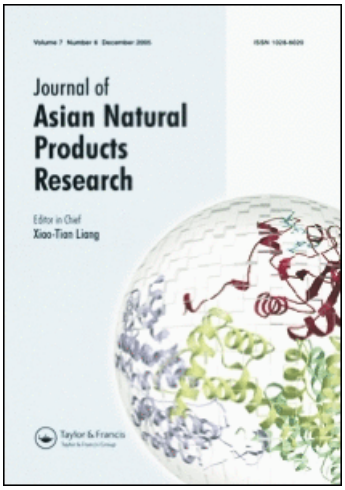

Journal of Asian Natural Products Research
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713454007

Two flavonoid glycosides and a phenylpropanoid glucose ester from the leaves of *Sterculia foetida*

Peng-Fei Xia[a]; Zi-Ming Feng[a]; Ya-Nan Yang[a]; Pei-Cheng Zhang[a]
[a] Key Laboratory of Bioactive Substances and Resources Utilization of Chinese Herbal Medicine (Ministry of Education), Institute of Materia Medica, Peking Union Medical College and Chinese Academy of Medical Sciences, Beijing, China

To cite this Article Xia, Peng-Fei , Feng, Zi-Ming , Yang, Ya-Nan and Zhang, Pei-Cheng(2009) 'Two flavonoid glycosides and a phenylpropanoid glucose ester from the leaves of *Sterculia foetida*', Journal of Asian Natural Products Research, 11: 8, 766 — 771
To link to this Article: DOI: 10.1080/10286020903055103
URL: http://dx.doi.org/10.1080/10286020903055103

Journal of Asian Natural Products Research
Vol. 11, No. 8, August 2009, 766–771

Two flavonoid glycosides and a phenylpropanoid glucose ester from the leaves of *Sterculia foetida*

Peng-Fei Xia, Zi-Ming Feng, Ya-Nan Yang and Pei-Cheng Zhang*

Key Laboratory of Bioactive Substances and Resources Utilization of Chinese Herbal Medicine (Ministry of Education), Institute of Materia Medica, Peking Union Medical College and Chinese Academy of Medical Sciences, Beijing 100050, China

(*Received 26 April 2009; final version received 20 May 2009*)

Two new flavonoid glycosides, hypolaetin 4′-methyl ether 8-*O*-β-D-glucuronide 2″-sulfate (**1**) and hypolaetin 4′-methyl ether 3′-*O*-β-D-glucoside (**2**), and a new phenylpropanoid glucose ester, 1,6-diferuloyl glucose (**3**), were isolated from the leaves of *Sterculia foetida* L. Their structures were elucidated by spectroscopic analysis and chemical evidence.

Keywords: *Sterculia foetida*; Sterculiaceae; flavonoid glycosides; phenylpropanoid glucose ester

1. Introduction

The genus *Sterculia* (Sterculiaceae), which comprises about 300 species, is widely distributed in tropical areas. About 23 species of them occurred in southwestern and southern China. *Sterculia foetida* is used as an aperient, diuretic, and insect repellent in herbal medicine [1]. Extracts of the leaves of *S. foetida* were reported to exhibit depressant activity on the central nervous system and significant anti-inflammatory activity [2]. Previous phytochemical investigation on *S. foetida* resulted in the isolation of steroids, flavonoids, and their glucuronyl derivatives [3–5]. As part of our searching for bioactive compounds, we report herein the isolation and structural elucidation of two new compounds, hypolaetin 4′-methyl ether 8-*O*-β-D-glucuronide 2″-sulfate (**1**), hypolaetin 4′-methyl ether 3′-*O*-β-D-glucoside (**2**), and a new phenylpropanoid glucose ester, 1,6-diferuloyl glucose (**3**) (Figure 1). Their structures were elucidated by spectroscopic analysis and chemical evidence.

