21. Cyclohexanecarboxylic-Acid Derivatives from *Psiadia trinervia*

by **Ying Wang**[a]), **Matthias Hamburger**[a]), **Joseph Gueho**[b]), and **Kurt Hostettmann**[a])*

[a]) Institut de Pharmacognosie et Phytochimie, Ecole de Pharmacie, BEP, Université de Lausanne, CH-1015 Lausanne

[b]) Mauritius Sugar Industry Research Institute, Le Réduit, Mauritius

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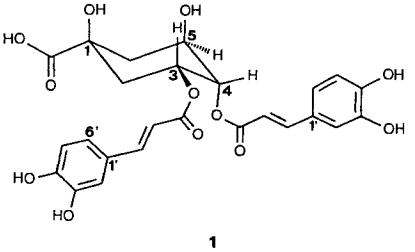
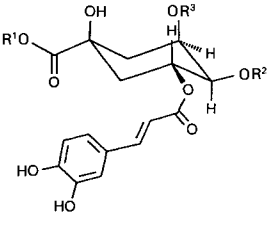
From a MeOH extract of *Psiadia trinervia*, seven phenolic compounds were isolated by gel filtration and reversed-phase chromatography. Six of them are known compounds, namely 3,4-di-*O*-caffeoylquinic acid (**2**), 3,5-di-*O*-caffeoylquinic acid (**3**), caffeic acid, and three 3-methoxyflavonoids. Compound **1** is a 3,4-di-*O*-caffeoyl derivative of (1*S*,3*R*,4*R*,5*R*)-1,3,4,5-tetrahydroxycyclohexanecarboxylic acid, a novel stereoisomer of (–)-quinic acid. Following hydrolytic treatment of the MeOH extract, ethyl 3-*O*-caffeoylquinate (**4**), ethyl 3,4-di-*O*-caffeoylquinate (**5**), and ethyl 3,5-*O*-caffeoylquinate (**6**) were isolated. The latter three compounds are artifacts. The configuration of **1**–**3** was established by NMR and CD (exciton chirality method).

Introduction. – *Psiadia trinervia* WILLD (Asteraceae) is an endemic species of the Mascarene Islands [1]. It was used as a vulnerary and expectorant for the treatment of asthma in the folk medicine of Mauritius [2] [3]. Several diterpenes [4–6] and some terpenes in the essential oil [7] [8] of this plant were reported prior to our own investigations. A phytochemical analysis of the CH_2Cl_2 extract and the hydrolyzed MeOH extract of *P. trinervia* afforded a series of 3-methylflavonols, some of which showed antimicrobial activities against the plant pathogenic fungus *Cladosporium cucumerinum* and the gram-positive bacterium *Bacillus cereus* [9]. Subsequently, we focused on the composition of the MeOH extract before and after hydrolytic treatment and report here on the isolation and structure determination of chlorogenic acid (= 3-*O*-caffeoylquinic acid) derivatives from these extracts.

Results and Discussion. – Dried leaves of *Psiadia trinervia* collected in Mauritius were ground and extracted successively with petroleum ether, CH_2Cl_2, and MeOH. Com-



1



2 $R^1 = R^3 = H$, R^2 = caffeoyl
3 $R^1 = R^2 = H$, R^3 = caffeoyl
4 R^1 = Et, $R^2 = R^3 = H$
5 R^1 = Et, R^2 = caffeoyl, $R^3 = H$
6 R^1 = Et, $R^2 = H$, R^3 = caffeoyl

pounds **1**–**3**, caffeic acid (= (*E*)-3-(3,4-dihydroxyphenyl)prop-2-enoic acid), and three hydroxymethoxyflavones were isolated from the MeOH extract by a combination of gel filtration on *Sephadex LH-20* and low and medium-pressure reversed-phase chromatography on *RP-18* (see *Exper. Part*). Aiming for a characterization of the aglycones of glycosides possibly present in the MeOH extract, a portion of the latter was refluxed with 1N HCl in EtOH/H_2O 2:1. Subsequent fractionation by column chromatography on silica gel, *Sephadex LH-20*, and *Diol* in the normal-phase mode (see *Exper. Part*) yielded compounds **4**–**6**. While showing the same fluorescence and staining behavior on TLC than **1**–**3**, **4**–**6** were less polar than **1**–**3**.

