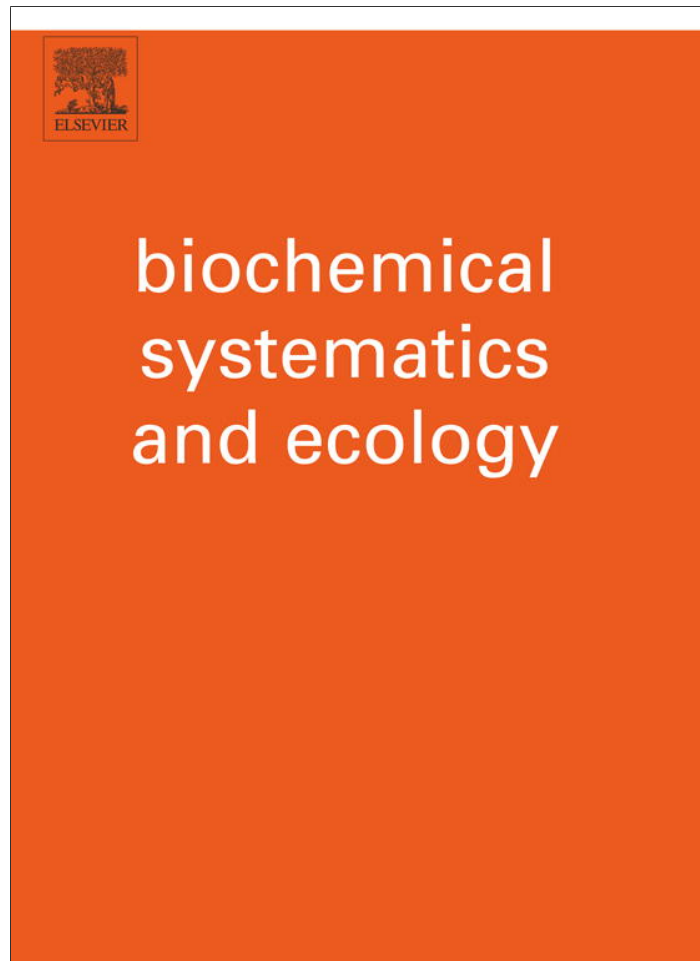


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## Biochemical Systematics and Ecology

journal homepage: [www.elsevier.com/locate/biochemsyseco](http://www.elsevier.com/locate/biochemsyseco)Steroidal sapogenins from *Solanum torvum*Chang-Hung Chou<sup>a</sup>, Yuan-Man Hsu<sup>b</sup>, Tsurng-Juhn Huang<sup>c</sup>, Fon-Chang Liu<sup>d</sup>, Jing-Ru Weng<sup>b,\*</sup><sup>a</sup> Research Center for Biodiversity, China Medical University, Taichung 404, Taiwan<sup>b</sup> Department of Biological Science and Technology, China Medical University, 91 Hsueh-Shih Road, Taichung 404, Taiwan<sup>c</sup> Graduate Institute of Ecology and Evolutionary Biology, China Medical University, Taichung 404, Taiwan<sup>d</sup> School of Pharmacy, China Medical University, Taichung 404, Taiwan

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## ABSTRACT

The present study reports the isolation of one sterol glycoside and three steroidal sapogenins from the leaves of *Solanum torvum*: 3-O-[ $\beta$ -D-(6'-nonadecanoate) glucopyranosyl]- $\beta$ -sitosterol (**1**), (25R)-3 $\beta$ ,6 $\beta$ -dihydroxy-5 $\alpha$ -spirostan-23-one (**2**), paniculogenin (**3**), and chlorogenin (**4**). Among them, compounds **1** and **2** were identified in *S. torvum* for the first time by this study, and compound **3** has only once been reported in *S. torvum* and *Solanum hispidium*. Our data suggest that these sterol glycoside and steroidal sapogenins could be considered as chemotaxonomic markers for the genus *Solanum*.

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## 1. Subject and source

*Solanum torvum* (Solanaceae) is an andromonoecious shrub distributed throughout tropical regions including Southern Taiwan and India. The leaves of *S. torvum* were collected in the Taichung County, Taiwan, in July, 2007, and a voucher specimen (2007) has been deposited in the Department of Biological Science and Technology, China Medical University, Taichung, Taiwan.

## 2. Previous work

Previous phytochemical investigations on *S. torvum* led to the isolation of sterols, sterol glycosides, and triterpenes (Arthan et al., 2006, 2002; Lu et al., 2008; Smith et al., 2008; Zhou et al., 2011), which, along with some glycoalkaloids (Milner et al., 2011), were the major constituents of the genus *Solanum*. Recent studies indicate that some of these sterols and sterol glycosides exhibited pharmacological activities against diabetic (Gandhi et al., 2011), depression (Sultana and Afolayan, 2007), hypertension (Mohan et al., 2009), inflammation (Ndebia et al., 2006), and tumors (Lu et al., 2009). Moreover, we found that the CHCl<sub>3</sub> extract of its leaves was effective in suppressing the growth of *Helicobacter pylori* in human gastric epithelial cells (Hsu et al., 2010).

