Isolation of a New Saponin and Cytotoxic Effect of Saponins from the Root of *Platycodon grandiflorum* on Human Tumor Cell Lines

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Abstract

A novel triterpenoid saponin, deapioplatycoside E (**1**) was isolated from the root extract of *Platycodon grandiflorum*, together with the seven known saponins **2** – **8**, i.e., platycoside E (**2**), deapioplatycodin D_3 (**3**), platycodin D_3 (**4**), polygalacin D_2 (**5**), platycodin D_2 (**6**), deapioplatycodin D (**7**) and platycodin D (**8**). The structure of the new saponin **1** was determined on the basis of spectral analysis and chemical evidence. The crude saponin fraction (ED_{50}: ca. 10 – 15 μg/mL) and compounds **6** – **8** (ED_{50}: ca. 4 – 18 μg/mL) exhibited significant inhibition on the proliferation of five kinds of cultured human tumor cell lines, i.e., A549 (non-small cell lung), SK-OV-3 (ovary), SK-MEL-2 (melanoma), XF498 (central nerve system) and HCT-15 (colon), *in vitro*.

The species, *Platycodon grandiflorum* A. DC (Campanulaceae), is a perennial herb commonly known as balloon flower widely spread in northeast Asia. It is often cultivated on the farmyard and the two- or three-year-old root of the species is used as a common food and frequently employed as a folk remedy for bronchitis, asthma and pulmonary tuberculosis, hyperlipidemia, diabetes and inflammatory diseases [1], [2]. Recently, it has been reported that the root extract of the species cultivated over 20 years [3] prevented hypercholesterolemia and hyperlipidemia [4] and also enhanced some of the functions of macrophages, such as their proliferation, spreading ability, phagocytosis, NO secretion, and the gene expression of TNFα, IL-1β, and IL-6 [5], [6].

During our ongoing search for potent antitumor substances from natural resources, we have found that the crude saponin fraction B of the root extract of *P. grandiflorum* had exhibited a marked inhibition on the proliferation of cultured human tumor cell lines *in vitro*. Thus, a phytochemical investigation has been un-

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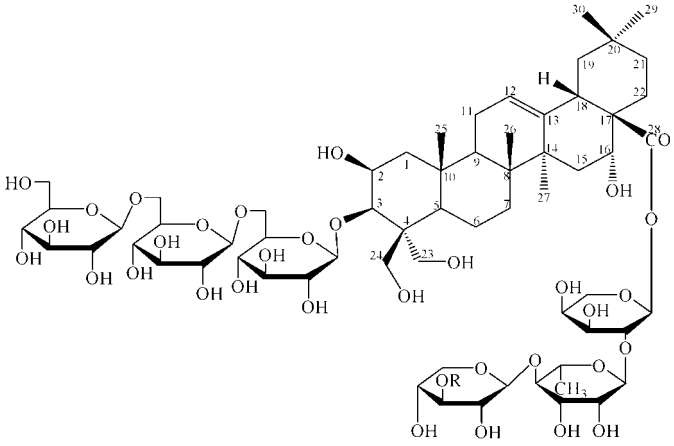
dertaken for the isolation of active constituents from the crude saponin fraction of the extract. By the serial chromatography of the saponin fraction, eight triterpenoid saponins (**1** – **8**) were isolated and their chemical structures were established by comparison of their spectral data with published ones. Among the isolates, compound **1** (Fig. **1**) was found to be a new component which had not been reported previously.

Compound **1**, an amorphous powder, $[\alpha]_D^{20}$: –22 (*c*, 0.1 in EtOH), possessed the molecular formula $C_{64}H_{104}O_{34}$ as determined by MALDI-TOF-MS (*m/z* = 1439: $[M + Na]^+$; Voyager; PE Biosystems USA). The ^{1}H-NMR and ^{13}C-NMR spectral data of **1** indicated that it had the sapogenin, 2*β*,3*β*,16*α*,23,24-pentahydroxyolean-12-en-28-oic acid and oligosaccharide moieties at C-3 and C-28.

