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Bonducellpins A−D, New Cassane Furanoditerpenes of *Caesalpinia bonduc*

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Four cassane furanoditerpenes, designated bonducellpins A (**1**), B (**2**), C (**3**), and D (**4**), were isolated from the roots of *Caesalpinia bonduc*. The ^{1}H- and ^{13}C-NMR spectra of all four compounds were completely assigned by using a combination of 2D NMR experiments, which included COSY, HMQC, HMBC, and NOESY sequences.

Plants belonging to the genus *Caesalpinia* have proven to be a rich source of cassane furanoditerpenes, some of which display interesting biological activity.[1−4] *Caesalpinia bonduc* (L.) Roxb. (Fabaceae, subfamily Caesalpiniodeae, tribe Caesalpinieae) is also known as *C. bonducella* and is widely distributed throughout the tropics and subtropics.[5−7] The taxonomy of the family Fabaceae (previously Leguminosae) has been the subject of much debate, and plants of the genus *Caesalpinia* are sometimes referred to in the literature as belonging to the family Caesalpiniaceae.[7] *C. bonduc* has been the subject of several chemical investigations, wherein a number of cassane furanoditerpenes have been isolated.[4,8−17] We have investigated the roots of *C. bonduc*, collected in Barbados, and report here the isolation of four new cassane furanoditerpenes, bonducellpins A (**1**), B (**2**), C (**3**), and D (**4**). The proton and carbon assignments as well as the relative stereochemistry of all four compounds were determined by 2D NMR spectroscopy.

Results and Discussion

Bonducellpin A (**1**) was isolated as white crystals, mp 118−119 °C, and had the molecular formula $C_{25}H_{34}O_9$. The IR spectrum exhibited absorptions typical of hydroxyl (3447 cm^{-1}) and ester (1735 cm^{-1}) functionalities. The ^{1}H-NMR spectrum had oxymethine resonances associated with acetoxyl groups at δ 4.87 (t, J = 3.0 Hz, H-1) and δ 5.36 (dd, J = 9.8, 2.3 Hz, H-6) and a secondary hydroxyl at δ 3.92 (d, J = 9.8 Hz, H-7). A 1,2-disubstituted furan was evident from lowfield doublets at δ 7.25 (J = 2.5 Hz, H-α) and δ 6.17 (J = 2.5 Hz, H-β), while a methoxycarbonyl group had a sharp singlet at δ 3.73. The carbomethoxyl group was located at C-17 because an HMBC correlation was observed between its carbonyl at δ 173.4 and a proton at δ 3.49, attributable to H-14. HMBC correlations were also observed between H-14 and C-7, C-8, C-12, and C-13. The COSY spectrum established the spin system involving H-6, H-7, H-8, H-9, H_2-11, and H-14. The relative stereochemistry of **1** was determined by interpretation of the results of a NOESY experiment (Figure 1). In particular, H-14 had cross peaks with H-7 and H-9, which indicated that they were α-oriented, while the stereochemistry of H-1 followed from its cross peak with H_3-10 and from its vicinal couplings to the C-2 protons. These results are summarized in Tables 1 and 2 and led to the structural assignment of bonducellpin A (**1**).

Bonducellpin B (**2**), $C_{23}H_{30}O_8$, had IR absorbances due

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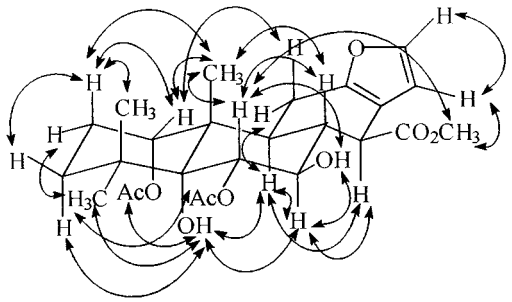


Figure 1. Major NOESY correlations for compound **1**.

to hydroxyl (3392 cm^{-1}), ester (1740 cm^{-1}), and ketone (1720 cm^{-1}) functionalities. The ^{1}H- and ^{13}C-NMR spectra of **2** were similar to those of **1** except for the disappearance of the oxymethine proton at C-1 and its replacement with a ketone having a ^{13}C resonance at δ 211.8 (Tables 1 and 2). The location of the ketone at C-1 was confirmed because it showed HMBC correlations to H_2-2, H_2-3, H-9, and H_3-20. Bonducellpin B (**2**) is, therefore, the 1-keto analogue of **1**.

