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IRIDOID GLUCOSIDES FROM *ROGERIA ADENOPHYLLA*

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Key Word Index—*Rogeria adenophylla*; Pedaliaceae; iridoid glucosides; harpagide derivatives; verbascoside.

Abstract—Three new harpagide derivatives have been isolated from the aerial parts of *Rogeria adenophylla* (Pedaliaceae). Their structures have been established as 8-*O*-*cis*-cinnamoylharpagide, 8-*O*-*cis*-cinnamoyl-6-*O*-β-D-glucosyl-harpagide and 6′-*O*-*p*-coumaroyl harpagide respectively, the *p*-coumaroyl moiety of the latter existing in either the *trans* or *cis* configuration. In addition, harpagide, harpagoside, 8-*O*-*trans*-*p*-coumaroylharpagide, procumbide and verbascoside have been isolated and identified.

INTRODUCTION

Continuing our studies on species of the family Pedaliaceae [1, 2], we have undertaken a phytochemical investigation of *Rogeria adenophylla*. This robust annual plant which grows in the Sahel Region of Africa, is used by traditional healers as a febrifuge and in the treatment of dysentery [3]. General screening procedures have indicated the presence of alkaloids [4, 5], but nothing further is known about its constituents.

Preliminary TLC investigation of methanolic extracts of *R. adenophylla* (detection with Godin reagent [6]) revealed several red spots. This suggested the presence of harpagide derivatives and prompted us to examine its polar constituents in more detail. Fractionation of the methanolic extract of the aerial parts afforded three new harpagide derivatives (**5–7**) together with the known compounds, harpagide (**1**), harpagoside (**2**), 8-*O*-*trans*-*p*-coumaroylharpagide (**3**), procumbide (**4**) and verbascoside (**8**). We report here the isolation of these compounds and the structure determination of the new iridoid glucosides. A HPLC comparison of the iridoid composition of aerial parts and roots is also presented.

RESULTS AND DISCUSSION

Aerial parts of *R. adenophylla*, collected in Niger, were successively extracted with methylene chloride and methanol. Fractionation of the methanolic extract by a combination of column chromatography on silica gel, centrifugal partition chromatography [CPC, $CHCl_3$–MeOH–*iso*-PrOH–H_2O (5:6:1:4), descending mode] [7] and low-pressure liquid chromatography (LPLC) on RP-8 afforded seven iridoid glucosides (**1–7**) and a phenylpropanoid glucoside (**8**). Compounds **1–4** and **8** were identified as harpagide, harpagoside [8], 8-*O*-*trans*-*p*-coumaroylharpagide [9], procumbide [10] and verbascoside [11], respectively, from their spectroscopic data (^1H and ^{13}C NMR, D/CI-MS, IR and UV). The structures of the new harpagide derivatives **5–7** were determined as follows.

The FAB mass spectrum of **5** showed a quasimolecular ion at *m/z* 493 ($[M-H]^-$), corresponding to the molecular formula $C_{24}H_{30}O_{11}$. Acid hydrolysis liberated glucose and *trans*-cinnamic acid. Harpagide and *trans*-cinnamic acid were identified after basic hydrolysis. When compared with harpagide (**1**), C-8 was shifted in the ^{13}C NMR spectrum of **5** from δ 78.1 to 88.8, whilst upfield shifts of 1.2, 3.9 and 2.4 ppm were observed for C-7, C-9 and C-10 respectively. A downfield shift of 0.25 ppm was also observed for the resonance of Me-10 in the ^1H NMR spectrum. These data, which are in good agreement with those found for harpagoside (**2**), indicated that OH-8 was esterified by the cinnamoyl residue. In the ^1H NMR spectrum of **5**, the olefinic protons H-α and H-β appeared as two doublets at δ 6.95 and 5.96, respectively, with a coupling constant of 12.6 Hz (16.1 Hz in harpagoside). This demonstrated the *cis* configuration of the cinnamoyl moiety which also accounts for the UV spectrum of **5** [λ_{max} 268 nm (log ε 3.97)]. Acetylation of **5** afforded the pentaacetyl derivative **5a**, confirming the structure of **5** as 8-*O*-*cis*-cinnamoylharpagide.