Basic hydrolysis of compound **1** afforded caffeic acid and an acid moiety showing the same color reaction on TLC upon staining with modified *Edward-Waldron* reagent [10] as quinic acid (= 1α,3α,4α,5β-tetrahydroxycyclohexanecarboxylic acid). However, its chromatographic behavior was clearly different (see below and *Exper. Part*). The presence of two caffeoyl moieties attached to a polyhydroxycyclohexanecarboxylic acid and the relative configuration of **1** were determined by UV, MS, and ^{1}H- and ^{13}C-NMR.

The UV spectrum of **1** exhibits four absorption maxima at 328, 300, 240, and 220 nm. The presence of *ortho* OH groups is readily established with the aid of UV/VIS shift reagents ($AlCl_3$, $AlCl_3$ + HCl, and NaOAc + H_3BO_3) [11]. The FAB-MS (negative-ion mode, thioglycerol) of **1** shows a reasonably intense quasi-molecular ion at *m/z* 515 ($[M-H]^-$), without any further fragment ions. In the DCI-MS (NH_3, positive-ion mode), diagnostic fragment peaks at *m/z* 163 ($[C_9H_6O_3+H]^+$) and 192 ($[C_7H_{10}O_5+NH_4]^+$) confirm the presence of a caffeoyl moiety and a cyclohexanecarboxylic acid. In the ^{13}C-NMR spectrum of **1**, the signals attributable to the two caffeoyl moieties appear as 9 pairs of sp^2-C resonances between 110 and 170 ppm (*Table 1*). Signals attributable to four O-bearing sp^3-C atoms (66.22, 68.22, 72.40, and 72.90 ppm), two aliphatic CH_2 groups (37.66 and 37.27 ppm), together with a resonance of a COOH group (178.82 ppm) are indicative of a tetra-*O*-substituted cyclohexanecarboxylic acid. The ^{1}H-NMR spectrum of **1** (*Table 2*) confirms the presence of two caffeoyl moieties. The two *ABM* systems in the aromatic region of the spectrum are indicative of 1,3,4-substituted aromatic rings. The (*E*)-configuration at the double bond is deduced from the coupling constant (J = 16.1 Hz) of the olefinic

Table 1. *^{13}C-NMR Spectral Data for Compounds* **1**–**6**

	1[a])	**2**[a])	**3**[a])	**4**[b])	**5**[b])	**6**[b])
COOR[1]	178.82	176.12	177.41	173.99	173.66	174.43
C(1)	72.92	74.81	73.43	75.91	75.86	74.27
C(2)	37.66	38.67	38.67	38.70	39.28	36.95
C(3)	72.40	75.53	72.66	73.21	75.29	71.59
C(4)	68.22	68.41	70.28	70.91	68.86	69.67
C(5)	66.22	68.11	71.23	71.49	68.23	71.83
C(6)	37.27	37.90	36.06	37.92	38.18	35.64
C(1′)	125.49	125.31	125.67, 125.57	127.57	127.46	127.70, 127.63
C(2′)	115.93, 115.89	115.82	115.96, 115.89	116.39	116.32	116.43, 116.37
C(3′)	115.00, 114.79	114.87	115.11, 114.95	115.73	115.51	116.14, 115.52
C(4′)	148.63, 148.53	148.49	148.47, 148.30	148.78	148.84	148.89, 148.70
C(5′)	145.69	145.58	145.69	146.29	145.30	146.32, 146.28
C(6′)	114.10	113.78	114.78, 114.56	115.13	115.34, 115.14	115.44, 115.12
*C*H=CHCOO	121.47	121.22	121.27, 121.03	122.54	122.64	122.61, 122.48
CH=*C*HCOO	145.41, 145.23	145.36, 145.29	144.77, 144.50	145.85	146.28	146.11, 145.66
CH=CH*C*OO	165.98, 165.76	166.08, 165.88	166.43, 166.12	167.98	166.96, 166.63	167.00, 166.58
CH_3CH_2O				61.76	61.88	61.72
CH_3CH_2O				14.34	14.32	14.30

[a]) Measured at 50.7 MHz in (D_6)DMSO; R^1 = H.
[b]) Measured at 50.7 MHz in (D_6)acetone; R^1 = Et.