Particularly, the ^{13}C-NMR spectrum of **1** is quite imposable with that of platycoside E (**2**; Fig. **1**) except for some typical signals (δ = 111.7, 81.0 and 65.9) due to the apiose moiety of **2**. These results suggested that **l** be a congener of **2** (platycoside E), which has been found recently in this species [7]. By the scrutiny of the spectral data of **1** with those of **2**, the chemical structure of **1** was established to be 3-*O*-*b*-D-glucopyranosyl-(1→6)-*β*-D-glucopyranosyl-(1→6)-*β*-D-glucopyranosyl-2*β*,3*β*,16*α*,23,24-pentahydroxyolean-12-ene-28-oic acid 28-*O*-*β*-D-xylopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→2)-*α*-L-arabinopyranoside, which bis the deapio analogue of platycoside E (**2**). Compound **2** was found to be converted slowly to **1** by mild acid hydrolysis in 0.1 N HCl.

All of the isolated saponins were examined for the cytotoxicity against five cultured human tumor cell lines [8], the currently used cell lines in the National Cancer Institute (USA) for their *in vitro* anti-cancer drug screening program, i.e., A549 (non-small cell lung), SK-OV-3 (ovary), SK-MEL-2 (melanoma), XF498 (central nerve system) and HCT-15 (colon), *in vitro* [9]. When the examined tumor cells were exposed continuously to each of compounds **1** – **8** for 48 hours, their proliferation was significantly decreased in a dose-dependent manner. The ED_{50} values of each component (**1** – **8**) on the proliferation of the five human tumor cells are summarized in Table **1**.



1: R = –H **2**: R = –apiofuranosyl

Fig. **1** Structures of saponins **1** and **2**.

Therefore, it could be concluded that the cytotoxic effect of the root extract of *P. grandiflorum* on cultured human tumor cell lines might be attributed predominantly to the saponin fraction (1.0 – 2.0% of the extract), particularly to the components, platycodin D_2 (**6**), deapioplatycodin D (**7**), and platycodin D (**8**).

Materials and Methods

Extraction and isolation: The species *P. grandiflorum* cultivated for three years in Kangwon Province, Korea was harvested in September 2000. The roots were cut into slices and dried. For future reference, a voucher specimen (herbarium No. KM-00024) has been preserved at the Herbarium of Kookmin University, Institute of Forest Science, Korea.

The dried roots (1.0 kg) were soaked in methanol at room temperature for 7 days. Concentration of the solvent gave 220 g of a brown syrupy MeOH extract which was suspended in 2.2 L of H_2O and poured into a Diaion HP-20 column (Ø = 5.0 × 100 cm), which was stabilized with H_2O. The column was eluted with additional 10 L of 20% MeOH. The eluate was combined and concentrated under reduced pressure to give 190 g of syrupy residue (Fr. A). The Diaion HP-20 column was further washed with additional 10 L of 85% MeOH. The eluate was concentrated under reduced pressure to give 24 g of brown powder (Fr. B). The column was finally washed out with MeOH. The washings were concentrated under reduced pressure to give 0.8 g of oily residue (Fr. C) [10]. The crude MeOH extract of the root and each fraction obtained from the MeOH extract by the Diaion HP-20 column chromatography (Fr. A – Fr. C) were evaluated for cytotoxic effects on the cultured human tumor cell lines. Among the tested, only the Fr. B exhibited a moderate cytotoxicity upon each of the tested cell lines. Therefore, the Fr. B was purified by repeated preparative HPLC (Futecs NS-3000i system equipped with GROM-SIL 120 ODS-4 HE column; 250 cm × 20 mm) with 26% acetonitrile in 20 mM KH_2PO_4 as eluent, which led to the isolation of eight triterpenoidal saponins (**1** – **8**), i.e., 22 mg of **1** (t_R = 12.8 min, GROM-SIL 120 ODS-5, ST column; 250 cm × 5 mm, flow rate 0.7 mL/min), 150 mg of **2** (t_R = 14.4 min), 15 mg of **3** (t_R = 24.3 min), 28 mg of **4** (t_R = 27.9 min), 14 mg of **5** (t_R = 37.3 min), 20 mg of **6** (t_R = 65.3 min), 24 mg of **7** (t_R = 74.7 min) and 42 mg of **8** (t_R = 77.4 min). The structure of the new saponin **1** was determined on the basis of spectral analysis and chemical evidences. The detailed chemical shifts of **1** in the ^{13}C-NMR (in pyridine-d_5) spectrum are as follows (the data in the parenthesis are those for the corresponding signals of **2** [10]); C1 : 45.3 (45.3), C2 : 68.7 (68.8), C3 : 88.8 (88.8), C4 : 48.2 (48.2), C5 : 47.6 (47.6), C6 : 19.4 (19.5), C7 : 33.6 (33.5), C8 : 40.5 (40.6), C9 : 45.0 (45.0), C10 : 38.0 (38.0), C11 : 24.1 (24.1), C12 : 123.1 (123.3), C13 : 144.4 (144.7), C14 : 42.5 (42.5), C15 : 36.1 (36.2), C16 : 74.0 (73.9), C17 : 49.7 (49.7), C18 : 41.6 (41.7), C19 : 47.2 (47.2), C20 : 31.0 (31.0), C21 : 36.1 (36.1), C22 : 32.2 (32.2), C23 : 63.5 (63.7), C24 : 67.3 (67.3), C25 : 19.2 (19.2), C26 : 17.7 (17.7), C27 : 27.1 (27.1), C28 : 176.0 (176.1), C29 : 33.4 (33.3), C30 : 24.8 (24.8), *i*G1 (*inner glucose*): 106.1 (106.1), *i*G2 : 74.9 (74.9), *i*G3 : 78.4 (78.5), *i*G4 : 72.4 (72.3), *i*G5 : 76.5 (76.6), *i*G6 : 70.2 (70.7), *c*G1 (*central glucose*): 105.0 (105.0), *c*G2 : 75.4 (75.4), *c*G3 : 78.5 (78.4), *c*G4 : 71.1 (71.3), *c*G5 : 77.2 (77.2), *c*G6 : 70.2 (70.2), *t*G1 (*terminal glucose*): 105.7 (105.6), *t*G2 : 75.2 (75.2), *t*G3 : 78.7 (78.7),