In the FAB mass spectrum of **6**, a quasimolecular ion was observed at *m/z* 655 ($[M-H]^-$), suggesting a molecular formula of $C_{30}H_{40}O_{16}$. Acid hydrolysis afforded glucose and *trans*-cinnamic acid. The ^1H and ^{13}C NMR spectra showed that **6** differed from **5** only in the substitution of the cyclopentane ring by a second glucose unit. Acetylation of **6** led to an octaacetyl derivative (**6a**) still presenting a free hydroxy group (signal at 3.11 ppm, exchangeable with D_2O), which indicated no substitution of OH-5. Moreover, compared with **5**, a downfield shift of 4.8 ppm and an upfield shift of 3.7 ppm were observed for C-6 and C-7, respectively, confirming the attachment of the second glucose unit to OH-6. Final evidence was obtained by a 2D long-range INEPT experiment [12]. Irradiation of the anomeric proton H-1‴ at δ 4.35 revealed a long range interaction between C-6 and H-1‴ ($^3J_{C\text{-}6-H\text{-}1'''}$ = 2.9 Hz) whereas no correlation could be detected between H-1‴ and C-5. The structure of **6** is thus 8-*O*-*cis*-cinnamoyl-6-*O*-β-D-glucosyl-harpagide.

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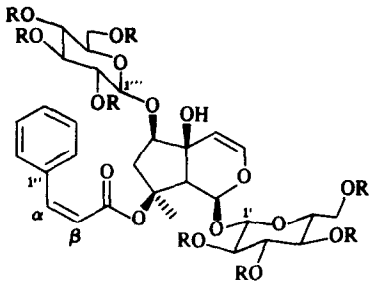

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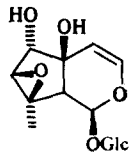
6a R = Ac



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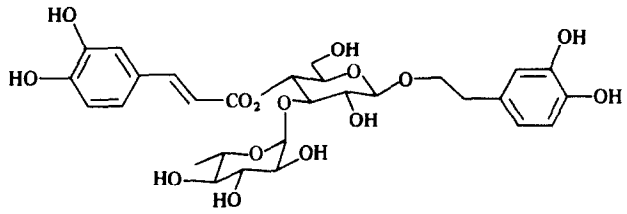

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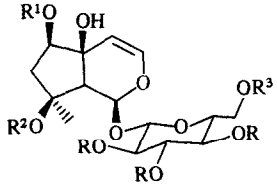

	R^1	R^2	R^3
1	H	H	H
2	H	*trans* - cinnamoyl	H
3	H	*trans* - *p* - coumaroyl	H
5	H	*cis* - cinnamoyl	H
5a	Ac	*cis* - cinnamoyl	Ac
7	H	H	*p* - coumaroyl

An HPLC–UV analysis [RP-8, MeOH–H_2O (3:7)] revealed that **7** was in fact a mixture of two compounds (**7a** and **7b**) presenting UV spectra corresponding to *trans*- and *cis*-*p*-coumaroyl derivatives, respectively. These compounds were separated by semipreparative HPLC on RP-18 with methanol–water (2:3). However, on evaporation of the solvent (temp. $< 40°$) from each isomer, mixtures once again resulted, indicating equilibrium between *trans* and *cis* isomers. Repetition of the separation on an analytical scale afforded the same result. The structure determination was therefore carried out on the isomeric mixture **7**. The D/CI mass spectrum of **7** presented quasimolecular ions at *m/z* 511 ($[M+H]^+$) and 528 ($[M+NH_4]^+$), agreeing with the molecular formula $C_{24}H_{30}O_{12}$. Glucose was identified after acid hydrolysis. Basic hydrolysis yielded *p*-coumaric-acid and harpagide. Compared with **1**, a downfield shift for C-6′ in the ^{13}C NMR spectrum of **7** together with an upfield shift for C-5′ (Table 1) demonstrated that the *p*-coumaroyl moiety was linked to C-6′. The protons H_2-6′ resonated downfield from those of **1**, confirming the position of attachment. In the ^1H NMR spectrum of **7**, the olefinic protons H-α′ and H-β appeared as two pairs of doublets with coupling constants of 16.0 and 12.8 Hz, corresponding to the *trans* and *cis* configurations, respectively. The ^1H and ^{13}C NMR data found for either the *trans* or *cis*-*p*-coumaroyl moiety were in fact in full agreement with those reported for decumbesides C and D (8-*O*-acetyl-3′-*O*-*trans* and 3′-*O*-*cis*-*p*-coumaroylharpagide, respectively) [13]. The structure of compound **7** is thus established as 6′-*O*-*p*-coumaroylharpagide in which the *p*-coumaroyl moiety exists in either the *trans* or *cis* configuration.