2. Results and discussion

Compound **1**, a yellow amorphous powder, showed a positive Mg–HCl color reaction. The HR-ESI-MS of **1** indicated the pseudo-molecular ion $[M-H]^-$ at *m/z* 571.0415, corresponding to the formula $C_{22}H_{20}O_{16}S$. The IR spectrum of **1** showed the presence of hydroxyl (3261 cm^{-1}), aromatic ring (1584, 1504 cm^{-1}), carbonyl (1727 cm^{-1}), conjugated carbonyl (1657 cm^{-1}), and S=O group (1254 cm^{-1}). The UV absorption maxima of **1** were observed at 346 and 273 nm in MeOH. The above data were indicative of a flavonoid skeleton and a sulfate unit in **1**.

The ^1H NMR spectrum of **1** (Table 1) showed two singlets at δ_H 6.74 (1H, s) and 6.24 (1H, s) and ABX spin system signals at δ_H 7.71 (1H, dd, $J = 2.0$, 8.5 Hz), 7.04 (1H, d, $J = 8.5$ Hz), and 7.60 (1H, d,

*Corresponding author. Email: pczhang@imm.ac.cn

ISSN 1028-6020 print/ISSN 1477-2213 online

DOI: 10.1080/10286020903055103
http://www.informaworld.com

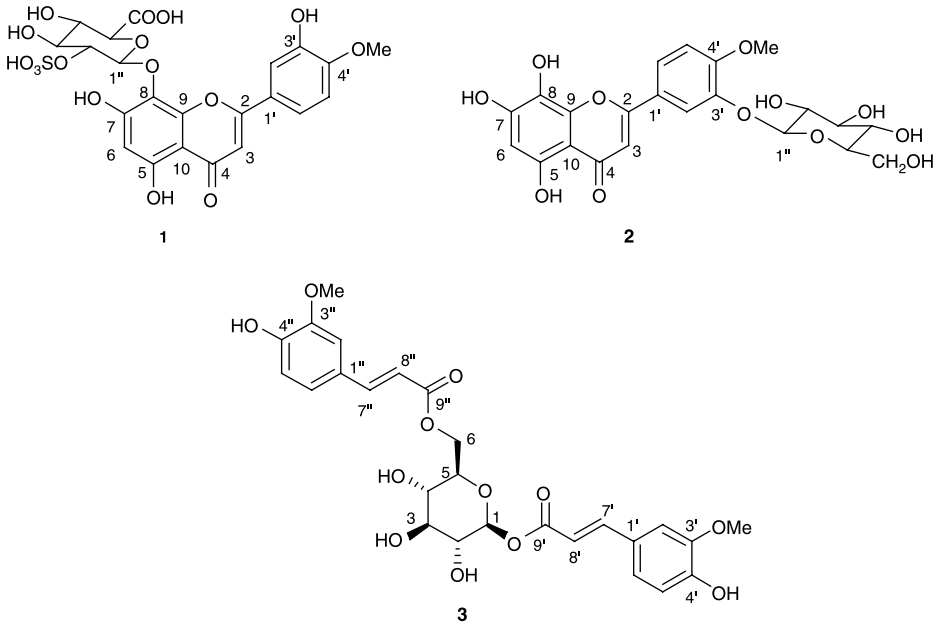

Figure 1. Structures of compounds **1**–**3**.

Table 1. ^{1}H and ^{13}C NMR spectral data of compounds **1** and **2** in DMSO-d_6.

