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Saurobacciosides A - C: three new glycosides from *Sauropus bacciformis* with their cytotoxic activity

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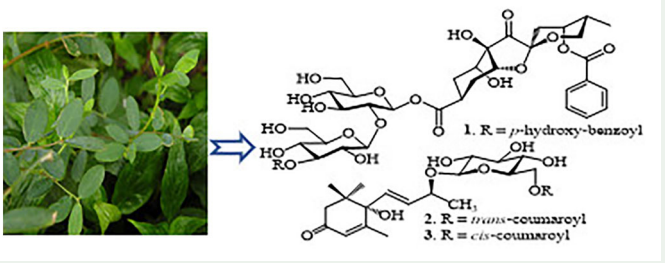
ABSTRACT

Three new glycosides, named as saurobaccioside A (**1**), saurobaccioside B (**2**), saurobaccioside C (**3**), together with five known magastigmanes, canangaionoside (**4**), (6*S*,9*S*)-roseoside (**5**), cucumegastigmane I (**6**), icariside B5 (**7**), linarionoside A (**8**) were isolated from the whole plant of *Sauropus bacciformis* (L.) Airy Shaw. Their structures were established by extensive spectroscopic analysis (UV, IR, HR-ESI-MS and NMR) and by comparison of the spectral data with those reported in the literature. The absolute configurations of compounds **2** and **3** were elucidated by experimental CD spectra. Compounds **1**-**8** were screened their cytotoxic activities towards CAL27 and MDAMB231 cancer cell lines. Compound **1** exhibited significant cytotoxic activity towards CAL27 and MDAMB231 cell lines with IC_{50} values of 3.21 ± 0.23 and 4.75 ± 0.17 μM, respectively, which were smaller than those of positive control capecitabine (IC_{50}: 8.20 ± 0.75 and 5.20 ± 0.89 μM). Other compounds (**2**-**8**) were inactive.



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1. Introduction

The genus *Sauropus* (family Phyllanthaceae) comprises about 40 species of herbs, shrubs or subshrubs, sometimes with woody bases. They are distributed in Southeast Asia (Thailand up to Vietnam), Malesia and Australia (Peter 2003). Some *Sauropus*

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species are highly valued due to their high nutritive value and inexpensive source of dietary protein which is also used in traditional medicine (Faisal and Muhammad 2020; Tamanna and Raviraja 2020). The phytochemical investigation of *Sauropus* genus suggested the presence of carotenoids, flavonoids, lignans, megastigmanes (Tripetch et al. 2003; Faisal and Muhammad 2020; Tamanna and Raviraja 2020). The methanol extract of whole plant of *Sauropus bacciformis* has potent hepatoprotective action upon carbon tetrachloride induced hepatic damage in rats (Sheela and Udhayakumari 2018). In Vietnam, *S. bacciformis* plant is widely distributed and used in folk medicine for treatment of snakebite, detoxify, diarrhea, hepatitis (Ho 1999; Chi 2012). However, up to now, there has been no publication of the chemical composition of *S. bacciformis*. This paper reports three new glycosides (**1**–**3**) together with five known magastigmanes from the whole plant of *Sauropus bacciformis*. Their cytotoxic activity towards human oral cancer cell lines (CAL27) and human breast cancer cell lines (MDAMB231) were also evaluated.