The iridoid composition of aerial parts and roots of *R. adenophylla* was compared by HPLC-UV analyses. While the leaves contained mainly the diglucoside **6**, harpagide (**1**) and procumbide (**4**) were shown to be the major iridoid glucosides in roots. No *cis* derivative could be detected in roots. Verbascoside was present in both aerial parts and roots. Except for **7**, no interconversion between *cis* and *trans* isomers was observed. In this context, it is interesting to notice that no isomerization of decumbesides C and D has been mentioned [13]. On the other hand, 2′ and 4′-*p*-coumaroyl-loganin and 4′-*p*-coumaroyl-loganic acid have also been isolated as isomeric mixtures from *Gentiana pedicellata* [14, 15]. Compounds **5** and **6** are, to our knowledge, the first examples of iridoids esterified with *cis*-cinnamic acid. The iridoid glucosides **1**–**4** as well as verbascoside (**8**) have already been found in *Harpagophytum procumbens* [9, 16], another member of the Pedaliaceae which is widely used for its antiinflammatory properties [17]. Tests are now in progress to determine if *R. adenophylla* could be a valid substitute for *H. procumbens*, as this plant is becoming very rare.

EXPERIMENTAL

General. CPC: ITO multi-layer coil separator–extractor (capacity 350 ml; i.d. 2.6 mm; 700 rpm). Prep. LPLC: Lobar RP-8 column (40–63 μm; i.d. 2.5 × 27 cm). Semiprep. HPLC: Knauer

Table 1. ^{13}C NMR data of iridoids **1**, **5**, **6**, **7a** and **7b** (CD_3OD) and acetylated derivatives **5a** and **6a** ($CDCl_3$)

C	1	5	5a	6*	6a	7a	7b
1	93.1	94.3	94.1	94.1	93.3	93.0	93.1
3	142.5	143.7	143.2	144.2	143.0	142.5	142.6
4	108.4	107.1	107.1	106.4	107.3	108.5	108.4
5	72.4	73.1	71.4	73.0	70.9	72.7	72.8
6	77.5[a]	77.6[a]	77.6[a]	82.5	83.6	77.4[a]	77.3[a]
7	47.2	46.0	43.1	42.3	42.0	47.0	47.0
8	78.1	88.8	86.3	88.0	85.6	78.3	78.3
9	59.5	55.6	54.6	55.9	54.9	59.5	59.5
10	24.9	22.5	22.0	22.2	21.9	25.0	25.0
1′	99.3	99.7	96.5	100.0	95.8	99.3	99.3
2′	74.5	74.5	71.0	74.5[a]	71.2[a]	74.5	74.4
3′	78.3[a]	78.2[a]	71.9[a]	78.1[b]	71.9[b]	78.3[a]	78.3[a]
4′	71.7	71.7	68.4	71.8[c]	68.4[c]	71.7	71.6
5′	78.2[a]	77.6[a]	72.0[a]	77.5[b]	72.4[b]	75.7	75.6
6′	62.8	62.8	61.8	62.9[d]	61.8[d]	64.5	64.4
1″	—	136.4	134.9	136.5	134.9	126.9	127.5
2″/6″	—	130.7	129.7	130.7	129.8	131.3	133.8
3″/5″	—	129.2	127.9	129.2	127.9	116.9	114.7
4″	—	130.0	129.0	130.0	128.9	161.8	160.3†
α	—	143.1	141.7	143.3	141.3	146.9	145.6
β	—	122.0	120.7	122.0	120.8	116.0	116.1
C=O	—	168.2	165.4	168.1	165.4	169.1	168.1
1‴	—	—	—	101.2	99.3	—	—
2‴	—	—	—	74.8[a]	70.6[a]	—	—
3‴	—	—	—	78.1[b]	71.9[b]	—	—
4‴	—	—	—	71.5[c]	68.2[c]	—	—
5‴	—	—	—	77.5[b]	72.8[b]	—	—
6‴	—	—	—	62.5[d]	61.8[d]	—	—

