Communications to the Editor

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STRUCTURE AND NMR SPECTRA OF BOERAVINONE C, A NEW ROTENOID ANALOGUE
FROM BOERHAAVIA DIFFUSA LINN

Shigetoshi Kadota, Nzunzu Lami, Yasuhiro Tezuka, and Tohru Kikuchi*

Research Institute for Wakan-Yaku (Oriental Medicines), Toyama Medical
and Pharmaceutical University, 2630 Sugitani, Toyama 930-01, Japan

A new rotenoid analogue, boeravinone C, has been isolated from the root of Boerhaavia diffusa Linn (Nyctaginaceae) and its structure has been determined by means of 2-D NMR. The ^1H -NMR of boeravinone C showed unusual splitting patterns due to ABC spin systems. These splitting patterns were analyzed by simulation.

KEYWORDS — Boerhaavia diffusa; Nyctaginaceae; rotenoid; boeravinone C; 2-D NMR; NMR simulation

In a preceding communication,¹⁾ we described the structures of two new rotenoids, boeravinone A (2) and B (3), which were isolated from the ether extract of the dried roots of Boerhaavia diffusa Linn (Nyctaginaceae) collected in Nepal. This communication deals with the structure of a new 12a-hydroxy rotenoid, boeravinone C, which showed an unusual splitting pattern due to ABC spin systems.

Boeravinone C (1a), $\text{C}_{18}\text{H}_{16}\text{O}_7$, pale yellow needles (from CHCl_3), mp 248–249°C, $[\alpha]_{\text{D}} -47^\circ$ (acetone), showed uv $\lambda_{\text{max}}^{\text{EtOH}}$ nm (log ϵ): 331_{sh} (3.05), 293.5 (3.94), 212_{sh} (4.01), and 207.4 (4.03). The IR (KBr) spectrum of 1a showed absorptions at 3550, 3440 (OH), 1630 (conj. CO), 1580, 1510, and 1480 cm^{-1} (phenyl) and the EIMS exhibited the M^+ peak at m/z 344 and fragment ion peaks at m/z 326 ($\text{M}^+ - \text{H}_2\text{O}$), 181, and 163.

The ^1H - and ^{13}C -NMR spectra (in pyridine- d_5) of 1a indicated the presence of a carbonyl (δ_{C} 195.60), a hydroxyl (δ_{H} 12.56), four aromatic CH groups (δ_{H} 8.34, 7.27, 7.06, and 6.25; δ_{C} 122.23, 117.20, 121.41, and 90.93), a methoxyl (δ_{H} 3.71; δ_{C} 55.97), and a *tert*-methyl group (δ_{H} 2.15; δ_{C} 7.04). Further, the ^1H -NMR spectrum showed signals with a complex splitting pattern in the 4.67–4.93 region, which were

1a: R, $\text{R}_1 = \text{H}$

1b: R = COCH_3 , $\text{R}_1 = \text{H}$

1c: R, $\text{R}_1 = \text{COCH}_3$

2: $\text{R}_2 = \text{CH}_3$

3: $\text{R}_2 = \text{H}$

ascribed to an O-CH-CH₂-O grouping (6a-H and 6-H₂) by the ¹H-¹³C COSY experiment (Fig. 1 and Table I).

Acetylation of **1a** gave an amorphous diacetate (**1b**), ν 1760 cm⁻¹ (CO), δ_{H} 2.29 and 2.53 (Ac x 2), and an amorphous triacetate (**1c**), ν 1760 and 1745 cm⁻¹ (CO), δ_{H} 1.74, 2.31, and 2.49 (Ac x 3). It was found that further acetylation of **1b** proceeded slowly to give **1c** and both showed no ¹H-signal due to a proton geminal to the acetoxyl group. Therefore, **1a** has an aliphatic tert-hydroxyl and two phenolic hydroxyls.

Reduction of **1a** with NaBH₄ in MeOH yielded solely an alcohol (**4**), C₁₈H₁₈O₇, mp 208–209°C, δ_{H} 5.59 (s, CH-OH) (Table I). On the other hand, reduction of **1a** with LiBH₄ in anhydrous ether afforded epimeric alcohols; the major alcohol (**5**), C₁₈H₁₈O₇, had mp 203–205°C, δ_{H} 6.17 (s, CH-OH) (Table I), while the minor product was identified as **4**.