2. Results and discussion

Compound **1** was obtained as colorless amorphous powder. Its molecular formula was determined to be $C_{40}H_{48}O_{21}$ by *quasi*-molecular ion peaks in HR-ESI-MS (*m/z* 899.2390 [M + ^{35}Cl]$^-$, calcd. for $C_{40}H_{48}O_{21}{}^{35}Cl$: 899.2377; *m/z* 901.2393 [M + ^{37}Cl]$^-$, calcd. for $C_{40}H_{48}O_{21}{}^{37}Cl$: 901.2347) and in conjunction with ^{13}C NMR data, indicating 17 degrees of unsaturation. The ^{1}H NMR spectrum of **1** observed resonant signals corresponding to a phenyl group [δ_H 8.09 (2H, dd, $J = 8.0$, 1.5 Hz, H-2′, H-6′), 7.49 (2H, dd, $J = 8.0$, 8.0, Hz, H-3′, H-5′), 7.61 (1H, tt, $J = 8.0$, 1.5 Hz, H-4′)], a *para*-substituted phenyl group [δ_H 8.10 (2H, br d, $J = 8.5$ Hz, H-2‴′, H-6‴′), 6.98 (2H, br d, $J = 8.5$ Hz, H-3‴′, H-5‴′)], two anomeric protons [δ_H 5.65 and 4.38 (each 1H, d, $J = 8.0$ Hz)], and a methyl group [δ_H 0.91 (3H, d, $J = 7.0$ Hz)]. The ^{13}C NMR spectrum of **1** showed signals of 40 carbons which were assigned by HSQC spectrum into nine non-protonated carbons, 24 methine carbons, six methylene carbons, and one methyl carbon. In particularly, eight signals of twelve aromatic carbons together with HMBC correlations from H-2′/H-6′ (δ_H 8.09) to C-7′ (δ_C 168.1), from H-2‴′/H-6‴′ (δ_H 8.10) to C-7‴′ (δ_C 167.9)/C-4‴′ (δ_C 163.1) indicated the presence of a benzoyl and a *para*-hydroxy benzoyl groups. Two anomeric carbons (δ_C 93.7 and 106.1) and 10 oxygenated carbons suggested for two hexose moieties. The chemical shift value of C-2″ resonanced at δ_C 83.3 suggested that a glycoside linkage was formed through C-2″. Remaining 14 carbons expected for a norsesquiterpene backbone of the aglycone. Structure of aglycone moiety was further elucidated by COSY and HMBC analysis as shown in Figure S1. COSY cross peaks of H-1 (δ_H 3.96)/H-2(δ_H 2.07 and 1.81)/H-3 (δ_H 2.94)/H-4 (δ_H 2.40 and 1.90)/H-5 (δ_H 4.31), as well as HMBC correlations from H-1 and H-5 to C-6 (δ_C 75.5) established structure of cyclohexane ring (A-ring). On the other hand, COSY cross peaks of H_2-9 (δ_H 2.29 and 1.99)/H-10 (δ_H 5.33)/H-11 (δ_H 2.18)/H_2-12 (δ_H 4.06 and 3.58), and of H-11 (δ_H 2.18)/H_3-14 (δ_H 0.91), together with HMBC correlations from H_2-9 and H_2-12 to C-8 (δ_C 100.6) revealed structure of tetrahydropyrane ring (B-ring). Deshielded carbon signals of C-7 (δ_C 213.7) and HMBC correlation from H-5 (δ_H 4.31) to C-8 (δ_C 100.6) suggested the formation of ketone functional group at C-7 and an ether-bridge between C-5 and C-

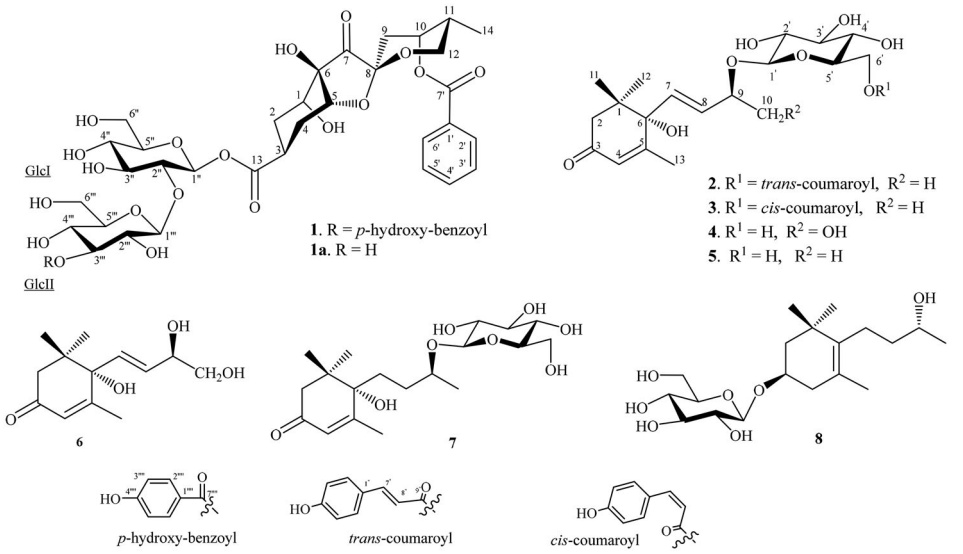

Figure 1. Chemical structures of compounds **1**–**8**.