Bonducellpin C (**3**), $C_{23}H_{32}O_7$, was isolated as white crystals, mp 110−113 °C. The IR spectrum had absorbances characteristic of hydroxyl (3401 cm^{-1}) and ester (1736 cm^{-1}) groups. The ^{1}H-NMR spectrum had resonances assignable to an acetoxyl methine at δ 4.90 (br s), a secondary hydroxyl at δ 4.00 (m), and a methoxycarbonyl at δ 3.74. The acetoxyl group was located at C-1 as the proton at δ 4.90 showed HMBC cross peaks to C-2, C-3, C-5, C-10, C-20, and the acetate carbonyl at δ 169.0. A signal at δ 3.47 (d, J = 8.8 Hz) was assigned to H-14, and it showed HMBC correlations to the methoxycarbonyl at δ 176.0, in addition to C-7, C-8, C-12, and C-13. When **3** was acetylated, the oxymethine resonance at δ 4.00 shifted downfield to δ 5.22 (ddd, J = 10.2, 10.2, 5.7). The foregoing evidence indicated that **3** was similar to **1** except that the acetoxyl group at C-6 was replaced by a methylene group. The stereochemistry of all the chiral centers in **3** were identical to those in **1** for they both had similar coupling constants at these positions (Tables 1 and 2), and this was confirmed by interpretation of a NOESY spectrum of **3**.

Bonducellpin D (**4**), mp 215−217 °C, had the molecular formula, $C_{22}H_{28}O_7$. The IR spectrum had absorbances characteristic of hydroxyl (3392 cm^{-1}), γ-lactone (1797 cm^{-1}), and ester (1735 cm^{-1}) functionalities. The ^{1}H-NMR specrum had resonances due to oxymethine protons at δ 5.58 (d, J = 9.8, H-6), δ 4.74 (dd, J = 13.1, 9.8, H-7), and δ 3.70 (m, H-1). The HMQC spectrum revealed that H-7 was directly attached to a carbon at δ 82.7. The downfield nature of C-7 and the lack of a resonance due to a methoxycarbonyl group indicated that the γ-lactone was formed between the oxygen at C-7 and the C-17 carbonyl. Bonducellpins A−D (**1**−**4**) represent the first examples of cassane furanoditerpenes bearing a C-17 ester from the genus *Caesalpinia*; however, cassane furanoditerpenes with a C-17 carboxylic acid or ester were previously isolated from plants of the genus *Pterodon*, which is also a member of the Fabaceae (subfamily Papilionoideae, tribe Dipterygeae).[18,19]

Experimental Section

General Experimental Procedures. Melting points were determined using a Koffler hotstage and are uncorrected. The IR spectra were recorded on a Perkin-Elmer 1725X FT-IR spectrometer. UV spectra were obtained on a Hewlett-Packard 8452A spectrophotometer in MeOH. Optical rotations were recorded on a Perkin-Elmer 341 polarimeter in $CHCl_3$ solutions. All NMR spectra were obtained on a Varian UNITY 500 MHz spectrometer, in $CDCl_3$ using TMS as an internal standard.

Plant Material. The roots of *Caesalpinia bonduc* were collected in St. Andrew, Barbados, in February 1995. The plant was identified by Dr. Sean Carrington, Biological and Chemical Sciences Department, University of the West Indies, where a voucher specimen (No. SC1785) is kept.

Extraction and Isolation. The dried, ground roots (1.7 kg) were extracted with 95% EtOH (9.6 L) and the solvent evaporated *in vacuo* to give a brown syrup (180 g). The extract was dissolved in 10% aqueous MeOH (500 mL) and extracted with light petroleum (6 × 300 mL). The aqueous MeOH layer was diluted with H_2O (200 mL) and extracted with CH_2Cl_2 (6 × 300 mL), dried over anhydrous Na_2SO_4, and the solvent evaporated to give a brown gum (24 g).

The CH_2Cl_2 extract was flash chromatographed over Si gel with light petroleum−Me_2CO (3:1) followed by reversed-phase preparative HPLC using MeOH−H_2O (75:25), to give compounds **1** (1.7 mg), **2** (12.8 mg), **3** (29.9 mg), and **4** (4.2 mg).

Bonducellpin A (1): colorless crystals; mp 118−119 °C; $[\alpha]_D$ +4.6° (*c* 0.33, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3447, 1735 cm^{-1}; UV (MeOH) λ_{max} (log ϵ) 226 (3.76) nm; EIMS *m/z* $[M]^+$ 478 (12), 446 (2), 418 (10), 400 (9), 386 (23), 358 (18), 340 (56), 281 (100), 263 (36), 243 (44), 145 (21), 107 (25); HREIMS 478.2206 calcd for $C_{25}H_{34}O_9$ 478.2203; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2, respectively.