Table 2. *^{1}H-NMR Spectral Data for Compounds* **1** *and* **4**–**6**

	1[a])	**4**[b])	**5**[b])	**6**[b])
CH_2(2), CH_2(6)	1.82 (*m*)	2.12 (*m*)	2.06 (*m*)	2.26 (*m*)
H–C(3)	5.52 (*ddd*, *J* = 10.1, 3.1, 3.1)	5.36 (*ddd*, *J* = 8.6, 8.6, 3.0)	5.66 (*ddd*, *J* = 9.3, 9.3, 3.9)	5.40 (*m*)
H–C(4)	5.05 (*dd*, *J* = 3.1, 3.1)	3.76 (*dd*, *J* = 8.6, 3.0)	5.11 (*dd*, *J* = 9.3, 3.0)	4.05 (*dd*, *J* = 7.9, 3.7)
H–C(5)	3.75 (br. *d*, *J* = 3.1)	4.19 (br. *s*)	4.40 (br. *d*, *J* = 3.0, 3.0)	5.40 (*m*)
H–C(2′)	7.06 (*d*, *J* = 1.8), 6.98 (*d*, *J* = 1.8)	7.17 (*d*, *J* = 2.3)	7.14 (*d*, *J* = 1.9), 7.13 (*d*, *J* = 1.9)	7.18 (*d*, *J* = 1.8), 7.16 (*d*, *J* = 1.8)
H–C(5′)	7.01 (*dd*, *J* = 8.0, 1.8), 6.89 (*dd*, *J* = 8.0, 1.8)	7.04 (*dd*, *J* = 7.9, 2.3)	7.02 (*dd*, *J* = 7.9, 1.9), 7.00 (*dd*, *J* = 7.9, 1.9)	7.05 (*dd*, *J* = 8.3, 1.8), 6.94 (*dd*, *J* = 8.3, 1.8)
H–C(6′)	6.75 (*d*, *J* = 8.0), 6.69 (*d*, *J* = 8.0)	6.88 (*d*, *J* = 7.9)	6.88 (*d*, *J* = 7.9), 6.84 (*d*, *J* = 7.9)	6.88 (*d*, *J* = 8.3), 6.83 (*d*, *J* = 8.3)
C*H*=CHCOO	7.46 (*d*, *J* = 16.1), 7.37 (*d*, *J* = 16.1)	7.55 (*d*, *J* = 16.1)	7.58 (*d*, *J* = 15.8), 7.54 (*d*, *J* = 15.8)	7.59 (*d*, *J* = 15.7), 7.56 (*d*, *J* = 15.7)
CH=C*H*COO	6.29 (*d*, *J* = 16.1), 6.11 (*d*, *J* = 16.1)	6.26 (*d*, *J* = 16.1), 6.21 (*d*, *J* = 15.8)	6.27 (*d*, *J* = 15.8), 6.24 (*d*, *J* = 15.7)	6.31 (*d*, *J* = 15.7)
CH_3CH_2O		4.15 (*q*, *J* = 7.0)	4.17 (*q*, *J* = 7.0)	4.13 (*q*, *J* = 7.2)
CH_3CH_2O		1.23 (*t*, *J* = 7.0)	1.26 (*t*, *J* = 7.0)	1.22 (*t*, *J* = 7.2)

[a]) Measured at 200 MHz in (D_6)DMSO.
[b]) Measured at 200 MHz in (D_6)acetone.

protons. Protons of the cyclohexanecarboxylic acid moiety are assigned with the aid of decoupling experiments and a double-quantum-filtered phase-sensitive COSY spectrum. The relative configuration at C(3), C(4), and C(5) of the cyclohexanecarboxylic acid moiety is deduced from vicinal coupling constants. A J(2eq,3) = 3.1 and J(2ax,3) = 10.1 Hz are indicative of the axial position of H–C(3), whereas the equatorial position of H–C(4) is inferred from J(3,4) = 3.1 Hz. That the signal attributable to H–C(5) appears as a broad *d* with J(4,5) = 3.1 Hz and unresolved J(5,6) is only compatible with an equatorial H–C(5). The position of attachment for the two caffeoyl moieties is deduced from ^{1}H-NMR chemical shifts. Compared to H–C(5) (3.75 ppm), the signals of H–C(3) and H–C(4) appear at significantly lower field (5.52 and 5.05 ppm, resp.). Thus the, two caffeoyl moieties are attached at O–C(3) and O–C(4).