8. HMBC correlations from H-3 (δ_H 2.94) to C-13 (δ_C 175.9), from H-10 (δ_H 5.33) to C-7′ (δ_C 168.1) confirmed the presence of carboxyl group at C-13 and *O*-benzoyl group at C-10, respectively. Thus, aglycone moiety of compound **1** was then identified to be phyllaemblic acid as previous described (Zhang et al. 2000). Moreover, ^{1}H and ^{13}C NMR spectral data of **1** were recognized close similarity to those of phyllaemblicin B, except for the observations of additional signals corresponding to *para*-hydroxy benzoyl group. The COSY cross peaks between H-1‴ (δ_H 4.38) and H-2‴ (δ_H 3.44), between H-2‴ and H-3‴ (δ_H 5.13) together with HMBC correlation from H-3‴ to C-7⁗ (δ_C 167.9) were observed confirming that the *para*-hydroxy benzoyl group was linked to C-3‴ of glcII. Continuously, COSY cross peaks from H-1″ (δ_H 5.65) to H-2″ (δ_H 3.56) together with HMBC correlation from H-1‴ (δ_H 4.38) to C-2″ (δ_C 83.3) confirmed the glcII linked to C-2″ of the glcI. The sugar linkages must be in the β-form as judged from the coupling constants ($J = 8.0$ Hz) of the anomeric protons at δ_H 5.65 and 4.38. Except for the additional *para*-hydroxy benzoyl group, the proton and carbon chemical shifts as well as the ^{1}H-^{1}H coupling constants of compound **1** matched perfectly with the corresponding data of phyllaemblicin B (**1a**) (Table S3) suggesting that the relative configuration of **1** was similar to that of phyllaemblicin B (Zhang et al. 2000), which was further confirmed by NOESY spectrum. Detailed key NOESY correlations in the aglycone moiety of **1** were shown in Figure S1a. Finally, the presence of D-glucose in the acid hydrolysis product of compound **1** was confirmed by HPLC analysis. Consequently, the chemical structure of compound **1** was established as shown in Figure 1, a new compound named as saurobaccioside A.

Compound **2** was obtained as colorless amorphous powder. Its molecular formula was determined to be $C_{28}H_{36}O_{10}$ by *quasi*-molecular ion peaks in HR-ESI-MS (*m/z* 567.2006 $[M + {}^{35}Cl]^-$ (Calcd. for $[C_{28}H_{36}O_{10}{}^{35}Cl]^-$, 567.1997), *m/z* 569.1994 $[M + {}^{37}Cl]^-$ (Calcd. for $[C_{28}H_{36}O_{10}{}^{37}Cl]^-$, 569.1967), indicating 11 degrees of unsaturation. The ^{1}H NMR spectrum of **2** exhibited three methyl singlet signals at δ_H 0.99, 1.04, 1.96

(each, 3H) and one methyl doublet at δ_H 1.30 ($J = 6.5$ Hz), four olefinic protons of two *trans* double bonds at δ_H 5.75/5.90 ($J = 16.0$ Hz) and δ_H 6.34/7.66 ($J = 16.0$ Hz), a broad singlet of olefinic proton at δ_H 5.90, a *para*-substituted benzene ring at δ_H 7.47 and 6.83 (each, 2H, br d, $J = 8.5$ Hz), and one anomeric proton at δ_H 4.31 (d, $J = 8.0$ Hz). The ^{13}C NMR spectrum of **2** showed signals of 28 carbons which were assigned by HSQC spectrum into seven quaternary carbons, 15 methine carbons, two methylene carbons, and four methyl carbon. One ketone carbon and one carboxylate group were identified at δ_C 201.1 and 169.0, respectively. One coumaroyl moiety was identified by signals of the *para*-substituted benzene ring at δ_C 127.2 (C), 116.9 (CH x 2), 131.2 (CH x 2), 161.4 (C), a *trans* double bond at δ_C 114.9 and 146.9, and of one carboxylate group at δ_C 169.0, which were further confirmed by HMBC correlation from H-7″ (δ_H 7.66) to C-9″ (δ_C 169.0) and C-2″ (δ_C 131.2). In addition, a set of signals of δ_C 101.3, 74.9, 78.2, 71.9, 75.6 (5 CH), and 64.7 (CH_2) was consistent with a glucose having an ester linkage at C-6′. Remaining 13 carbon signals including four methyl groups (δ_C 19.6, 22.2, 23.5, 24.7), two double bond (127.1/166.9, 133.9/133.6), one C = O carbon (δ_C 201.1), two carbons bearing oxygene atoms at δ_C 79.9 and 74.8, were assigned for the megastigmane having ketone group at C-3, two double bonds at C-4/C-5 and C-7/C-8, and one hydroxyl group at C-6 and an ether linkage at C-9 as roseosides (Son et al. 2015). The NMR data of **2** were found to be similar to the corresponding data of 6′-*O*-caffeoyl-(6*S*,9*R*)-roseoside (Son et al. 2015) except for the data of the caffeoyl group were replaced by the data of coumaroyl group of **2**. This evidence was further confirmed by COSY and HMBC correlations as shown in Figure S1. In the literature, the ^{13}C NMR chemical shifts of the (9*R*)- and (9*S*)-configuration are 77.0 and 74.7, respectively (Yamano and Ito 2005). So that, the ^{13}C NMR chemical shifts of C-9, δ_C 74.8, suggested (9*S*)-configuration of **2**. Comparison to literature data (Yamano and Ito 2005), the stereochemistry at C-6 was established as 6*S* on the basis of circular dichroism (CD) with the exhibition of a positive maximum at 240 nm ($\Delta\varepsilon + 19.5$). Furthermore, the coupling constant ($J = 8.0$ Hz) observed for the anomeric proton in the ^{1}H NMR spectrum of **2** indicated the β-glucoside linkage for the *O*-glucose moiety. Finally, the presence of D-glucose in the acid hydrolysis product of compound **2** was confirmed by HPLC analysis. Consequently, the chemical structure of compound **2** was established as shown in Figure 1, a new compound named as saurobaccioside B.