Bonducellpin B (2): colorless gum; $[\alpha]_D$ +18.7° (*c* 0.14, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3392, 1735, 1720 cm^{-1}; UV (MeOH) λ_{max} (log ϵ) 218, 254 (3.74, 3.29) nm; EIMS *m/z* $[M]^+$ 434 (29), 416 (2), 402 (7), 374 (35), 356 (26), 314 (52), 297 (39), 257 (28), 199 (45), 149 (100), 109 (41); HREIMS 434.1953 calcd for $C_{23}H_{30}O_8$ 434.1941; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2, respectively.

Bonducellpin C (3): colorless crystals; mp 112−113 °C; $[\alpha]_D$ +12.6° (*c* 0.78, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3401, 1736 cm^{-1}; UV (MeOH) λ_{max} (log ϵ) 216 (3.81) nm; EIMS *m/z* $[M]^+$ 420 (15), 402 (3), 360 (9), 342 (53), 283 (27), 265 (100), 227 (22), 209 (31), 195 (51), 177 (42), 121 (42); HREIMS 420.2155 calcd for $C_{23}H_{32}O_7$ 420.2148; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2, respectively.

Acetate of 3. Acetylation of **3** (5.6 mg) with Ac_2O and pyridine (1:1) gave the acetate **3a** as a colorless gum (4.2 mg): $[\alpha]_D$ +26.5° (*c* 0.05, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3401, 1736 cm^{-1}; UV (MeOH) λ_{max} (log ϵ) 216, 256 (3.80, 3.14) nm; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.24 (d, J = 2.6 Hz, H-16), 6.12 (d, J = 2.6 Hz, H-15), 5.22 (ddd, J = 10.2, 10.2, 5.7 Hz, H-7), 4.92 (br t, J = 3.4 Hz, H-1), 3.73 (s, OCH_3), 3.39 (br d, J = 8.2 Hz, H-14), 2.69 (ddd, J = 12.1, 12.1, 5.6 Hz, H-9), 2.52 (dd, J = 16.2, 12.1 Hz, H-11β), 2.30 (dd, J = 16.2, 5.6 Hz, H-11α), 2.17 (dd, J = 12.7, 5.7 Hz, H-6), 2.09 (s, 1-CH_3CO), 2.00 (s, 7-CH_3CO), 1.98 (m, H-2), 1.78 (m, H-2), 1.75 (m, H-3), 1.65 (ddd, J = 12.7, 11.0, 3.0 Hz, H-6), 1.22 (s, H-20), 1.15 (m, H-3), 1.08 (s, H-19), 1.04 (s, H-18); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 174.6 (C-17), 170.1 (7-CH_3*C*O), 169.0 (1-CH_3*C*O), 149.8 (C-12), 141.5 (C-16), 113.3 (C-

Table 1. ^{1}H-NMR Assignments for Bonducellpins A−D (**1**−**4**)[a]

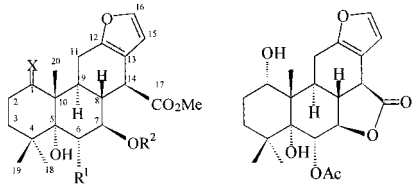
H	1	2	3	4
1	4.87 (t, 3)		4.90 (br s)	3.70 (m)
2	1.78 (m)	2.44 (m)	1.78 (m)	1.66 (m)
	1.95 (m)	2.65 (m)	1.99 (m)	2.06 (m)
3	1.12 (m)	1.78 (m)	1.15 (m)	1.11 (m)
	1.75 (m)	1.92 (m)	1.74 (m)	2.07 (m)
6	5.36 (dd, 9.8, 2.3)	5.31 (d, 10)	1.65 (ddd, 13.6, 11.3, 2.8)	5.58 (d, 9.8)
			2.02 (m)	
7	3.92 (dd, 14.7, 9.8)	3.75 (m)	4.00 (m)	4.74 (dd, 13.1, 9.8)
8	2.40 (m)	2.35 (m)	2.23 (m)	2.15 (m)
9	2.65 (ddd, 12, 12, 5)	2.67 (ddd, 11, 11, 5.3)	2.61 (ddd, 12.8, 12.8, 6.4)	3.19 (ddd, 13.7, 8.9, 7)
11α	2.30 (dd, 15.5, 6)	3.38 (dd, 16, 5.3)	2.50 (ddd, 16, 6.4, 3.2)	2.79 (dd, 16.3, 7)
11*β*	2.48 (dd, 15.5, 12)	2.45 (dd, 16, 11)	2.26 (dd, 16, 12.8)	2.57 (dd, 16.3, 8.9)
14	3.49 (br d, 8.5)	3.51 (br d 8)	3.47 (d, 8.8)	3.31 (ddd, 12.8, 1.4, 1.4)
15	6.17 (d, 2.5)	6.16 (d, 2)	6.17 (d, 2.5)	6.60 (d, 2.5)
16	7.25 (d, 2.5)	7.23 (d, 2)	7.24 (d, 2.5)	7.31 (d, 2.5)
18	1.14 (s)	1.18 (s)	1.05 (s)	1.12 (s)
19	1.15 (s)	1.27 (s)	1.09 (s)	1.16 (s)
20	1.26 (s)	1.50 (s)	1.19 (s)	1.13 (s)
1-Ac	2.10 (s)		2.10 (s)	
6-Ac	2.16 (s)	2.16 (s)		2.15 (s)
OMe	3.73 (s)	3.73 (s)	3.74 (s)	