	1		**2**	
	^{1}H	^{13}C	^{1}H	^{13}C
Aglycone				
2		163.7		162.9
3	6.74 (1H, s)	102.9	6.85 (1H, s)	103.3
4		181.7		182.1
5		157.2		153.7
6	6.24 (1H, s)	98.9	6.24 (1H, s)	98.6
7		156.9		153.2
8		123.6		124.7
9		149.3		145.7
10		103.5		103.2
1′		122.8		121.1
2′	7.60 (1H, d, $J = 2.0$ Hz)	113.2	7.75 (1H, d, $J = 2.0$ Hz)	112.8
3′		146.6		146.4
4′		151.2		152.1
5′	7.04 (1H, d, $J = 8.5$ Hz)	112.2	7.17 (1H, d, $J = 8.5$ Hz)	112.3
6′	7.71 (1H, dd, $J = 2.0$, 8.5 Hz)	119.4	7.81 (1H, dd, $J = 2.0$, 8.5 Hz)	122.9
Gly				
1″	5.00 (1H, d, $J = 7.5$ Hz)	101.5	5.16 (1H, d, $J = 6.5$ Hz)	99.4
2″	4.27 (1H, t, $J = 8.0$ Hz)	79.0	3.80 (1H, m)	73.1
3″	3.52 (1H, t, $J = 8.0$ Hz)	75.0	3.67 (1H, m)	76.8
4″	3.58 (1H, t, $J = 8.0$ Hz)	71.2	3.61 (1H, m)	69.5
5″	3.67 (1H, d, $J = 8.0$ Hz)	75.2	3.86 (1H, m)	76.9
6″		169.6	4.66 (1H, m)	60.5
MeO-4′	3.85 (3H, s)	55.6	3.88 (3H, s)	55.8

$J = 2.0$ Hz), suggesting the presence of a trisubstituted A-ring and a 3′,4′-disubstituted B-ring in **1**. An anomeric proton signal at δ_H 5.00 (1H, d, $J = 7.5$ Hz) and overlapped oxymethine proton signal at δ_H 3.4–3.7 revealed the existence of a β-glycosyl moiety. Additionally, the ^{1}H NMR spectrum of **1** displayed a methoxyl proton signal at δ_H 3.85. The ^{13}C NMR spectral data of **1** (Table 1) exhibited 22 carbon signals, suggesting the existence of a flavonoid aglycone, a glucuronide (carbonyl carbon signal at δ_C 169.6), and methoxyl moieties in **1**. The carbon chemical shift values of the aglycone were similar to the corresponding data for hypolaetin 4′-methyl ether 8-*O*-β-D-glucuronide [6], which revealed that flavonoid aglycone of **1** was pentaoxygenated at C-5, C-7, C-8, C-3′, and C-4′. The location of the glycosyl linkage was verified to be at C-8 as β-glycosyl linkage ($J = 7.5$ Hz) by HMBC correlations (Figure 2) from H-1″ at δ_H 5.00, H-6 at δ_H 6.24 to C-8 at δ_C 123.6. Further acid hydrolysis of **1** yielded glucuronic acid with positive optical rotation indicating a D-configuration. Attachment of the methoxyl at C-4′ was supported by the HMBC correlation between the methoxyl protons at δ_H 3.85 and C-4′ at δ_C 151.2, which in turn correlated with H-2′ at δ_H 7.60, H-6′ at δ_H 7.71, and H-5′ at δ_H 7.04 (Figure 2). In addition, the chemical shifts were observed for H-2″ (+0.8 ppm), C-2″ (+4.9 ppm), and C-1″ (−5.8 ppm) as compared with those of hypolaetin 4′-methyl ether 8-*O*-β-D-glucuronide [6], which suggested that the sulfate group must be linked to the C-2″ of the glucuronic acid unit [7]. This was confirmed by the negative ESI-MS ion peak at *m/z* 491.1 $[M-SO_3-H]^-$, 315.2 $[M-SO_3-GlcA-H]^-$, and 255.1 $[M-aglycone-H]^-$. On the basis of these data, the structure of **1** was elucidated as hypolaetin 4′-methyl ether 8-*O*-β-D-glucuronide 2″-sulfate.