[a–d]Values with the same superscript in each column are interchangeable.
DEPT sequences allowed distinction of carbon multiplicities.
*C–H connectivities by the use of HETCOR experiments.
†Tentative assignment (low intensity signal).

RP-18 column (LiChrosorb 7 μm; i.d. 16 × 250 mm), UV detection at 313 nm. TLC: silica gel precoated Al sheets (Merck) with $CHCl_3$–MeOH–H_2O (13:7:1) (system I). Mps: uncorr. ^{1}H and ^{13}C NMR: unless specified, at 200 and 50.5 MHz, respectively; HETCOR and 2D-INEPT experiments at 100.6 MHz; chemical shifts in δ relative to TMS. D/CIMS: quadrupole instrument with NH_3 as reactant gas; positive ion mode. FABMS: negative ion mode; samples were suspended in glycerol and the target bombarded with CsI.

Plant material. Rogeria adenophylla J. Gay ex Del. was collected in Niger. A voucher specimen is deposited at the Botany Department of the University of Niamey.

Extraction and isolation. Powdered aerial parts (174 g) were extracted at room temp with CH_2Cl_2 followed by MeOH. A portion (11.5 g) of the MeOH extract (12.5 g) was fractionated on a silica gel column (63–200 μm; i.d. 5 × 70 cm) with $CHCl_3$–MeOH and $CHCl_3$–MeOH–H_2O mixts of increasing polarity [$CHCl_3$–MeOH (9:1)→$CHCl_3$–MeOH–H_2O (13:7:1)]. 14 frs were collected (I–XIV). Fr. XIII (1.12 g) was submitted to LPLC on RP-8; elution with MeOH–H_2O (3:47) gave **1** (107 mg); subsequent elution with MeOH–H_2O (7:13) and MeOH–H_2O (2:3) provided **8** (180 mg) and **6** (270 mg), respectively. Compound **2** (25 mg) was isolated by the same technique from fr. VIII (107 mg) with MeOH–H_2O (12:13). Further sepn of fr. X (796 mg) by CPC with $CHCl_3$–MeOH–*iso*-PrOH–H_2O (5:6:1:4) in the descending mode (4 ml min^{-1}) afforded 9 frs (A–I). Compounds **4** (99 mg) and **5** (38 mg) were purified by LPLC from frs I [236 mg, MeOH-H_2O (1:99)] and C [111 mg, MeOH-H_2O (9:11)]. respectively. Compounds **3** (12 mg) and **7** (8 mg) were obtained from fr. E (126 mg) by the same technique with MeCN–H_2O (17:83). The *trans* (**7a**) and *cis* (**7b**) isomers were sepd by semiprep. HPLC or RP-18 with MeOH–H_2O (2:3) (10 ml min^{-1}). Evapn of solvent gave mixts of isomers which were combined (5 mg) and submitted to spectroscopic analysis. Powdered roots (3.6 g) were extracted successively at room temp. with CH_2Cl_2 and MeOH. The MeOH extract (370 mg) was submitted to TLC and HPLC analyses.