The absolute configuration of **1** was determined by CD. As a dicaffeate, the compound was a suitable candidate for the exciton chirality method [12] without need for previous transformation to a derivative. The CD spectrum of **1** (*Fig. 1*) shows positive first and negative second *Cotton* effects. Hence, the two chromophores constitute a right-handed screw, and C(3) and C(4) of the cyclohexanecarboxylic-acid moiety have (*R*)- and (*S*)-configuration, respectively. The parent cyclohexanecarboxylic acid, therefore, is (1*S*,3*R*,4*R*,5*R*)-1,3,4,5-tetrahydroxycyclohexanecarboxylic acid, a novel stereoisomer of (–)-quinic acid, for which we propose the trivial name 'isoquinic acid'. Thus, compound **1** is (1*S*,3*R*,4*S*,5*R*)-3,4-bis{[(*E*)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-1,5-dihydroxycyclohexanecarboxylic acid.

Compounds **2** and **3** showed UV, FAB-MS, and DCI-MS similar to those of dicaffeate **1**. Analysis of the ^{1}H- and ^{13}C-NMR spectral data indicated that they were the known 3,4- and 3,5-di-*O*-caffeoylquinic acid, respectively [13]. Their absolute configuration was confirmed by CD measurements. Indeed, the spectra of both **2** and **3** showed negative exciton chirality by negative first and positive second *Cotton* effects (*Fig. 1*), which is in accord with the (3*R*,4*R*)- and (3*R*,4*S*)-configuration, respectively, at the cyclohexanecarboxylic-acid moiety. Thus, in both cases, the parent cyclohexanecarboxylic acid is (–)-quinic acid (= (1*R*,3*R*,4*S*,5*R*)-1,3,4,5-tetrahydroxycyclohexanecar-

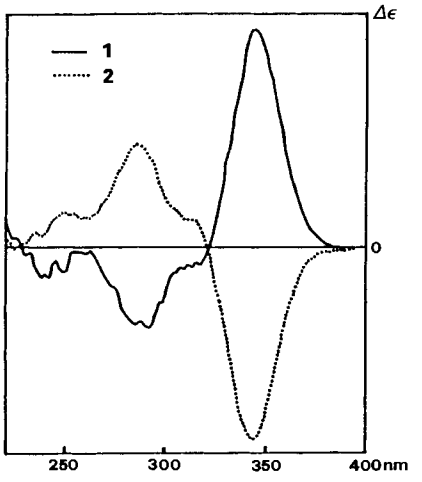


Fig. 1. *CD spectra of compounds* **1** *and* **2**

boxylic acid), the structure of which was established by total synthesis [14]. It should be noted that the two diastereoisomers (−)-quinic acid and isoquinic acid (from **1**) show quite different chromatographic behavior (see *Exper. Part*). The corresponding di-*O*-caffeoyl derivatives **1**–**3** could be easily separated by HPLC on a *RP-18* column (*Fig. 2*).

Caffeic acid and the three hydroxymethoxyflavones, *i.e.* 3′,4′,5,7-tetrahydroxy-3-methoxyflavone (= 2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-3-methoxy-4*H*-1-benzo-

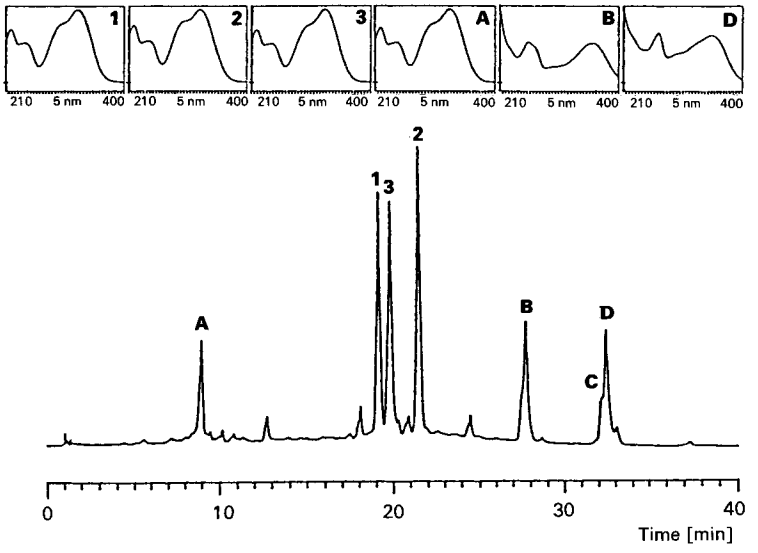


Fig. 2. *HPLC analysis of the MeOH extract from* Psiadia trinervia. *Novapak RP-18* (5 μm, 3.9·125 mm (i.d.)); MeCN/H_2O 5:95→40:60 in 40 min; 1 ml/min; detection at 254 nm. Top: UV spectra recorded with diode-array detector. **A**, caffeic acid; **B**, 3′,4′,5,7-tetrahydroxy-3-methoxyflavone; **C**, 4′,5,7-trihydroxy-3,8-dimethoxyflavone; **D**, 4′,5,7-trihydroxy-3-methoxyflavone.