Compound **2** was isolated as a yellow amorphous powder. Its IR spectrum

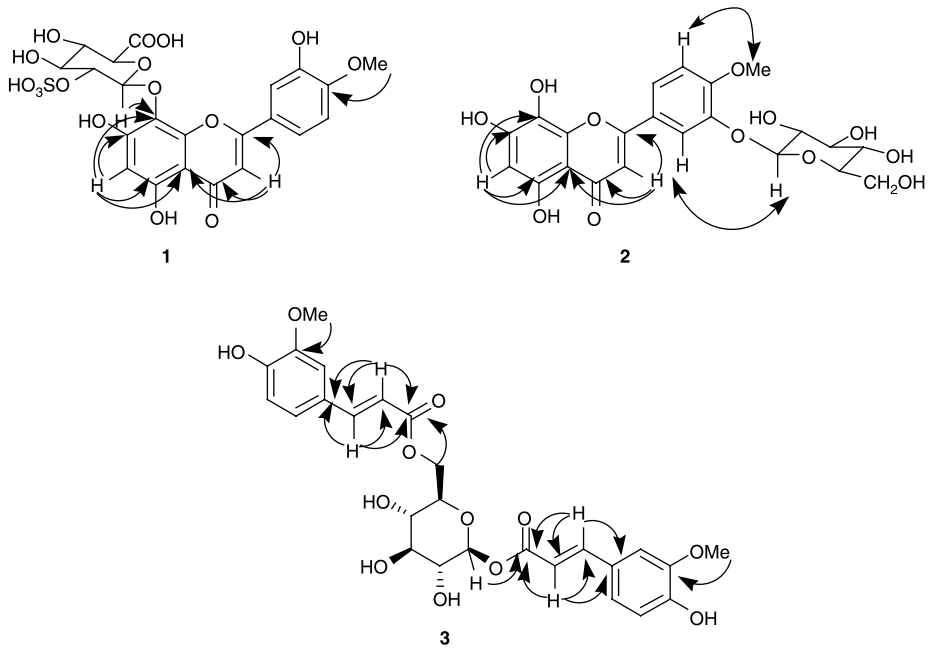

Figure 2. The key HMBC (⟶) and NOESY (⟷) correlations of **1**–**3**.

showed absorptions of a hydroxyl group (3415 cm^{-1}), aromatic groups (1589, 1519 cm^{-1}), and a conjugated carbonyl group (1665 cm^{-1}). The UV absorption maxima at 340 and 275 nm were observed in **2**. The positive HR-ESI-MS displayed an ion at *m/z* 479.1205 $[M + H]^+$, in agreement with the molecular formula $C_{22}H_{22}O_{12}$. Comparing the ^1H NMR spectral data of **2** (Table 1) with those of **1** indicated that **2** has the same aglycone as **1**. The ^{13}C NMR spectral data (Table 1) exhibited 22 carbon signals, suggesting the presence of 5,7,8,3′-tetrahydroxy-4′-methoxyflavone and glucose units. In the HMBC experiment, a long-range correlation between the methoxyl protons at δ_H 3.88 and C-4′ at δ_C 152.1 established that the methoxyl must be linked at C-4′ in ring B (Figure 2). In the NOE experiment, the signal of H-2′ at δ_H 7.75 was enhanced by irradiating the signal of H-1″ at δ_H 5.16, while H-5′ at δ_H 7.17 was enhanced by irradiating the signals of MeO-4′ at δ_H 3.88 (Figure 2). So, the glycosyl linkage was determined to be at C-3′. Along with further acid hydrolysis, the structure of **2** was concluded as hypolaetin 4′-methyl ether 3′-*O*-β-D-glucoside.