Compound **3** was obtained as colorless amorphous powder. Its molecular formula was determined to be $C_{28}H_{36}O_{10}$ by *quasi*-molecular ion peaks in HR-ESI-MS (*m/z* 567.2004 [M + ^{35}Cl]$^-$ (Calcd. for [$C_{28}H_{36}O_{10}{}^{35}$Cl]$^-$, 567.1997), *m/z* 569.1995 [M + ^{37}Cl]$^-$ (Calcd. for [$C_{28}H_{36}O_{10}{}^{37}$Cl]$^-$, 569.1967), indicating 11 degrees of unsaturation. The NMR spectra of **3** were similar to those of **2** except for slight differences at the coumaroyl group (Table S4). The smaller proton coupling constant ($J = 13.0$ Hz) of H-7″ (δ_H 6.85) and H-8″ (δ_H 5.77) indicated *cis*-configuration of the double bond at C-7″/C-8″. The NMR assignments of **3** were assigned by comparing its NMR data with the corresponding data of **2** and further confirmed by HSQC, HMBC, COSY, and NOESY spectra. The ^{13}C NMR chemical shifts of C-9, δ_C 74.7, suggested (9*S*)-configuration of **3** (Yamano and Ito 2005). The CD spectrum of **3** exhibited a positive maximum at 240 nm ($\Delta\varepsilon + 21.0$) indicated the stereochemistry at C-6 as 6*S* (Yamano and Ito 2005; Son et al. 2015). The proton coupling constant of the anomeric proton at δ_H 4.28 ($J = 8.0$ Hz)

confirmed the β-form of the glucoside linkage. The presence of D-glucose was indicated by acid hydrolysis product of **3**. Consequently, the chemical structure of compound **3** was established as shown in Figure 1, a new compound named as saurobaccioside C.

The other compounds isolated from *Sauropus bacciformis* were identified as canangaionoside (**4**) (Katsuyoshi et al. 2010), (6*S*,9*S*)-roseoside (**5**) (Yamano and Ito 2005), cucumegastigmane I (**6**) (Hisahiro et al. 2007), icariside B5 (**7**) (Katsuyoshi et al. 2010b), linarionoside A (**8**) (Otsuka 1994) by comparisons of their NMR data with those data reported in the literature and found to match.