pyran-4-one), 4′,5,7-trihydroxy-3,8-dimethoxyflavone (= 5,7-dihydroxy-2-(4-hydroxyphenyl)-3,8-dimethoxy-4*H*-1-benzopyran-4-one), and 4′,5,7-trihydroxy-3-methoxyflavone (= 5,7-dihydroxy-2-(4-hydroxyphenyl)-3-methoxy-4*H*-1-benzopyran-4-one) [9], were identified by UV and ^{1}H-NMR spectra and comparison with authentic samples.

Compounds **4–6** were also *O*-caffeoylquinic acid derivatives, as shown by their UV, MS, NMR, and CD data (see *Exper. Part* and *Tables 1* and *2*). The ^{1}H-NMR spectra suggested the presence of an ethyl moiety (*t* at 1.2 and *q* at 4.1 ppm) which was confirmed by the DCI-MS (characteristic loss of 46 amu (EtOH) from $[M + H]^+$). Comparison of the ^{13}C-NMR data with that of **1–3** (upfield shift of the *C*OOR^1 signal of **4–6**) showed them to be ethyl 3-*O*-caffeoylquinic acid (**4**), ethyl 3,4-di-*O*-caffeoylquinic acid (**5**), and ethyl 3,5-di-*O*-caffeoylquinic acid (**6**). Ethyl ester **4** (ethyl chlorogenate) was isolated before from sunflower seeds as a minor compound with auxin-like activity, but no detailed physicochemical data were reported [15].

Discussion. – Three acyloxycyclohexanecarboxylic acids were isolated from *Psiadia trinervia*. Among them, di-*O*-caffeoylisoquinic acid **1** is a new natural compound, as it contains a previously unknown stereoisomer of (–)-quinic acid. Compounds **2** and **3**, first isolated from coffee seeds (*Coffea arabica*, Rubiaceae) [13], are rather common *O*-acylquinic acids occurring in plants of the families Rubiaceae [16], Asteraceae [17], Rosaceae [18], and Aquifoliaceae [19] along with other chlorogenic-acid (= 3-*O*-caffeoylquinic acid) derivatives.

The three hydroxymethoxylflavones (see above) were already isolated during our earlier investigations of *P. trinervia*, but from the hydrolyzed MeOH extract [9]. Apparently, these compounds do not occur as glycosides, a finding that was corroborated by chromatographic comparison. The ethyl esters **4–6** obviously are artifacts due to the high EtOH concentration which was required to solubilize the MeOH extracts for hydrolysis. In that context, the reportedly genuine nature of ethyl chlorogenate (**4**) from sunflower seeds [15] appears questionable, as the isolation procedure for this trace compound involved an extraction under conditions that might have induced esterification.

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Experimental Part

General. TLC: silica gel *60* F_{254} Al sheets (*Merck*); *Diol*, *RP-8* precoated HPTLC plates (*Merck*); *RP-18 W/UV254* precoated plates (*Macherey-Nagel*); detection at 254 and 366 nm. Open column chromatography (CC): *Sephadex LH-20* (*Pharmacia*). Low-pressure liquid chromatography (LPLC): *Lobar LiChroprep Diol* (40–63 μm; 27 × 2.5 cm (i.d.); *Merck*) equipped with *Duramatic 80* pump (*Chemie und Filter*, Regensdorf); flow rate 1 ml/min. Medium-pressure liquid chromatography (MPLC): *B 681* MPLC system (*Büchi*, Flawil); 2.6 × 46 cm column packed with *LiChroprep RP-18* (15–25 μm; *Merck*); flow rate 3 ml/min. HPLC (purity controls): *Spectra-Physics-8700* pump (San José, USA), photodiode array detector *HP-1040A*, coupled with a *HP-85* personal computer and a *HP-7470A* plotter (*Hewlett Packard*); columns, *LiChrosorb RP-8* and *RP-18* (7 μm; 4 × 250 mm (i.d.); *Knauer*). M.p.: *Mettler FP 80/82* hot-stage apparatus; uncorrected. Optical rotation: *Perkin-Elmer-241* polarimeter; at 25°. UV Spectra: *Varian-DBS-100S* spectrophotometer. CD Spectra: *Auto-Dichrograph Mark V Jobin Yvon*, coupled with an *Apple II DS* personal computer and recorded as $\Delta\varepsilon$ (nm). ^{1}H- and ^{13}C-NMR: *Varian VXR 200* at 200.06 and 50.30 MHz, resp.; in (D_6)DMSO and (D_6)acetone; TMS as internal standard. DCI-MS and FAB-MS:

Nermag-R-10-10 (NH_3, positive-ion mode) and *Finnigan-MAT-TSQ-70* spectrometer (thioglycerol matrix, negative-ion mode), resp.

Plant Material. Psiadia trinervia was collected in November 1987 in Mauritius. A voucher specimen is deposited at the Herbarium of Mauritius Sugar Industry Research Institute, Réduit, Mauritius.

Extraction and Isolation. The air-dried leaves (156 g) were ground and extracted at r.t. successively with petroleum ether, CH_2Cl_2, and MeOH to afford 16.9, 24.8, and 44.4 g of extracts, respectively. A portion (30 g) of the MeOH extract was subjected to gel filtration (*Sephadex LH-20*, MeOH, 11 fractions). Compounds **1** (189 mg), **2** (63 mg), and **3** (49 mg) were isolated from *Frs. 8* and *11* by chromatography on *Lobar RP-18* (MeOH/H_2O) and *Sephadex LH-20* (MeOH). Caffeic acid (241 mg), 3′,4′,5,7-tetrahydroxy-3-methoxyflavone (47 mg), 4′,5,7-trihydroxy-3,8-dimethoxyflavone (65 mg), and 4′,5,7-trihydroxy-3-methoxyflavone (6 mg) were obtained from *Frs. 4* and *6* by LPLC or MPLC (*LiChroprep RP-18*, MeOH/H_2O 2:8 or 55:45) and gel chromatography (*Sephadex LH-20*, MeOH).

To 10 g of the MeOH extract in 100 ml of EtOH were added 50 ml of 1N HCl. The mixture was refluxed for 2 h. EtOH was evaporated and the remaining aq. mixture extracted with $CHCl_3$ (4 × 100 ml) and AcOEt (3 × 100 ml). The org. phase was washed with H_2O and evaporated. The residue (5.7 g) was submitted to CC (silica gel, $CHCl_3$/MeOH 95:5→50:50, 10 fractions). The last two fractions were rechromatographed on *Sephadex LH-20* ($CHCl_3$/MeOH 1:1) and *Lobar Diol* ($CHCl_3$/MeOH 93:7): **4** (51 mg), **5** (27 mg), and **6** (53 mg).

Basic Hydrolysis. A soln. of **1** (60 mg) in MeOH/H_2O 1:1 (3 ml) and 1N NaOH (3 ml) was stirred under N_2 at r.t. for 24 h. After neutralization with 1N HCl to pH 4–5 and filtration, MeOH was evaporated and the aq. soln. extracted with Et_2O (3 × 5 ml). The org. and aq. phases were each evaporated. The org. phase yielded caffeic acid (40 mg). The residue of the aq. phase was extracted with acetone (3 × 5 ml). After evaporation and column chromatography (*Sephadex LH-20*), (*1S,3R,4R,5R*)-1,3,4,5-tetrahydroxycyclohexanecarboxylic acid (= isoquinic acid; 5 mg) was obtained. Co-TLC with an authentic sample of (−)-quinic acid on *Lobar Diol* ($CHCl_3$/MeOH 84:16) and *RP-18* (H_2O/MeOH 9:1; detection by modified *Edward-Waldron* reagent [10]): R_f (isoquinic acid) 0.24 and 0.77, resp.; R_f ((−)-quinic acid) 0.30 and 0.86, resp.