Table **1** Inhibition of tumor cell proliferation by saponins from *Platycodon grandiflorum*

	ED_{50} (μg/mL)[a]				
	A549	*SK-OV-3*	*SK-MEL-2*	*XF498*	*HCT15*
MeOH extract	> 50	> 50	> 50	> 50	> 50
Fr. A	> 50	> 50	> 50	> 50	> 50
Fr. B	10.8 ± 0.3[b]	6.2 ± 0.3	13.2 ± 0.2	15.2 ± 0.2	12.1 ± 0.3
Fr. C	30.2 ± 0.6	24.2 ± 0.5	42.2 ± 0.2	35.2 ± 0.5	32.1 ± 0.6
1	> 50	> 50	> 50	> 50	> 50
2	> 50	> 50	> 50	> 50	> 50
3	> 50	> 50	> 50	> 50	> 50
4	> 50	> 50	> 50	> 50	> 50
5	> 50	> 50	> 50	> 50	> 50
6	3.7 ± 0.1	3.6 ± 0.2	3.8 ± 0.2	3.9 ± 0.3	3.8 ± 0.2
7	13.2 ± 0.1	12.9 ± 0.2	17.4 ± 0.2	17.1 ± 0.3	17.5 ± 0.2
8	3.8 ± 0.2	3.7 ± 0.2	3.9 ± 0.2	3.9 ± 0.3	3.8 ± 0.2
cisplatin	1.4 ± 0.1	0.9 ± 0.3	0.8 ± 0.2	0.9 ± 0.3	2.2 ± 0.4

[a] ED_{50} value of compound against each cancer cell line, which was defined as the concentration that caused 50% inhibition of cell proliferation *in vitro*.
[b] Data are mean ± S.E.M. of three distinct experiments.

*t*G4 : 71.0 (70.9), *t*G5 : 77.7 (77.7), *t*G6 : 62.7 (62.7), A1 (*arabinose*): 93.7 (93.7), A2 : 75.3 (75.3), A3 : 71.3 (71.6), A4 : 66.4 (66.6), A5 : 63.1 (63.1), R1 (*rhamnose*): 101.2 (101.2), R2 : 72.0 (71.9), R3 : 72.8 (72.8), R4 : 83.6 (84.0), R5 : 68.7 (68.6), R6 : 18.5 (18.4), X1 (*xylose*): 106.9 (106.8), X2 : 76.1 (76.1), X3 : 78.6 (84.8), X4 : 71.6 (69.5), X5 : 67.5 (67.0). The other components **2** – **8** had been identified by direct comparison of their physical and spectral properties (^{1}H-NMR and ^{13}C-NMR) with those in the literature [7], [11], [12]. Details of the work-up procedure and copies of the original spectra of **1** – **8** are obtainable from the author of correspondence.