Cytotoxic activity of compounds **1**-**8** were assessed towards CAL27 and MDAMB231 human cancer cell lines. Firstly, each compound was screened cytotoxic effects at concentration of 30 μM. As shown in the Table S1, compound **1** significantly exhibited cytotoxic effects by showing low percentages of cell viability in both tested cell lines (14.0 ± 0.01% and 25.6 ± 0.72% for CAL27 and MDAMB231 experiments, respectively). The cell viability percentages were in range from 71.3 ± 0.74% to 95.4 ± 0.62 in the presence of compounds **2**-**8** suggested that those compounds were inactive. Compound **1** was then performed dose-dependent study. Its IC_{50} values were calculated to be 3.21 ± 0.23 μM and 4.75 ± 0.17 μM against CAL27 and MDAMB231 cells, respectively (Table S2). Phyllaemblic acid and its derivatives such as phyllaemplicins were previously reported to be major components of *Phyllanthus emblica* (Zhang et al. 2004; Lv et al. 2015). These compounds exhibited potent antiviral and cytotoxic activities. Interesting that, phyllaemblic acid and its monoglucoside derivative (phyllaemblic acid β-D-glucopyranosyl ester) did not show cytotoxic activity but several phyllaemblic acid glycosides containing two or more monosaccharide units significantly exhibited cytotoxic activity (Zhang et al. 2004). In our study, compound **1** was a diglucoside derivative of phyllaemblic acid and showed significantly cytotoxic effect against CAL27 and NDAMB231 cells.

3. Experimental

3.1. General

Optical rotation was measured on a Jasco P2000 polarimeter. IR spectrum was recorded on a Spectrum Two FT-IR spectrometer. CD spectrum was obtained on a Chirascan spectrometer (Applied Photophysics, Surrey, UK). HR-ESI-MS was acquired on an Agilent 6530 Accurate Mass Q-TOF LC/MS. NMR spectra were recorded on a Bruker 500 MHz spectrometer. Preparative HPLC were run on an Agilent 1100 system including quaternary pump, autosampler, DAD detector, and preparative HPLC column YMC J'sphere ODS-H80 (4 μm, 20 × 250 mm). Isocratic mobile phase with the flow rate of 3 mL/min was used in pre-HPLC. The compound was monitored at wavelengths of 205, 230, 254, and 280 nm. Flash column chromatography was performed using silica gel, reversed phase C-18, and diaion HP-20 resins as stationary phase. Thin layer chromatography was carried out on pre-coated silica gel 60 F_{254} and RP-18 F_{254S} plates. The spots were detected by spraying with aqueous solution of H_2SO_4 5% followed by heating with a heat gun.

3.2. Plant material

The aerial parts of *Sauropus bacciformis* (L.) Airy Shaw were collected at Xuan Thuy District, Nam Dinh Province, Vietnam in Jun 2019 and taxonomically identified by Dr Nguyen The Cuong at the Institute of Ecology and Biological Resources, VAST. Voucher specimen (NCCT-P118) was deposited at the Institute of Marine Biochemistry, VAST.

3.3. Extraction and isolation

The dried powder of aerial parts of *Sauropus bacciformis* (10 kg) were sonicated with methanol (3 times, each 15 L MeOH). After removal of solvent, the MeOH extract (350 g) was suspended with water and then partitioned with dichloromethane and then ethyl acetate to give corresponding residues, (HSBD, 90 g) and (HSBE, 8 g), and water layer (HSBW). The HSBE (8 g) was chromatographed on a RP-18 column eluting with MeOH/water (1.2/1, v/v) to give seven fractions, HSBE1 → HSBE7. HSBE4 (160 mg) was chromatographed on HPLC (J'sphere H-80 column, 250 mm length x 20 mm ID, eluting with 30% acetonitrile in water, a flow rate of 2.5 mL/min) to give compounds **1** (4.5 mg) and **6** (6.0 mg). HSBE5 (259 mg) was chromatographed on HPLC (J'sphere H-80 column, 250 mm length x 20 mm ID, eluting with 30% acetonitrile in water, a flow rate of 2.5 mL/min) to give compounds **2** (4.0 mg) and **3** (5 mg). The water layer (HSBW) was chromatographed on a Diaion HP-20 column, first eluting with water to remove sugar components, then increasing concentration of MeOH in water (25, 50, 75, and 100%) to obtain four fractions, HSBW1 (6.8 g), HSBW2 (17 g), HSBW3 (8.5 g), HSBW4 (2.9 g). The HSBW2 fraction was subjected on a silica gel CC eluting with gradient solvent of CH_2Cl_2/MeOH (30/1, 10/1, 5/1, 0/1 v/v) to give four fractions, HSBW2A → HSBW2D. The HSBW2B (685 mg) was re-chromatographed on a silica gel CC eluting with CH_2Cl_2/MeOH (10/1, v/v) to give five smaller sub-fractions, HSBW2B1 → HSBW2B5. HSBW2B1 (56 mg) was chromatographed on HPLC (J'sphere H-80 column, 250 mm length x 20 mm ID, eluting with 20% acetonitrile in water, a flow rate of 2.5 mL/min) to give **5** (5.0 mg). HSBW2B3 (46 mg) was chromatographed on HPLC (J'sphere H-80 column, 250 mm length x 20 mm ID, eluting with 20% acetonitrile in water, a flow rate of 2.5 mL/min) to give compounds **7** (8.0 mg) and **8** (11.0 mg). HSBW2C (3 g) was chromatographed on a sephadex LH-20 column, eluting with MeOH/water (1/1, v/v) to give two fractions, HSBW2C1 and HSBW2C2. HSBW2C1 (352 mg) was chromatographed on a RP-18 column eluting with MeOH/water (1/1.5, v/v) to give four smaller sub-fractions, HSBW2C1A → HSBW2C1D. HSBW2C1B (35 mg) was chromatographed on HPLC (J'sphere H-80 column, 250 mm length x 20 mm ID, eluting with 16% acetonitrile in water, a flow rate of 2 mL/min) to give **4** (4.7 mg).