HPLC analysis of MeOH *extracts (aerial parts and roots).* Analyses were performed on a RP-8 column (Nucleosil 5 μm; i.d. 4 × 125 mm) equipped with a precolumn (i.d. 4 × 30 mm). A gradient of aq. MeCN, containing TFA (0.05%), was used as eluent [MeCN–H_2O (0:100), 5 min; MeCN–H_2O (0:100→1:9), 5 min; MeCN–H_2O (1:9→1:3), 50 min; 1 ml min^{-1}]; 10 μl corresponding to 500 μg of extract were inj. Sepns were followed at 206 nm with a photodiode array detector. Identification of compounds by their R_ts and UV spectra, was confirmed by co-chromatography with authentic substances.

Acid hydrolysis. Compounds **5** (1 mg) and **6** (2 mg) were refluxed in 2 M HCl (10 ml) for 2 hr. The reaction mixt. was extracted with Et_2O and *trans*-cinnamic acid was identified by TLC on silica gel with C_6H_6–dioxane–MeOH–HOAc (90:25:5:4). After subsequent extraction with BuOH, the aq.

layer was adjusted to pH 5 with $NaHCO_3$ and evapd to dryness. The sugar was extracted from the residue with pyridine and analysed by TLC on silica gel with EtOAc–MeOH–H_2O–HOAc (13:3:3:4); detection with *p*-anisidine phthalate. Compound **7** (0.5 mg) was hydrolysed by the same procedure. TLC examination of the Et_2O extract revealed complete decomposition of *p*-coumaric acid.

Basic hydrolysis. Compound **5** (1 mg) was dissolved in 0.5 M KOH (1 ml) and kept overnight at room temp. After acidification, the reaction mixt. was extracted with Et_2O, followed by BuOH. The organic layers were examined by TLC. *trans*-Cinnamic acid and harpagide were identified in the Et_2O and BuOH extracts, respectively. Compound **7** (0.5 mg) was hydrolysed following the same procedure with 0.5 M KOH (0.5 ml). *p*-Coumaric acid and harpagide were identified by TLC.

8-O-cis-*Cinnamoylharpagide* (**5**). Amorphous powder. TLC (silica gel, system 1) R_f 0.52. $[\alpha]_D^{25}$ −103° (MeOH; *c* 0.374); FABMS: *m/z* 493 ($[M-H]^-$), 363 ($[(M-H)-130]^-$). UV λ_{max}^{MeOH} nm (log ε): 268 (3.97). IR ν_{max}^{KBr} cm^{-1}: 3400, 1690, 1080. ^1H NMR (CD_3OD): δ7.6–7.5 (2H, *m*, H-2″, H-6″), 7.4–7.3 (3H, *m*, H-3″, H-4″, H-5″), 6.95 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-α), 6.38 (1H, *d*, $J_{3,4}$ = 6.4 Hz, H-3), 6.08 (1H, *d*, $J_{1,9}$ = 1.1 Hz, H-1), 5.96 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-β), 4.92 (1H, *dd*, $J_{4,3}$ = 6.4 Hz, $J_{4,6}$ = 1.6 Hz, H-4), 4.58 (1H, *d*, $J_{1',2'}$ = 7.8 Hz, H-1′), 3.71 (1H, *m*, H-6), 2.90 (1H, *br s*, H-9), 2.14 (1H, *br d*, $J_{7\alpha,7\beta}$ = 15.0 Hz, H-7β), 1.95 (1H, *dd*, $J_{7\alpha,7\beta}$ = 15.0 Hz, $J_{6,7\alpha}$ = 4.4 Hz, H-7α), 1.49 (3H, *s*, H_3-10). ^{13}C NMR: see Table 1.