Compound **3** was isolated as a white amorphous powder and showed IR absorptions of a hydroxyl group (3396 cm^{-1}), aromatic groups (1593, 1513 cm^{-1}), a carbonyl group (1701 cm^{-1}), and a double bond (1630 cm^{-1}). The UV absorption maximum was observed to be at 327 nm. Its molecular formula was deduced as $C_{26}H_{27}O_{12}$ from HR-ESI-MS at *m/z* 531.1511. The ^1H NMR spectrum of **3** (Table 2) showed two sets of *trans*-olefinic hydrogen signals at δ_H 7.62 (1H, d, $J = 15.5$ Hz) and 6.47 (1H, d, $J = 15.5$ Hz), 7.52 (1H, d, $J = 15.5$ Hz) and 6.48 (1H, d, $J = 15.5$ Hz), and two methoxyl signals at δ_H 3.79. In addition, two sets of ABX-type phenyl hydrogen signals at δ_H 7.32 (1H, d, $J = 2.0$ Hz), 7.31 (1H, d, $J = 2.0$ Hz), 7.12 (1H, dd, $J = 2.0$, 8.0 Hz), 7.09 (1H, dd, $J = 2.0$, 8.0 Hz), 6.78 (1H, d, $J = 8.0$ Hz), and 6.76 (1H, d, $J = 8.0$ Hz) indicated the existence of two trisubstituted aromatic rings in **3**. The ^{13}C NMR spectrum of **3** (Table 2) demonstrated carbon resonances corresponding to two carbonyl, two sets of trisubstituted phenyl, two sets of olefinic, two methoxyl, and six saccharide carbon signals. Furthermore, two main peaks were shown in the positive ESI-MS at *m/z* 555.1 $[M+Na]^+$ and 361.1 $[M+Na-194]^+$. These data of ESI-MS and NMR revealed that two feruloyl groups and a glucose moiety existed in **3**. These were confirmed by the HMBC correlation (Figure 2) from the methoxyl, H-2′/2″ and H-5′/5″ to C-3′/3″, and from H-7′/7″ and H-8′/8″ to C-9′/9″. The long-range correlations (Figure 2) from H-1 to C-9′ and H-6 to C-9″ indicated that two ferulic acid units were

Table 2. ^1H and ^{13}C NMR spectral data of compound **3** in DMSO-d_6.

	3	
	^1H	^{13}C
1	5.51 (1H, d, $J = 8.5$ Hz)	94.0
2	3.23 (1H, m)	72.4
3	3.30 (1H, m)	76.1
4	3.25 (1H, m)	69.5
5	3.56 (1H, t, $J = 7.5$ Hz)	74.6
6	4.40 (1H, d, $J = 12.0$ Hz), 4.14 (1H, d, $J = 6.0$ Hz)	63.2
1′		125.4
2′	7.32 (1H, d, $J = 2.0$ Hz)	115.5
3′		147.9
4′		149.6
5′	6.78 (1H, d, $J = 8.0$ Hz)	111.3
6′	7.12 (1H, dd, $J = 2.0$, 8.0 Hz)	123.4
7′	7.62 (1H, d, $J = 15.5$ Hz)	146.4
8′	6.47 (1H, d, $J = 15.5$ Hz)	113.6
9′		165.2
MeO-3′	3.79 (3H, s)	55.6
1″		125.3
2″	7.31 (1H, d, $J = 2.0$ Hz)	115.4
3″		147.9
4″		149.4
5″	6.76 (1H, d, $J = 8.0$ Hz)	111.0
6″	7.09 (1H, dd, $J = 2.0$, 8.0 Hz)	123.3
7″	7.52 (1H, d, $J = 15.5$ Hz)	145.3
8″	6.48 (1H, d, $J = 15.5$ Hz)	114.5
9″		166.6
MeO-3″	3.79 (3H, s)	55.6

respectively attached at C-1 and C-6 of the glucose. The same acid hydrolysis verified the glucose to be of D-configuration. Consequently, the structure of **3** was determined as 1,6-diferuloyl glucose.