(1S,3R,4S,5R)-3,4-Bis{[(E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-1,5-dihydroxycyclohexanecarboxylic Acid (**1**). Yellow crystals. HPTLC (*Diol*, $CHCl_3$/MeOH 85:15): R_f 0.28. M.p. 178–180°. $[\alpha]_D$ = +33.0 (MeOH, *c* = 0.6). UV (MeOH): 328, 300, 240 (sh), 220. UV (MeOH + $AlCl_3$/HCl): unchanged. UV (MeOH + $AlCl_3$): 344, 305 (sh), 255. UV (MeOH + NaOAc): 380 (sh), 334, 300 (sh). UV (MeOH + NaOAc/HBO_3): 350, 305, 255. CD (MeOH): $+2.561 \cdot 10^{-4}$ (346), 0 (323), $-9.551 \cdot 10^{-5}$ (292). ^{1}H-NMR: *Table 2*. ^{13}C-NMR: *Table 1*. FAB-MS (neg.-ion mode, thioglycerol): 515 ($[M-H]^-$). DCI-MS (NH_3, pos.-ion mode): 192 ($[C_7H_{10}O_5 + NH_4]^+$), 163 ($[C_9H_6O_3 + H]^+$).

(1S,3R,4R,5R)-3,4-Bis{[(E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-1,5-dihydroxycyclohexanecarboxylic Acid (**2**). Yellow crystals. HPTLC (*Diol*, $CHCl_3$/MeOH 85:15): R_f 0.57. TLC (*RP-18*, MeOH/H_2O 2:8): R_f 0.34. M.p. 147–150°. $[\alpha]_D$ = −149.3 (MeOH, *c* = 0.6). UV (MeOH): 329, 301 (sh), 240 (sh), 220. UV (MeOH + $AlCl_3$/HCl): unchanged. UV (MeOH + $AlCl_3$): 350, 307 (sh), 257. UV (MeOH + NaOAc): 332, 301 (sh), 248 (sh). UV (MeOH + NaOAc/HBO_3): 350, 304, 254. CD (MeOH): −6.739 (344), 0 (321), +3.639 (286). ^{1}H-NMR (200 MHz, (D_6)DMSO): 7.45, 7.42 (*2d*, *J* = 15.8, 2 C*H*=CHCOO); 7.11 (*d*, *J* = 2.2, 2H–C(2′)); 6.94, 6.93 (*2dd*, *J* = 8.0, 2.2, 2H–C(5′)); 6.75, 6.73 (*2d*, *J* = 8.0, 2H–C(6′)); 6.21, 6.17 (*2d*, *J* = 15.8, 2CH=C*H*COO); 5.52 (*ddd*, *J* = 9.4, 9.4, 3.0, H–C(3)); 4.93 (br. *d*, *J* = 9.4, H–C(4′)); 4.16 (br. *s*, H–C(5)); 1.93 (*m*, CH_2(2), CH_2(6)). ^{13}C-NMR: *Table 1*. FAB-MS (neg.-ion mode, thioglycerol): 515 ($[M-H]^-$). DCI-MS (NH_3, pos.-ion mode): 192 ($[C_7H_{10}O_5 + NH_4]^+$), 180 ($[C_9H_6O_3 + NH_4]^+$), 163 ($[C_9H_6O_3 + H]^+$).

(1R,3R,4S,5R)-3,5-Bis{[(E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-1,4-dihydroxycyclohexanecarboxylic Acid (**3**). Yellow crystals. HPTLC (*Diol*, $CHCl_3$/MeOH 85:15): R_f 0.55. TLC (*RP-18*, MeOH/H_2O 2:8): R_f 0.52. M.p. 159–161°. $[\alpha]_D$ = −87.8 (MeOH, *c* = 0.6). UV (MeOH): 328, 300, 242 (sh), 220. UV (MeOH + $AlCl_3$/HCl): unchanged. UV (MeOH + $AlCl_3$): 329, 300 (sh), 242, 235. UV (MeOH + NaOAc): 334, 300 (sh), 246 (sh). UV (MeOH + NaOAc/HBO_3): 350, 304, 254. CD (MeOH): −1.527 · 10 (342), 0 (316), +6.123 (284). ^{1}H-NMR (200 MHz, (D_6)DMSO): 7.50, 7.48 (*2d*, *J* = 15.7, 2C*H*=CHCOO); 7.09, 7.06 (*2d*, *J* = 2.0, 2H–C(2′)); 6.99 (*dd*, *J* = 7.6, 2.0, 2H–C(5′)); 6.78 (*d*, *J* = 7.6, H–C(6′)); 6.25, 6.23 (*2d*, *J* = 15.7, 2CH=C*H*COO); 5.34 (*ddd*, *J* = 8.6, 8.6, 3.0, H–C(3)); 5.18 (br. *s*, H–C(5)); 3.75 (br. *d*, *J* = 8.6, H–C(4)); 1.85 (*m*, CH_2(2), CH_2(6)). ^{13}C-NMR: *Table 1*. FAB-MS (neg.-ion, thioglycerol): 515 ($[M-H]^-$). DCI-MS (NH_3, pos.-ion mode): 192 ($[C_7H_{10}O_5 + NH_4]^+$), 163 ($[C_9H_6O_3 + H]^+$).