8-O-cis-*Cinnamoylharpagide pentaacetate* (**5a**). Treatment of **5** (10 mg) with Ac_2O (0.5 ml) in pyridine (0.5 ml) overnight at room temp. afforded after usual work-up 14 mg of **5a**. Needles from CH_2Cl_2–hexane, mp 183–186° dec., D/CIMS (NH_3): *m/z* 722 ($[M+NH_4]^+$), 366, 331. ^1H NMR ($CDCl_3$): δ7.6–7.5 (2H, *m*, H-2″, H-6″), 7.35–7.3 (3H, *m*, H-3″, H-4″, H-5″), 6.94 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-α), 6.28 (1H, *d*, $J_{3,4}$ = 6.4 Hz, H-3), 6.07 (1H, *d*, $J_{1,9}$ = 1.4 Hz, H-1), 5.87 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-β), 4.84 (1H, *d*, $J_{1',2'}$ = 8.0 Hz, H-1′), 4.38 and 4.11 (1H, *dd*, $J_{6'a,6'b}$ = 12.2 Hz, $J_{5',6'a}$ = 4.6 Hz and 1H, *dd*, $J_{5',6'b}$ = 2.5 Hz, H_2-6′), 3.77 (1H, *ddd*, $J_{4',5'}$ = 9.9 Hz, $J_{5',6'a}$ = 4.6 Hz, $J_{5',6'b}$ = 2.5 Hz, H-5′), 3.07 (1H, *s*, ex. with D_2O, HO-5), 3.03 (1H, *br s*, H-9), 2.05 (2×), 2.04, 2.03, 2.01 (together 15H, 4*s*, Ac_5), 1.49 (3H, *s*, H_3-10). ^{13}C NMR: see Table 1.

8-O-cis-*Cinnamoyl*-6-O-β-D-*glucosylharpagide* (**6**). Amorphous powder. TLC (silica gel, system 1) R_f 0.26. $[\alpha]_D^{25}$ −134° (MeOH; *c* 0.7); FABMS: *m/z* 655 ($[M-H]^-$), 525 ($[(M-H)-130]^-$). UV λ_{max}^{MeOH} nm (log ε): 269 (3.96). IR ν_{max}^{KBr} cm^{-1}: 3400, 1690, 1080. ^1H NMR (CD_3OD, 400 MHz): δ7.54 (2H, *m*, H-2″, H-6″), 7.4-7.3 (3H, *m*, H-3‴, H-4″, H-5″), 6.96 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-α), 6.41 (1H, *d*, $J_{3,4}$ = 6.4 Hz, H-3), 6.06 (1H, *d*, $J_{1,9}$ = 1.0 Hz, H-1), 6.00 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-β), 4.99 (1H, *dd*, $J_{3,4}$ = 6.4 Hz, $J_{4,6}$ = 1.6 Hz, H-4), 4.58 (1H, *d*, $J_{1',2'}$ = 7.8 Hz, H-1′), 4.35 (1H, *d*, $J_{1''',2'''}$ = 7.7 Hz, H-1‴), 4.00 (1H, *m*, H-6), 2.92 (1H, *br s*, H-9), 2.29 (1H, *br d*, $J_{7\alpha,7\beta}$ = 15.3 Hz, H-7β), 1.95 (1H, *dd*, $J_{7\alpha,7\beta}$ = 15.3 Hz, $J_{6,7\alpha}$ = 4.3 Hz, H-7α), 1.52 (3H, *s*, H_3-10). ^{13}C NMR: see Table 1.

8-O-cis-*Cinnamoyl*-6-O-β-D-*glucosylharpagide octaacetate* (**6a**). Treatment of **6** (25 mg) with Ac_2O (2 ml) in pyridine (2 ml) overnight at room temp. afforded after usual work-up 37 mg of **6a**. Needles from CH_2Cl_2–hexane, mp 180–182°. D/CIMS (NH_3): *m/z* 1010 ($[M+NH_4]^+$), 366, 331. ^1H NMR ($CDCl_3$): δ7.6–7.5 (2H, *m*, H-2″, H-6″), 7.35–7.3 (3H, *m*, H-3″, H-4″, H-5″), 6.93 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-α), 6.25 (1H, *d*, $J_{3,4}$ = 6.4 Hz, H-3), 5.93 (1H, *d*, $J_{1,9}$ = 1.5 Hz, H-1), 5.89 (1H, *d*, $J_{\alpha,\beta}$ = 12.6 Hz, H-β), 4.81 (1H, *d*, $J_{1',2'}$ = 8.0 Hz, H-1′), 4.50 (1H, *d*, $J_{1''',2'''}$ = 7.7 Hz, H-1‴), 3.79 (1H, *m*, H-6), 3.11 (1H, *s*, ex. with D_2O, HO-5), 2.82 (1H, *br s*, H-9), 2.09, 2.06, 2.04, 2.03, 2.02, 2.01 (2×), 2.00 (together 24H, 7*s*, Ac_8), 1.50 (3H, *s*, H_3-10). ^{13}C NMR: see Table 1.