3.3.1. Saurobaccioside A (1)

Colorless amorphous powder, $[\alpha]_D^{25}$: +5.5° (*c* 0.1, MeOH); UV (MeOH) λ_{max} 234, 257 nm; IR (KBr): ν_{max} 3360 (broad), 2932, 1707, 1607, 1278, 1075 cm^{-1}; HR-ESI-MS *m/z* 899.2390 [M + $^{35}Cl]^-$, calcd. for $C_{40}H_{48}O_{21}{}^{35}Cl$: 899.2377; *m/z* 901.2393 [M + $^{37}Cl]^-$, calcd. for $C_{40}H_{48}O_{21}{}^{37}Cl$: 901.2347. ^{1}H-NMR ($CD_3OD$, 500 MHz), δ (ppm): 3.96 (1H, br s, H-1), 2.07 (1H, br d, $J = 14.5$ Hz, H_{eq}-2), 1.81 (1H, ddd, $J = 3.0$, 13.0, 14.5 Hz, H_{ax}-2), 2.94

(1H, m, H-3), 2.40 (1H, br d $J = 14.5$ Hz, H_{eq}-4), 1.90 (1H, ddd, $J = 4.0$, 13.0, 14.5 Hz, H_{ax}-4), 4.31 (1H, br s, H-5), 2.29 (1H, dd, $J = 3.0$, 14.5 Hz, H_a-9), 1.99 (1H, dd, $J = 3.0$, 14.5 Hz, H_b-9), 5.33 (1H, br d, $J = 3.0$ Hz, H-10), 2.18 (1H, m, H-11), 4.06 (1H, dd, $J = 11.0$, 11.0 Hz, H_{ax}-12), 3.58 (1H, dd, $J = 5.0$, 11.0 Hz, H_{eq}-12), 0.91 (1H, d, $J = 7.0$ Hz, H-14), **Benzoyl**: 8.09 (2H, dd, $J = 8.0$, 1.5 Hz, H-2′, H-6′), 7.49 (2H, dd, $J = 8.0$, 8.0 Hz, H-3′, H-5′), 7.61 (1H, tt, $J = 8.0$, 1.5 Hz, H-4′), **Glcl**: 5.65 (1H, d, $J = 8.0$ Hz, H-1″), 3.56 (1H, dd, $J = 8.0$, 9.0 Hz, H-2″), 3.63 (1H, t, $J = 9.0$ Hz, H-3″), 3.57 (1H, t, $J = 9.0$ Hz, H-4″), 3.44 (1H, m, H-5″), 3.81 (1H, dd, $J = 5.5$, 12.0 Hz, H-6″), 3.95 (1H, dd, $J = 2.0$, 12.0 Hz, H-6″), **GlcII**: 4.38 (1H, d, $J = 8.0$ Hz, H-1‴), 3.44 (1H, dd, $J = 8.0$, 9.0 Hz, H-2‴), 5.13 (1H, t, $J = 9.0$ Hz, H-3‴), 3.61 (1H, t, $J = 9.0$ Hz, H-4‴), 2.93 (1H, m, H-5‴), 3.60-3.64 (2H, H-6‴), ***p*-hydroxy-benzoyl**: 8.10 (1H, br d, $J = 8.5$ Hz, H-2⁗, H-6⁗), 6.98 (1H, br d, $J = 8.5$ Hz, H-3⁗, H-5⁗). ^{13}C-NMR (CD_3OD, 125 MHz), δ (ppm): 71.5 (C-1), 32.2 (C-2), 32.2 (C-3), 29.4 (C-4), 76.3 (C-5), 75.5 (C-6), 213.7 (C-7), 100.6 (C-8), 32.8 (C-9), 70.4 (C-10), 34.4 (C-11), 63.5 (C-12), 175.9 (C-13), 13.1 (C-14), 131.7 (C-1′), 130.7 (C-2′, C-6′), 129.4 (C-3′, C-5′), 134.1 (C-4′), 168.1 (C-7′), **Glcl**: 93.7 (C-1″), 83.3 (C-2″), 77.9 (C-3″), 70.6 (C-4″), 79.1 (C-5″), 62.4 (C-6″), **GlcII**: 106.1 (C-1‴),74.2 (C-2‴), 79.5 (C-3‴), 68.9 (C-4‴), 77.6 (C-5‴), 61.6 (C-6‴), ***p*-hydroxy-benzoyl**: 123.2 (C-1⁗), 133.2 (C-2⁗, C-6⁗), 116.6 (C-3⁗, C-5⁗), 163.2 (C-4⁗), 167.9 (C-7⁗).