## 3. Present study

Leaves of *S. torvum* (2 kg dry weight) were extracted with 95% CHCl<sub>3</sub> (10 L) at room temperature three consecutive times with the duration of one week each time. Removed of the solvent in vacuo afforded 21 g of crude residues, which were loaded

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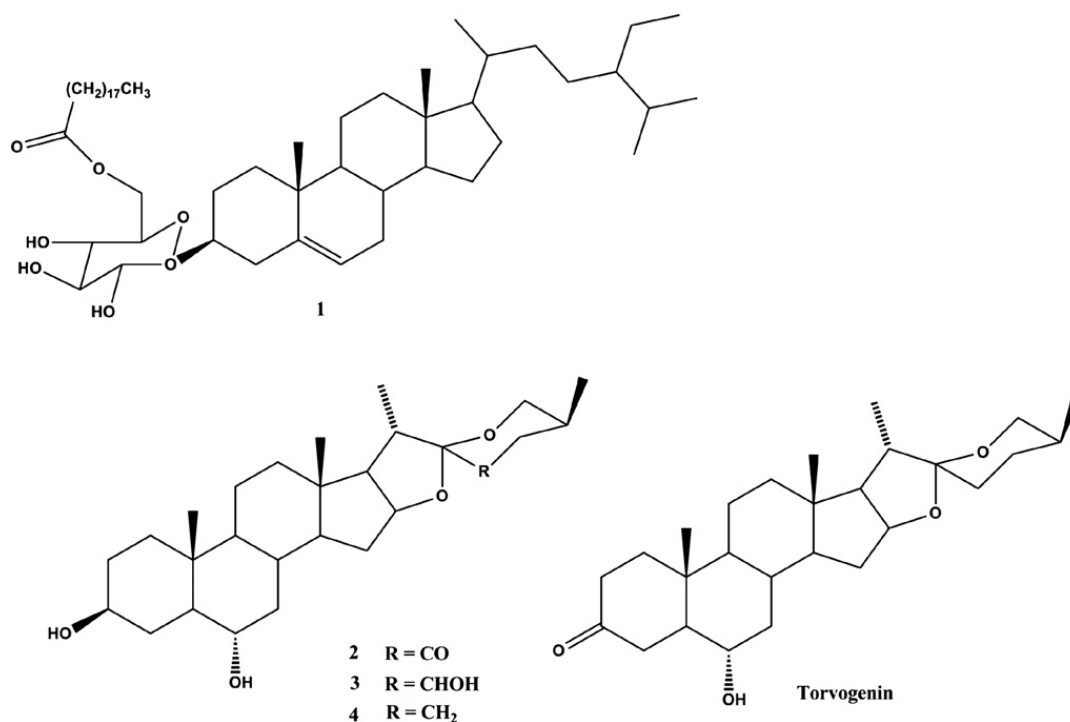


Fig. 1. The structures of compounds 1–4 isolated from *S. torvum*.

onto a silica gel column (60 × 12 cm), and compounds 1–4 were purified as described below. The column was eluted, in tandem, with 700 ml each of *n*-hexane-CHCl<sub>3</sub> (9:1), *n*-hexane-CHCl<sub>3</sub> (6:4), *n*-hexane-CHCl<sub>3</sub> (3:7), *n*-hexane-EtOAc (6:4), *n*-hexane-EtOAc (2:8), EtOAc-MeOH (9:1), and EtOAc-MeOH (4:1), to afford fractions 1–7 after drying the solvent. Fraction 4 was rechromatographed with CH<sub>2</sub>Cl<sub>2</sub>/EtOAc (19:1) to yield **1** (2 mg), and fraction 5 was purified using *n*-hexane-Acetone (4:1) to give 5 sub-fractions (5-1 to 5-5). Sub-fraction 5-1 was purified by eluting the column with CH<sub>2</sub>Cl<sub>2</sub>/acetone (7:1) to yield **2** (5 mg) and **3** (4 mg), and sub-fraction 5-2 was eluted with CH<sub>2</sub>Cl<sub>2</sub>/EtOAc (5:1) to generate **4** (2 mg).