6′O-p-*Coumaroylharpagide* (**7**). Amorphous white powder. D/CIMS (NH_3): *m/z* 528 ($[M+NH_4]^+$), 511 ($[M+H]^+$), 382 ($[(M+H)-146]^+$). ^1H NMR (CD_3OD): δ *trans* isomer **7a**–7.65 (1H, *d*, $J_{\alpha,\beta}$ = 16.0 Hz, H-α), 7.46 (2H, *d*, $J_{2'',3''}$ = 8.5 Hz, H-3″, H-5″), 6.80 (2H, *d*, $J_{2'',3''}$ = 8.5 Hz, H-2″, H-6″), 6.36 (1H, *d*, $J_{\alpha,\beta}$ = 16.0 Hz, H-β), 6.31 (1H, *d*, $J_{3,4}$ = 6.4 Hz), 5.66 (1H, *d*, $J_{1,9}$ = 1.3 Hz, H-1), 4.95 (1H, *dd*, $J_{3,4}$ = 6.4 Hz, $J_{4,6}$ = 1.5 Hz, H-4), 4.60 (1H, *d*, $J_{1',2'}$ = 7.8 Hz, H-1′), 4.50 and 4.36 (1H, *dd*, $J_{6'a,6'b}$ = 12.0 Hz, $J_{5',6'a}$ = 2.3 Hz and 1H, *dd*, $J_{5',6'b}$ = 5.5 Hz, H_2-6′), 3.68 (1H, *m*, H-6), 2.54 (1H, *br s*, H-9), 1.87 and 1.75 (1H, *dd*, $J_{7a,7b}$ = 13.7 Hz, $J_{6,7a}$ = 4.5 Hz and 1H, *dd*, $J_{6,7b}$ = 3.6 Hz, H_2-7), 1.18 (3H, *s*, H_3-10), *cis* isomer **7b**–7.66 (2H, *d*, $J_{2'',3''}$ = 8.8 Hz, H-3″, H-5″), 6.89 (1H, *d*, $J_{\alpha,\beta}$ = 12.8 Hz, H-α), 6.77 (2H, *d*, $J_{2'',3''}$ = 8.8 Hz, H-2″, H-6″), 6.32 (1H, *d*, $J_{3,4}$ = 6.4 Hz, H-3), 5.79 (1H, *d*, $J_{\alpha,\beta}$ = 12.8 Hz, H-β), 5.64 (1H, *d*, $J_{1,9}$ = 1.4 Hz, H-1), 4.95 (1H, *dd*, $J_{3,4}$ = 6.4 Hz, $J_{4,6}$ = 1.5 Hz, H-4), 4.59 (1H, *d*, $J_{1',2'}$ = 7.7 Hz, H-1′), 4.45 and 4.29 (1H, *dd*, $J_{6'a,6'b}$ = 12.0 Hz, $J_{5',6'a}$ = 2.2 Hz, and 1H, *dd*, $J_{5',6'b}$ = 5.4 Hz, H_2-6′), 3.68 (1H, *m*, H-6), 2.54 (1H, *br s*, H-9), 1.88 and 1.76 (1H, *dd*, $J_{7a,7b}$ = 13, 7 Hz, $J_{6,7a}$ = 4.6 Hz and 1H, *dd*, $J_{6,7b}$ = 3.6 Hz, H_2-7), 1.21 (3H, *s*, H_3-10). ^{13}C NMR: see Table 1.

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