(—): connectivity was detected;
 ---: connectivity was not detected)

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The 2-D INADEQUATE spectrum²⁾ of boeravinone C (**1a**) (in acetone-d₆) indicated the gross structure to be **6**, in which the correlated peaks of all the coupled ¹³C-¹³C pairs, except those of the carbons a and h, g and o, and h and q, were clearly observed.

Then we applied the ¹H-¹³C long-range COSY³⁾ to **1a** in order to determine the connectivities of the carbons a, g, h, and q, and the substituent groups. As shown in formula **7**, the carbon signals at δ_{C} 102.98 (g, C-11a), 106.80 (h, C-10), 166.87 (q, C-9), 144.20 (m, C-4a), and 162.68 (p, C-11) are correlated with the proton signals at δ_{H} 6.20 (8-H), at δ_{H} 1.97 (10-CH₃) and 6.20 (8-H), at δ_{H} 3.93 (9-OCH₃) and 1.97 (10-CH₃), at δ_{H} 4.47 (6-H), and at δ_{H} 11.98 (11-OH), respectively. Some of the other significant long-range correlations observed are also shown by arrows.

Although long-range correlation could not be detected between the carbon 7a and 6a-proton, an ether linkage should exist between C-6a and C-7a, in view of the molecular formula. Thus, the plane structure of boeravinone C is represented by the formula **7**.

The relative stereochemistry of the B and C rings was determined on the basis of NOE experiments with the reduction products **4** and **5**. Irradiation at 6a-H (δ_{H} 4.56) and 12-H (δ_{H} 5.59) in **4** caused the increase of signal intensity of 12-H and 1- and 6a-H, respectively, and irradiation at 1-H (δ_{H} 8.36) gave rise to the increase of signal intensity of 2- and 12-H. On the other hand, irradiation at 6a-H (δ_{H} 5.27) and 12-H (δ_{H} 6.17) in **5** caused the increase of signal intensity of 6-H and 1-H,

4: R = H, R₁ = OH

5: R = OH, R₁ = H

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Fig. 1. Comparisons of Observed and Simulated ^1H -NMR Spectra of Complex Splitting Patterns of Boeravinone C ($1a$) in Pyridine- d_5 , Acetone- d_6 , and Acetone- $d_6 + D_2O$.
 a, b) Observed and simulated ^1H -NMR spectra of 1-, 2-, 3-, 6a-, and 6-protons in pyridine- d_5 .
 c, d) Observed and simulated ^1H -NMR spectra of 1-, 2-, 3-, 6a-, and 6-protons in acetone- d_6 .
 e, f) Observed and simulated ^1H -NMR spectra of 1-, 2-, 3-, 6a-, and 6-protons in acetone- $d_6 + D_2O$.

respectively. These observations led us to conclude that the B/C ring junction of boeravinone C is trans.

From the foregoing evidence, the structure of boeravinone C was assigned to $1a$. The absolute configuration is currently under investigation.

As mentioned before, the ^1H -NMR spectrum of $1a$ showed a complicated splitting pattern due to an ABC spin system. This spectral pattern changed markedly when the solvent was changed from pyridine- d_5 to acetone- d_6 or acetone- $d_6 + D_2O$.⁴⁾ Since these splitting patterns could not be interpreted in the first-order analysis, a simulative approach was applied by calculating the positions and intensities of respective resonance lines in these three spin systems. For this purpose, the JEOL program COMIC was used and the results are reproduced in Fig. 1. Comparisons of observed and simulated splitting patterns gave excellent agreement in each case.