#### 4. Chemotaxonomic significance

Among these four isolated compounds, one sterol glycoside and three steroidal saponins were identified, including **1**, 3-*O*-[β-D-(6'-nonadecanoate)glucopyranosyl]-β-sitosterol (Sultana and Afolayan, 2007); **2**, (25*R*)-3β,6β-dihydroxy-5α-spirostan-23-one (Ripperger et al., 1967); **3**, paniculogenin (Agrawal et al., 1985); **4**, chlorogenin (Zamilpa et al., 2002) (Fig. 1). Although compounds **1** and **2** have previously been identified in the family Asteraceae (Sultana and Afolayan, 2007) and *Solanum paniculatum* (Ripperger et al., 1967), respectively, this study is the first report of isolation of these two compounds in *S. torvum*. Compound **4** is widely present in a number of genera, including *Solanum* (De Valeri and Usubillaga, 1989), *Allium* (Amaryllidaceae) (Itakura et al., 2001), *Agave* (Liliaceae) (Blunden et al., 1986), *Yucca* (Asparagaceae) (Dewidar and el-Munajjed, 1970), and *Tribulus* (Zygophyllaceae) (Gheorghiu and Ionescu-Matiu, 1968), suggesting a biogenetic association among these genera. Relative to the other three compounds, compound **3** (paniculogenin) has only once been reported in *Solanum hispidum* (Chakravarty et al., 1978) and *S. torvum* (Solanaceae) (Schreiber and Ripperger, 1968) after the hydrolysis of spirostan glycosides, suggesting that it might be a characteristic chemical constituent of these two species. It should be noted that compound **3** was designated as torvogenin in a recent paper (Matsushita et al., 2007), which, however, contrasts the structure of torvogenin reported in the previous publication (Fig. 1) (Dopke et al., 1975). This discrepancy warrants attention. Together, our data suggest that the sterol glycoside (compound **1**) and steroidal saponins (compound **2** and **3**) could be considered as chemotaxonomic markers for the genus *Solanum*.

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#### References

- Agrawal, P.K., Jain, D.C., Gupta, P.K., Thakur, R.S., 1985. *Phytochemistry* 24, 2479.  
Arthan, D., Kittakoop, P., Esen, A., Svasti, J., 2006. *Phytochemistry* 67, 27.

- Arthan, D., Svasti, J., Kittakoop, P., Pittayakhachonwut, D., Tanticharoen, M., Thebtaranonth, Y., 2002. *Phytochemistry* 59, 459.
- Blunden, G., Patel, A.V., Crabb, T.A., 1986. *J. Nat. Prod.* 49, 687.
- Chakravarty, A.K., Dhar, T.L., Pakrashi, S.C., 1978. *Tetrahedron Lett.* 40, 3875.
- De Valeri, B., Usubillaga, A., 1989. *Phytochemistry* 28, 2509.
- Dewidar, A.M., el-Munajjed, D., 1970. *Planta Med.* 19, 87.
- Dopke, W., Nogueiras, C., Hess, U., 1975. *Pharmazie* 30, 755.
- Gandhi, G.R., Ignacimuthu, S., Paulraj, M.G., Sasikumar, P., 2011. *Eur. J. Pharmacol.* 670, 623.
- Gheorghiu, A., Ionescu-Matiu, E., 1968. *Ann. Pharm. Fr.* 26, 745.
- Hsu, Y.M., Weng, J.R., Huang, T.J., Lai, C.H., Su, C.H., Chou, C.H., 2010. *Oncol. Rep.* 23, 1401.
- Itakura, Y., Ichikawa, M., Mori, Y., Okino, R., Udayama, M., Morita, T., 2001. *J. Nutr.* 131, 963S.
- Lu, Y., Luo, J., Huang, X., Kong, L., 2009. *Steroids* 74, 95.
- Lu, Y., Luo, J., Xu, D., Huang, X., Kong, L., 2008. *Rapid Commun. Mass Spectrom.* 22, 2447.
- Matsushita, S., Yanai, Y., Fusyuku, A., Ikeda, T., Ono, M., Nohara, T., 2007. *Chem. Pharm. Bull.* 55, 1079.
- Milner, S.E., Brunton, N.P., Jones, P.W., O'Brien, N.M., Collins, S.G., Maguire, A.R., 2011. *J. Agric. Food Chem.* 59, 3454.
- Mohan, M., Jaiswal, B.S., Kasture, S., 2009. *J. Ethnopharmacol.* 126, 86.
- Ndebia, E.J., Kamgang, R., Nkeh-ChungagAnye, B.N., 2006. *Afr. J. Tradit. Complement. Altern. Med.* 4, 240.
- Ripperger, H., Schreiber, K., Budzikiewicz, H., 1967. *Chem. Ber.* 100, 1741.
- Schreiber, K., Ripperger, H., 1968. *Kulturpflanze* 15, 199.
- Smith, S.W., Giesbrecht, E., Thompson, M., Nelson, L.S., Hoffman, R.S., 2008. *Toxicol.* 52, 667.
- Sultana, N., Afolayan, A.J., 2007. *Nat. Prod. Res.* 21, 889.
- Zamilpa, A., Tortoriello, J., Navarro, V., Delgado, G., Alvarez, L., 2002. *J. Nat. Prod.* 65, 1815.
- Zhou, H., Wang, F., Fang, Z., 2011. *Zhongguo Zhong Yao Za Zhi* 36, 2096.