3.3.2. Saurobaccioside B (2)

Colorless amorphous powder, $[\alpha]_D^{25}$: + 5.1° (*c* 0.1, MeOH); UV (MeOH) λ_{max} 232, 314 nm; IR (KBr): ν_{max} 3415 (broad), 2971, 1695, 1649, 1604, 1168, 1040 cm^{-1}; CD (MeOD) $mdeg_{(\lambda)}$: $+19.5_{(240)}$. HR-ESI-MS *m/z* 567.2006 [M + ^{35}Cl]$^-$ (Calcd. for $[C_{28}H_{36}O_{10}{}^{35}Cl]^-$, 567.1997), *m/z* 569.1994 [M + ^{37}Cl]$^-$ (Calcd. for $[C_{28}H_{36}O_{10}{}^{37}Cl]^-$, 569.1967). ^{1}H-NMR ($CD_3OD$, 500 MHz), δ (ppm): 2.17 (1H, d, $J = 17.0$ Hz, H_a-2), 2.52 (d, $J = 17.0$ Hz, H_b-2), 5.90 (1H, brs, H-4), 5.90 (1H, d, $J = 16.0$ Hz, H-7), 5.75 (1H, dd, $J = 16.0$, 7.0 Hz, H-8), 4.47 (1H, m, H-9), 1.30 (3H, d, $J = 6.5$ Hz, H-10), 1.04 (3H, s, H-11), 0.99 (3H, s, H-12), 1.96 (3H, d, $J = 2.0$ Hz, H-13), **Glc**: 4.31 (1H, d, $J = 8.0$ Hz, H-1′), 3.25 (1H, dd, $J = 8.0$, 9.0 Hz, H-2′), 3.33 (1H, t, $J = 9.0$ Hz, H-3′), 3.33 (1H, t, $J = 9.0$ Hz, H-4′), 3.41 (1H, m, H-5′), 4.51 (1H, dd, $J = 2.0$, 12.0 Hz, H_a-6′), 4.32 (dd, 6.0, 12.0 Hz, H_b-6′), ***(E)*-coumaroyl**: 7.47 (2H, br d, $J = 8.5$ Hz, H-2″, H-6″), 6.83 (2H, br d, $J = 8.5$ Hz, H-3″, H-5″), 7.66 (1H, d, $J = 16.0$ Hz, H-7″), 6.34 (1H, d, $J = 16.0$ Hz, H-8″). ^{13}C-NMR (CD_3OD, 125 MHz), δ (ppm): 42.4 (C-1), 50.8 (C-2), 201.1 (C-3), 127.1 (C-4), 166.9 (C-5), 79.9 (C-6), 133.9 (C-7), 133.6 (C-8), 74.8 (C-9), 22.2 (C-10), 23.5 (C-11), 24.7 (C-12), 19.6 (C-13), **Glc**: 101.3 (C-1′), 74.9 (C-2′), 78.2 (C-3′), 71.9 (C-4′), 75.6 (C-5′), 64.7 (C-6′), ***(E)*-coumaroyl**: 127.2 (C-1″), 131.2 (C-2″, C-6″), 116.9 (C-3″, C-5″), 161.4 (C-4″), 146.9 (C-7″), 114.9 (C-8″), 169.0 (C-9″).