3. Experimental

3.1 General experimental procedures

Optical rotation was measured on a Perkin-Elmer 341LC polarimeter (Waltham, MA, USA). UV spectra were measured on a JASCO V650 spectropolarimeter (Tokyo, Japan). IR spectra were recorded on a Nicolet 5700 FT-IR (KBr) instrument (ThermoNicolet, MA, USA). The ^{1}H (500 MHz) and ^{13}C NMR (125 MHz) spectra, NOE, and HMBC spectra were performed on INOVA-500 MHz spectrometers (Varian NMR System, Palo Alto, CA, USA). HR-ESI-MS were performed on a Finnigan LTQ FT mass spectrometer (Thermofinnigan, MA, USA). ESI-MS were performed on a Finnigan LCQ Advantage ion trap mass spectrometer (Thermofinnigan, MA, USA). Silica gel (100–200, 200–300 mesh) and silica gel GF-254 (Qingdao Haiyang Chemical Group Corp., Qingdao, China) were used for CC and TLC, respectively. The spots on TLC were detected under UV or by heating after spraying with 5% H_2SO_4 in EtOH. Preparative HPLC was performed with an LC-6AD pump (Shimadzu, Kyoto, Japan) equipped with an SPD-20A detector (Shimadzu, Kyoto, Japan) using an ODS column (20 × 250 mm, 5 μm; YMC, Kyoto, Japan). HPLC was performed with Agilent 1200 equipped with a DAD detector (Santa Clara, CA, USA) using an ODS column (4.6 × 250 mm, 5 μm; Apollo, IL, USA).

3.2 Plant material

The leaves of *S. foetida* were collected from Hainan Province of China in July 2006. The plant was identified by Professor Lin Ma (Institute of Materia Medica, Peking Union Medical College, and Chinese Academy of Medical Science, China). A voucher specimen (No. 20060723) has been deposited in the Herbarium of the Department of Medicinal Plants, Institute of Materia Media, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China.

3.3 Extraction and isolation

The shade-dried leaves of *S. foetida* (10 kg) were powdered and extracted with ethanol three times. The EtOH extract was evaporated under reduced pressure to yield a dark brown residue (728 g). The residue was suspended in H_2O and further extracted sequentially using petroleum ether, EtOAc, and *n*-BuOH. After analysis by HPLC, the *n*-BuOH (100 g) and H_2O (85 g) fractions were subjected to macroporous resin column eluting with EtOH–H_2O (0:1 → 1:0) to provide four fractions (Fr_{Bu}. 1–4). Fr_{Bu}. 3 eluted by 30% EtOH–H_2O was rechromatographed over Sephadex LH-20, eluted with MeOH–H_2O (0:1 → 1:0) to afford flavonoid-containing fractions (Fr_n. 1–8). The Fr_n. 3 was chromatographed over Sephadex LH-20, eluted with MeOH–H_2O (5:95 → 1:0) and further purified by preparative HPLC (MeOH–H_2O 33:67, 3 ml/min) to obtain compound **1** (15 mg). Fr_n. 4 was chromatographed over Sephadex LH-20 column, eluted with CH_3OH–H_2O (20:80 → 1:0) and then further purified by preparative HPLC using MeOH–H_2O (42:58, 3 ml/min) as the mobile phase to yield compound **2** (8.5 mg). The EtOAc extract was subjected to a silica gel column and eluted with $CHCl_3$–MeOH (0:1 → 1:0) to give 12 fractions (Fr_{Et}. 1–12). Fr_{Et}. 8 was rechromatographed repeatedly on Sephadex LH-20, eluted with MeOH–H_2O (45:55) to yield **3** (8.7 mg).

3.3.1 Hypolaetin 4′-methyl ether 8-O-β-D-glucuronide 2″-sulfate (1)

A yellow amorphous powder (15 mg); $[\alpha]_D^{20}$ −81.3 ($c = 0.21$, MeOH); UV

(MeOH) λ_{max} (log ε): 273 (4.19), 346 (4.19) nm. IR (KBr) ν_{max}: 3261, 1727, 1657, 1584, 1504, 1440, 1254, 1362, 1314, 814 cm^{-1}; ^1H and ^{13}C NMR spectral data: see Table 1; ESI-MS *m/z*: 571.0 (100, $[M-H]^-$), 491.1 (5, $[M-SO_3-H]^-$), 315.2 (20, $[M-SO_3-GlcA-H]^-$), 255.1 (10, $[M-315-H]^-$); HR-ESI-MS *m/z*: 571.0415 $[M-H]^-$ (calcd for $C_{22}H_{19}O_{16}S$, 571.0388).

