brs	7.01, brs
5''	6.73, d (8.1)	6.72, d (7.8)	6.78, d (7.9)	6.76, d (8.1)	6.74, d (8.2)	6.75, d (8.1)	6.77, d (8.1)
6''	6.87, m	6.86, d (7.8)	6.94, overlapped	6.95, d (8.1)	6.96, dd (8.2, 1.9)	6.80, overlapped	6.84, overlapped
7''	7.59, d (15.9)	7.58, d (15.9)	7.55, d (15.9)	7.60, d (15.8)	7.48, d (15.9)	7.51, d (15.9)	7.58, d (15.9)
8''	6.29, d (15.9)	6.28, d (15.9)	6.28, d (15.9)	6.33, d (15.8)	6.24, d (15.9)	6.25, d (15.9)	6.28, d (15.9)
2'''						7.02, brs	7.04, brs
5'''						6.71, overlapped	6.71, d (8.1)
6'''						6.80, overlapped	6.90, dd (8.1, 1.4)
7'''						7.53, d (15.9)	7.56, d (15.9)
8'''						6.25, d (15.9)	6.27, d (15.9)
-OCH$_3$		3.84, s			3.79, s		3.82, s

^{a} Data were recorded in CD_3OD; ^{b}Data were recorded in DMSO-d_6

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Table 2

^{13}C NMR spectroscopic data of compounds **1**–**7** (δ in ppm)

Pos.	**1**[a]	**2**[a]	**3**[a]	**4**[a]	**5**[b]	**6**[a]	**7**[a]
1	66.6, CH_2	66.3, CH_2	64.1, CH_2	64.9, CH_2	65.8, CH_2	64.1, CH_2	64.1, CH_2
2	72.5, CH	72.4, CH	72.8, CH	72.8, CH	70.7, CH	72.9, CH	73.9, CH
3	71.0, CH	70.6, CH	71.6, CH	72.2, CH	69.1, CH	71.1, CH	71.0, CH
4	70.9, CH	70.9, CH	70.6, CH	70.1, CH	71.1, CH	71.1, CH	71.0, CH
5	75.6, CH	75.4, CH	74.9, CH	74.8, CH	68.6, CH	72.5, CH	72.5, CH
6	61.7, CH_2	61.7, CH_2	64.0, CH_2	64.2, CH_2	66.5, CH_2	66.7, CH_2	66.5, CH_2
1'	127.7, C	128.6, C	127.7, C	127.8, C	126.9, C	127.8, C	127.7, C
2'	115.3, CH	114.7, CH	115.2, CH	115.3, CH	114.1, CH	115.5, CH	114.9, CH
3'	146.8, C	147.7, C	146.8, C	146.8, C	146.6, C	146.6, C	147.0, C
4'	149.6, C	151.4, C	149.7, C	149.6, C	150.0, C	149.5, C	149.6, C
5'	116.6, CH	112.4, CH	116.5, CH	116.5, CH	111.9, CH	116.9, CH	116.6, CH
6'	123.0, CH	122.7, CH	123.2, CH	123.3, CH	121.1, CH	123.4, CH	123.3, CH
7'	147.2, CH	146.7, CH	147.6, CH	147.4, CH	144.6, CH	147.6, CH	147.4, CH
8'	114.9, CH	115.7, CH	114.9, CH	114.9, CH	115.2, CH	114.8, CH	115.8, CH
9'	169.2, C	168.9, C	168.5, C	169.0, C	166.5, C	169.4, C	169.2, C
1"	127.7, C	127.6, C	127.7, C	127.8, C	125.5, C	127.8, C	128.7, C
2"	115.3, CH	115.2, CH	115.2, CH	115.3, CH	114.7, CH	115.5, CH	115.3, CH
3"	146.8, C	146.7, C	146.8, C	147.3, C	145.6, C	146.6, C	146.7, C
4"	149.6, C	149.5, C	149.7, C	149.6, C	148.3, C	149.6, C	149.6, C
5"	116.6, CH	116.5, CH	116.5, CH	116.5, CH	115.7, CH	116.9, CH	116.6, CH
6"	123.0, CH	123.0, CH	123.2, CH	123.3, CH	121.2, CH	123.4, CH	123.3, CH
7"	147.4, CH	147.4, CH	147.4, CH	147.4, CH	144.9, CH	148.0, CH	147.8, CH
8"	115.1, CH	115.0, CH	114.8, CH	115.2, CH	114.2, CH	114.8, CH	114.8, CH
9"	168.8, C	168.7, C	169.1, C	169.0, C	166.7, C	168.7, C	168.5, C
1'''						127.8, C	127.8, C
2'''						115.5, CH	115.4, CH
3'''						146.6, C	147.8, C
4'''						149.6, C	151.4, C
5'''						116.9, CH	112.5, CH
6'''						123.4, CH	123.0, CH
7'''						147.5, CH	147.5, CH
8'''						114.8, CH	114.8, CH
9'''						169.5, C	169.0, C
$-OCH_3$		56.3, CH_3			55.6, CH_3		56.5, CH_3