3.3.3. Saurobaccioside C (3)

$[\alpha]_D^{25}$: + 4.2° (*c* 0.1, MeOH); UV (MeOH) λ_{max} 232, 314 nm; IR (KBr): ν_{max} 3382 (broad), 2970, 1696, 1604, 1651, 1169, 1054 cm^{-1}; CD (MeOD) $mdeg_{(\lambda)}$: $+21.0_{(240)}$. HR-ESI-MS *m/z* 567.2004 [M + ^{35}Cl]$^-$ (Calcd. for $[C_{28}H_{36}O_{10}{}^{35}Cl]^-$, 567.1997), *m/z* 569.1995 [M + ^{37}Cl]$^-$ (Calcd. for $[C_{28}H_{36}O_{10}{}^{37}Cl]^-$, 569.1967).

^{1}H-NMR (CD_3OD, 500 MHz), δ (ppm): 2.19 (1H, d, $J = 17.0$ Hz, H_a-2), 2.56 (1H, d, $J = 17.0$ Hz, H_b-2), 5.87 (1H, brs, H-4), 5.86 (1H, d, $J = 16.0$ Hz, H-7), 5.72 (1H, dd,

$J = 16.0, 7.0$ Hz, H-8), 4.39 (1H, m, H-9), 1.26 (3H, d, $J = 6.5$ Hz, H-10), 1.05 (3H, s, H-11), 1.00 (3H, s, H-12), 1.95 (3H, s, H-13), **Glc**: 4.28 (1H, d, $J = 8.0$ Hz, H-1′), 3.23 (1H, dd, $J = 8.0, 9.0$ Hz, H-2′), 3.31 (1H, t, $J = 9.0$ Hz, H-3′), 3.30 (1H, t, $J = 9.0$ Hz, H-4′), 3.35 (1H, m, H-5′), 4.45 (1H, dd, $J = 2.0, 12.0$ H_a-6′), 4.29 (1H, dd, $J = 6.0, 12.0$ H_b-6′), **(*Z*)-coumaroyl**: 7.67 (2H, br d, $J = 8.5$ Hz, H-2″, H-6″), 6.78 (2H, br d, $J = 8.5$ Hz, H-3″, H-5″), 6.85 (1H, d, $J = 13.0$ Hz, H-7″), 5.77 (1H, d, $J = 13.0$ Hz, H-8″). ^{13}C-NMR (CD_3OD, 125 MHz), δ (ppm): 42.4 (C-1), 50.8 (C-2), 201.2 (C-3), 127.1 (C-4), 167.0 (C-5), 79.9 (C-6), 134.0 (C-7), 133.6 (C-8), 74.7 (C-9), 22.3 (C-10), 23.5 (C-11), 24.7 (C-12), 19.6 (C-13), **Glc**: 101.1 (C-1′), 74.9 (C-2′), 78.3 (C-3′), 71.8 (C-4′), 75.6 (C-5′), 64.5 (C-6′), **(*Z*)-coumaroyl**: 127.5 (C-1″), 133.8 (C-2″, C-6 ″), 116.0 (C-3″, C-5″), 160.2 (C-4″), 145.0 (C-7″), 116.2 (C-8″), 168.1 (C-9″).

4. Conclusions

Three new glycosides named as saurobacciosides A-C (**1-3**) were identified from the whole plant of *Sauropus bacciformis* (L.) Airy Shaw. Their structures were established by extensive spectroscopic analysis. The absolute configurations of compounds **2** and **3** were elucidated by CD spectra. Compound **1** exhibited significantly cytotoxic activity against CAL27 and MDAMB231 cells with IC_{50} values of 3.21 ± 0.23 and 4.75 ± 0.17 μM, respectively, in comparison to those of positive control capecitabine (IC_{50}: 8.20 ± 0.75 and 5.20 ± 0.89 μM).

Disclosure statement

No potential conflict of interest was reported by the authors.

List of abbreviations

COSY: Correlation Spectroscopy; HR-ESI-MS: high-resolution electrospray ionization mass spectrometry; HMBC: Heteronuclear Multiple Bond Correlation; HSQC: Heteronuclear Single Quantum Coherence; Prep-HPLC: Preparative High Performance Liquid Chromatography. CD: Circular Dichroism Spectroscopy. CAL27: Adenosquamous carcinoma cancer cell lines; MDAMB231: Breast cancer cell lines.

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