[a] Chemical shifts (*δ*) in ppm (mult., *J* in Hz).

Table 2. ^{13}C NMR Assignments for Bonducellpins A−D (**1**−**4**)[a]

C	1	2	3	4
1	75.6	211.8	75.5	72.6
2	22.2	35.2	22.5	25.7
3	32.2	38.6	30.0	32.1
4	38.6	38.1	38.4	39.5
5	79.5	82.1	78.5	84.4
6	76.1	76.6	36.2	72.9
7	76.5	76.4	73.4	82.7
8	41.6	41.8	42.4	44.5
9	35.9	37.4	36.5	32.3
10	45.1	55.7	43.6	47.6
11	21.6	24.1	21.5	21.2
12	149.6	151.2	150.0	151.9
13	113.6	112.2	113.6	113.8
14	46.2	45.8	46.4	41.6
15	108.4	108.3	108.5	107.8
16	141.6	141.2	141.4	141.7
17	175.3	175.6	176.0	173.4
18	30.6	28.6	28.0	30.4
19	24.6	26.6	25.0	24.2
20	17.1	15.5	17.7	16.9
1-Ac	168.9		169.0	
	21.4		21.5	
6-Ac	171.6	170.9		169.6
	21.8	21.6		21.7

[a] Chemical shift (*δ*) in ppm.



(**1**) X = H, α-OAc, R^1 = OAc, R^2 = H

(**2**) X = O, R^1 = OAc, R^2 = H

(**3**) X = H, α-OAc, R^1 = H_2, R^2 = H

(**3a**) X = H, α-OAc, R^1 = H_2, R^2 = Ac

4

13), 108.3 (C-15), 78.3 (C-5), 76.0 (C-7), 75.4 (C-1), 51.9 (O*C*H$_3$), 45.9 (C-14), 43.5 (C-10), 38.9 (C-8), 38.4 (C-4), 36.6 (C-9), 32.0 (C-6), 29.9 (C-3), 27.9 (C-18), 24.9 (C-19), 22.4 (C-2), 21.4 (1−*C*H$_3$CO), 21.3 (C-11), 21.1 (7−*C*H$_3$CO), 17.6 (C-10); EIMS *m*/*z* [M]$^+$ 462 (5), 402 (34), 370 (72), 342 (41), 309 (69), 286 (38), 265 (100), 209 (37), 195 (56), 145 (57), 109 (23); HREIMS 462.2251 calcd for $C_{25}H_{34}O_8$ 462.2254.

Bonducellpin D (4): colorless crystals; mp 216−217 °C, [α]$_D$ +8.4° (*c* 0.35 $CHCl_3$) IR ($CHCl_3$) ν_{max} 3392, 1797, 1735 cm^{-1}; UV (MeOH) λ_{max} (log ϵ) 218, 260 (3.84, 3.21) nm; EIMS *m*/*z* [M]$^+$ 404 (25), 386 (64), 371 (3), 335 (46), 307 (100), 262 (11), 249 (17), 217 (41), 188 (50), 145 (30), 121 (53); HREIMS 404.1850 calcd for $C_{22}H_{28}O_7$ 404.1835; ^{1}H- and ^{13}C-NMR data, see Tables 1 and 2, respectively.

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