[a] Data were recorded in CD_3OD; [b] Data were recorded in DMSO-d_6

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Table 3

Antioxidant and α-glucosidase inhibitory activities of compounds **1**-**25**

sample	DPPH IR (%)[a]	DPPH IC_{50} (μg/mL)[b]	$ABTS^+$ IR (%)[a]	$ABTS^+$ IC_{50} (μg/mL)[b]	α-glucosidase inhibitory activities IR (%)[c]	IR (%)[d]	IC_{50} (μg/mL)[e]
1	85.3 ± 0.8	10.2 ± 0.4	85.9 ± 0.9	31.9 ± 2.3	100.2 ± 0.8	61.7 ± 7.2	nd
2	83.2 ± 0.3	18.0 ± 0.3	74.6 ± 2.1	7.5 ± 0.7	77.5 ± 3.2	21.2 ± 8.8	nd
3	83.4 ± 0.1	5.4 ± 0.1	94.2 ± 0.1	18.3 ± 1.3	99.6 ± 0.4	81.7 ± 17.7	27.9 ± 2.2
4	83.9 ± 0.4	3.7 ± 0.2	94.1 ± 0.1	23.8 ± 3.4	100.7 ± 1.0	100.0 ± 4.2	10.9 ± 1.0
5	84.0 ± 0.2	18.3 ± 0.5	82.8 ± 1.2	7.8 ± 0.4	45.4 ± 15.6	nd	nd
6	85.7 ± 0.3	3.0 ± 0.1	94.3 ± 0.1	3.9 ± 0.2	100.6 ± 1.2	94.2 ± 13.9	0.2 ± 0.1
7	83.3 ± 0.3	12.7 ± 0.6	94.6 ± 0.1	10.6 ± 1.0	99.9 ± 1.2	100.0 ± 2.0	10.7 ± 2.0
8	87.0 ± 0.2	10.9 ± 0.5	77.0 ± 2.8	5.0 ± 0.8	56.5 ± 10.8	nd	nd
9	0.2 ± 1.9	nd	4.3 ± 3.1	nd	2.0 ± 2.8	nd	nd
10	7.0 ± 0.6	nd	11.8 ± 2.5	nd	13.0 ± 7.8	nd	nd
11	11.0 ± 2.4	nd	82.4 ± 2.9	24.1 ± 2.7	39.1 ± 13.2	nd	nd
12	0.3 ± 2.7	nd	7.9 ± 4.8	nd	1.3 ± 2.2	nd	nd
13	77.9 ± 0.4	11.5 ± 0.8	94.7 ± 1.6	2.2 ± 0.1	34.7 ± 17.4	nd	nd
14	4.4 ± 0.6	nd	35.4 ± 5.3	nd	3.4 ± 3.2	nd	nd
15	30.8 ± 9.5	nd	91.5 ± 1.8	12.9 ± 2.2	89.7 ± 3.6	72.9 ± 2.1	105.5 ± 13.1
16	14.7 ± 1.8	nd	64.6 ± 6.1	55.4 ± 4.3	29.5 ± 7.9	nd	nd
17	87.5 ± 0.4	4.8 ± 0.4	94.8 ± 0.7	4.6 ± 0.3	52.7 ± 12.1	nd	nd
18	85.6 ± 0.3	4.9 ± 0.6	95.1 ± 0.2	4.8 ± 0.3	100.1 ± 0.5	83.1 ±13.6	55.0 ± 14.6
19	24.9 ± 0.3	nd	90.8 ± 0.6	36.7 ± 4.5	88.4 ± 5.2	56.7 ±1.5	nd
20	16.4 ± 4.8	nd	89.2 ± 1.6	13.3 ± 1.9	41.7 ± 9.1	nd	nd
21	84.4 ± 0.5	2.8 ± 0.1	94.6 ± 0.3	2.9 ± 0.2	100.1 ± 0.4	86.5 ± 3.7	80.7 ± 5.9
22	15.0 ± 3.4	nd	91.8 ± 1.1	14.4 ± 1.6	64.1 ± 16.3	nd	nd
23	72.5 ± 5.6	11.9 ± 0.7	94.8 ± 0.4	6.1 ± 0.7	45.3 ± 11.5	nd	nd
24	30.0 ± 4.1	nd	92.1 ± 1.2	9.4 ± 1.4	43.8 ± 14.2	nd	nd
25	16.5 ± 3.9	nd	70.4 ± 4.1	nd	99.7 ± 0.6	100.3 ± 3.3.	62.0 ± 9.8
Ascorbic acid	91.2 ± 0.1	6.3 ± 0.3	94.9 ± 0.2	7.2 ± 0.5			
Acarbose					63.7 ± 0.8	51.2 ± 0.8	118.4 ± 12.7

Compounds **1**–**8** are sorbitol *O*-caffeic acid ester derivatives; **9**–**19** are phenylpropanoids; **20** is a phenethyl alcohol; **21** and **22** are benzaldehydes; **23** and **24** are benzoic acids; **25** is a flavonoid.

nd: not determined.

Data were represented as mean ± SD (n=3).

[a] DPPH and $ABTS^+$ radical inhibition rates at the concentration value of 100 μg/mL.

[b] The IC_{50} value is defined as the inhibitor concentration to inhibit 50% of DPPH and $ABTS^+$ radical.

[c] α-Glucosidase inhibition rates at the concentration value of 250 μg/mL.

[d] α-Glucosidase inhibition rates at the concentration value of 125 μg/mL.

[e] The IC_{50} value is defined as the inhibitor concentration to inhibit 50% of α-glucosidase activity.

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Highlights

Twenty-five phenolic compounds were isolated and identified from “Liucha”.

Twenty-three compounds were reported from *Sibiraea laevigata* for the first time.

Phenolic compounds showed potent α-glucosidase inhibition and antioxidant activities.

Sorbitol ester F showed the best α-glucosidase inhibitory activity *in vitro*.

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