Preparation of **1** *by acid hydrolysis of* **2**: One mg of **2** was dissolved in 0.2 mL of 0.1 N HCl at room temperature and an aliquot of reaction mixture was subjected to HPLC analysis (GROM-SIL 120 ODS-5, ST column; 250 cm × 5 mm at 40 °C) every 8 hours; it was observed that **2** (t_R = 14.4 min) was slowly converted to **1** (t_R = 12.8 min) in a time-dependent manner. More than 90% of **2** were converted to **1** after 48 hours.

Cytotoxicity assessment: The cytotoxicity of the compounds against cultured human tumor cell lines was evaluated by the SRB method [8], [9]. Briefly, each tumor cell line was inoculated over a series of standard 96-well flat-bottom microplates and were then preincubated for 24 h at 37 °C in a humidified atmosphere of 5% CO_2. The attached cells were then incubated with serially diluted saponin samples (**1** – **8**). After continuous exposure to the compounds for 48 h, the culture medium was removed from each well and the cells fixed with 10% cold trichloroacetic acid at 4 °C for 1 h. After washing with tap water, the cells were stained with 0.4% SRB dye and incubated for 30 min at room temperature. The cells were washed again and then solubilized with 10 mM unbuffered Tris bases solution (pH 10.5). The absorbance was measured spectrophotometrically at 520 nm with a microtiter plate reader.

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References

[1] Lee EB. Pharmacological studies on *Platycodon grandiflorum* A. DC. IV. A comparison of experimental pharmacological effects of crude platycodin with clinical indications of Platycodi Radix. Yakugaku Zasshi 1973; 93: 1188 – 94
[2] Takagi K, Lee EB. Pharmacological studies on *Platycodon grandiflorum* A. DC. Activities of crude platycodin on respiratory and circulatory systems and its other pharmacological activities, Yakugaku Zasshi 1972; 92: 969 – 73
[3] Lee SH. Method of cultivating the perennial balloon flower. Korean Patent 100 045 791, 1991
[4] Kim KS, Ezaki O, Ikemoto S, Itakura H. Effects of *Platycodon grandiflorum* feeding on serum and liver lipid concentrations in rats with diet-induced hyperlipidemia. J Nutri Sci Vitaminol 1995; 41: 485 – 91
[5] Choi CY, Kim JY, Kim YS, Chung YC, Hahm KS, Jeong HG. Augmentation of macrophage functions by an aqueous extract isolated from *Platycodon grandiflorum*. Cancer Lett 2001; 166: 17 – 25
[6] Choi CY, Kim JY, Kim YS, Chung YC, Seo JK, Jeong HG. Aqueous extract isolated from *Platycodon grandiflorum* elicits the release of nitric oxide and tumor necrosis factor-α from murine macrophages. Intl Immunopharmacol 2001; 1: 1141 – 51
[7] Nikaido T, Koike K, Mitsunaga K, Saeki T. Two new triterpenoid saponins from *Platycodon grandiflorum*. Chem Pharm Bull 1999; 47: 903 – 4
[8] Skehan P, Streng R, Scudiero D, Monks A, McMahon J, Vistica D et al. New colorimetric cytotoxicity assay for anticancer-drug screening. J Natl Cancer Inst 1990; 82: 1107 – 12
[9] Ryu SY, Choi SU, Lee SH, Lee CO, No Z, Ahn JW. Antitumor triterpenes from medicinal plants. Arch Pharm Res 1994; 17: 375 – 7
[10] Saeki T, Koike K, Nikaido T. A comparative study on commercial, botanical gardens and wild samples of the roots of *Platycodon grandiflorum* by HPLC analysis. Planta Med 1999; 65: 428 – 31
[11] Ishii H, Tori K, Tozyo T, Yoshimura Y. Saponins from roots of *Platycodon grandiflorum*. part 2. Isolation and Structure of new triterpene glycosides. J Chem Soc Perkin Trans 1, 1984: 661 – 8
[12] Ishii H, Tori K, Tozyo T, Yoshimura Y. Saponins from roots of *Platycodon grandiflorum*. part 1. structure of prosapogenin. J Chem Soc Perkin Trans 1, 1981: 1928 – 33