Table I. ^1H -(400 MHz) and ^{13}C -(100 MHz) NMR Data of Boeravinone C and Its Derivatives (Coupling Constants in Parentheses)

position	boeravinone C (1a) (pyridine- d_5)		boeravinone C (1a) (acetone- d_6)		boeravinone C (1a) (acetone- d_6 + D_2O)	alcohol (4) (pyridine- d_5)		alcohol (5) (pyridine- d_5 + D_2O)
	$\delta_{\text{H}}^{\text{a)}$	$\delta_{\text{C}}^{\text{b,c)}$	$\delta_{\text{H}}^{\text{a)}$	$\delta_{\text{C}}^{\text{b,c)}$	$\delta_{\text{H}}^{\text{d)}$	δ_{H}	$\delta_{\text{C}}^{\text{b,c)}$	$\delta_{\text{H}}^{\text{d)}$
1	8.34 dd (7.5,1.9)	122.23 d	7.81 ^{e)} (8.20,1.35) ^{e)}	123.21 d	7.80 ^{e)} (8.82,0.84) ^{e)}	8.36 dd (8.0,1.5)	121.69 d	7.61 dd (8.0,1.0)
1a	—	122.13 s	—	121.91 s	—	—	127.02 s	—
2	7.06 t (7.5)	121.41 s	6.87 ^{e)} (8.20,7.98) ^{e)}	121.95 d	6.85 ^{e)} (8.82,8.39) ^{e)}	7.02 t (8.0)	119.61 d	6.98 t (8.0)
3	7.27 dd (7.5,1.9)	117.20 s	6.86 ^{e)} (7.98,1.35) ^{e)}	117.12 d	6.86 ^{e)} (8.39,0.84) ^{e)}	7.23 dd (8.0,1.5)	116.73 d	7.22 dd (8.0,1.0)
4	—	147.50 s	—	146.97 s	—	—	147.25 s	—
4a	—	144.31 s	—	144.20 s	—	—	143.25 s	—
6	4.67 ^{e)} 4.92 (11.64, -10.23, 4.66) ^{e)}	62.25 t	4.46 ^{e)} 4.49 (11.50, -10.02, 4.44) ^{e)}	62.72 t	4.47 ^{e)} 4.48 (9.95, -9.98, 6.66) ^{e)}	4.62 dd (9.5,7.5) 4.89 dd (11.0,9.5)	62.98 t	4.74 dd (9.6,4.5) 4.92 dd (11.5,9.6)
6a	4.93 ^{e)} (11.64, 4.66) ^{e)}	77.16 d	4.80 ^{e)} (11.50, 4.44) ^{e)}	77.40 d	4.76 ^{e)} (9.95, 6.66) ^{e)}	4.56 dd (11.0,4.5)	74.01 d	5.27 dd (11.5,4.5)
7a	—	160.69 s	—	161.52 s	—	—	153.17 s	—
8	6.25 s	90.93 d	6.20 s	91.64 d	6.22 s	6.24 s	91.21 d	6.39 s
9	—	165.76 s	—	166.87 s	—	—	158.80 s	—
10	—	106.18 s	—	106.80 s	—	—	106.31 s	—
11	—	162.02 s	—	162.68 s	—	—	157.50 s	—
11a	—	102.57 s	—	102.98 s	—	—	105.33 s	—
12	—	195.60 s	—	195.59 s	—	5.59 s	71.33 d	6.17 s
12a	—	66.67 s	—	67.23 s	—	—	64.66 s	—
9-OMe	3.71 s	55.97 q	3.93 s	57.00 q	3.93 s	3.65 s	55.39 q	3.72 s
10-Me	2.15 s	7.04 q	1.97 s	7.62 q	1.97 s	2.30 s	8.35 q	2.41 s
11-OH	13.44 s	—	11.98 s	—	—	—	—	—

δ values in ppm and coupling constants in Hz. a) ^1H - ^1H correlation spectra were measured. b) The multiplicities of carbon signals were determined by means of the DEPT method and are indicated as s, d, t, and q. c) ^1H - ^{13}C correlation spectra were measured. d) Only ^1H -NMR spectrum was measured. e) Chemical shifts and coupling constants were determined by means of the simulation and rounded to three decimal places.

It is interesting that the coupling constants between 6a-H and 6-H₂ and between aromatic protons in 1a changed considerably when D₂O was added to the acetone- d_6 solution. This may be due to the change of the solvation state or the aggregation state, which may cause the conformational change. This problem is still under investigation.

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REFERENCES AND NOTES

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- 4) In CDCl_3 , 1a also showed a complex ^1H -NMR pattern, which we are unable to interpret.

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