3.3.2 *Hypolaetin 4′-methyl ether 3′-O-β-D-glucoside (**2**)*

A yellow amorphous powder (8.5 mg); $[\alpha]_D^{20}$ −23.4 ($c = 0.04$, MeOH); UV (MeOH) λ_{max} (log ε): 275 (4.24) and 340 (4.19) nm; IR (KBr) ν_{max}: 3415, 1665, 1589, 1519, 1429, 1365, 1268, 1095, 1083 cm^{-1}; ^1H and ^{13}C NMR spectral data: see Table 1; HR-ESI-MS *m/z*: 479.1205 $[M+H]^+$ (calcd for $C_{22}H_{23}O_{12}$, 479.1189).

3.3.3 *1,6-Diferuloyl glucose (**3**)*

A white amorphous powder (8.7 mg); $[\alpha]_D^{20}$ −31.1 ($c = 0.10$, MeOH); UV (MeOH) λ_{max} (log ε): 327 (4.36) nm; IR (KBr) ν_{max}: 3396, 1701, 1630, 1593, 1513, 1452, 1429, 1268, 1161, 1066, 845, 817 cm^{-1}; ^1H and ^{13}C NMR spectral data: see Table 2; ESI-MS *m/z*: 555.1 (50, $[M+Na]^+$), 361.1 (100, $[M+Na-194]^+$); HR-ESI-MS *m/z*: 531.1511 $[M-H]^-$ (calcd for $C_{26}H_{27}O_{12}$, 531.1497).

3.4 *Acid hydrolysis*

A solution of compounds **1**–**3** (5 mg) in MeOH (1.5 ml) was treated with 5% HCl (1.5 ml) at 85°C for 4 h [8]. After evaporation of MeOH, the reaction mixtures were extracted with EtOAc (3 × 5 ml); the sulfate ion was precipitated in the water layer with $BaCl_2$ [8]. Then, D-glucuronate and glucose were determined by the measurement of optical rotation (gave positive optical rotation). The solvent systems $CHCl_3$–MeOH–AcOH–H_2O (14:6:2:1) [9] were used for TLC identification of glucuronate (R_f: 0.18) and glucose (R_f: 0.22).

Acknowledgement

The authors are grateful to Mrs Yinghong Wang for her assistance in obtaining the NMR spectra.

References

[1] R.N. Chopra, S.L. Nayar, and I.C. Chopra, *Glossary of Indian Medicinal Plants* (Publication and Information Directorate, New Delhi, 1992), p. 234.
[2] A.M. Mujumdar, D.G. Naik, R.J. Waghole, D.K. Kulkarni, and M.S. Kumbhojkar, *Pharm. Biol.* **38**, 13 (2000).
[3] N.A.G. Ramachandran, P. Ramesh, and S.S. Sankara, *Curr. Sci.* **46**, 14 (1977).
[4] A.S.R. Anjaneyulu and M.V. Suryanarayana, *Indian J. Chem.* **20B**, 87 (1981).
[5] H. Dubey and J.S. Tiwari, *Indian J. Chem.* **68**, 427 (1991).
[6] M. Billeter, B. Meier, and O. Sticher, *Phytochemistry* **30**, 987 (1991).
[7] J. Gudej, *Planta Med.* **57**, 284 (1991).
[8] K. Kamiya, Y. Saiki, T. Hama, Y. Fujimoto, H. Endang, M. Umar, and T. Satake, *Phytochemistry* **57**, 297 (2001).
[9] Z.Z. Zhang, H.N. ElSohly, X.C.J. Li, and S.I. Khan, *J. Nat. Prod.* **66**, 39 (2003).