Ethyl (1S,3R,4R,5R)-3-{[(E)-3-(3,4-Dihydroxyphenyl)prop-2-enoyl]oxy}-1,4,5-trihydroxycyclohexanecarboxylate (**4**). Yellow crystals. HPTLC (*Diol*, $CHCl_3$/MeOH 9:1): R_f 0.34. M.p. 86–88°. $[\alpha]_D$ = −17.2 (MeOH,

$c = 0.6$). UV (MeOH): 330, 302 (sh), 242, 218. UV (MeOH + $AlCl_3$/HCl): unchanged. UV (MeOH + $AlCl_3$): 358, 308 (sh), 260. UV (MeOH + NaOAc): 368, 340, 300 (sh). UV (MeOH + NaOAc/HBO_3): 349, 305, 254. ^{1}H-NMR: *Table 2*. ^{13}C-NMR: *Table 1*. DCI-MS (NH_3, pos.-ion mode): 400 ($[M + NH_4]^+$), 383 ($[M + H]^+$), 365 ($[M + H - 18]^+$), 354 ($[M + H - 29]^+$), 337 ($[M + H - 46]^+$), 192 ($[C_7H_{10}O_5 + NH_4]^+$), 163 ($[C_9H_6O_3 + H]^+$).

Ethyl (1S,3R,4R,5R)-3,4-Bis{[(E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-1,5-dihydroxycyclohexanecarboxylate (**5**). Yellow crystals. HPTLC (*Diol*, $CHCl_3$/MeOH 9:1): R_f 0.25. M.p. 114–116°. $[\alpha]_D = -122.5$ (MeOH, $c = 0.6$). UV (MeOH): 331, 300 (sh), 245, 216. UV (MeOH + $AlCl_3$/HCl): unchanged. UV (MeOH + $AlCl_3$): 357, 308 (sh), 259. UV (MeOH + NaOAc): 347, 307, 250. UV (MeOH + NaOAc/HBO_3): 350, 306, 255. CD (MeOH): −3.870 (344), 0 (316), +1.280 (285). ^{1}H-NMR: *Table 2*. ^{13}C-NMR: *Table 1*. DCI-MS (NH_3, pos.-ion mode): 545 ($[M + H]^+$), 527 ($[M + H - 18]^+$), 383 ($[M + H - 162]^+$), 354 ($[M + H - 191]^+$), 337 ($[M + H - 208]^+$), 192 ($[C_7H_{10}O_5 + NH_4]^+$), 180 ($[C_9H_6O_3 + NH_4]^+$), 163 ($[C_9H_6O_3 + H]^+$).

Ethyl (1R,3R,4S,5R)-3,5-Bis{[(E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-1,4-dihydroxycyclohexanecarboxylate (**6**). Yellow crystals. HPTLC (*Diol*, $CHCl_3$/MeOH 9:1): R_f 0.18. M.p. 120–122°. $[\alpha]_D = -109.2$ (MeOH, $c = 0.6$). UV (MeOH): 331, 300 (sh), 245, 217. UV (MeOH + $AlCl_3$/HCl): unchanged. UV (MeOH + $AlCl_3$): 359, 310, 260. UV (MeOH + NaOAc): 343, 301 (sh). UV (MeOH + NaOAc/HBO_3): 350, 305, 255. CD (MeOH): −7.170 (344), 0 (316), +2.571 (284). ^{1}H-NMR: *Table 2*. ^{13}C-NMR: *Table 1*. DCI-MS (NH_3, pos.-ion mode): 562 ($[M + NH_4]^+$), 545 ($[M + H]^+$), 527 ($[M + H - 18]^+$), 383 ($[M + H - 162]^+$), 354 ($[M + H - 191]^+$), 337 ($[M + H - 208]^+$), 192 ($[C_7H_{10}O_5 + NH_4]^+$), 163 ($[C_9H_6O_3 + H]^+$).

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