CYCLOADDUCTS OF TERPENE QUINONES FROM *TAIWANIA CRYPTOMERIOIDES*

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Abstract—Four [4+2] or [5+2] cycloadducts formed from *trans*-ozic acid and a diterpene or norditerpene quinone were isolated from the leaves of *Taiwania cryptomerioides*. Among them, the [4+2] cycloadduct (taiwaniadduct 1) formed from *trans*-ozic acid and a norditerpene quinone underwent an intramolecular [2+2] cycloaddition on standing at room temperature. The structures of these cycloadducts were determined by spectral analyses and of one by X-ray crystallography. © 1997 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Taiwania cryptomerioides Hayata is an endemic evergreen species with thick linear-triangular leaves and elongate ovoid cones. The chemical constituents of this plant have been investigated extensively [1–3]. Various sesquiterpenes, lignans and bisflavones have been found in the leaves and wood. We recently isolated from this plant five diterpene quinones (taiwaniaquinones A–E), a diterpene quinol (taiwaniaquinol A), a norditerpenequinol (taiwaniaquinol B), and five related [4+2] and [5+2] cycloadducts (taiwaniadducts A–E) derived by the combination of taiwaniaquinone A with β -myrcene or *trans*-ozic acid [4, 5]. We report herein five new cycloadducts 1–5 (taiwaniadducts F–J) of such an uncommon type.

RESULTS AND DISCUSSION

Compound 1 gave rise to a molecular ion $[M]^+$ at m/z 632.4075 consistent with a molecular formula $C_{40}H_{56}O_6$. By detailed analyses of its IR, and 1H and ^{13}C NMR spectra, the structure was assigned as a [5+2] cycloadduct of two diterpenes, taiwaniaquinone A and *trans*-ozic acid, with the linkages at C-8–C-15' and C-13–C-14' (Scheme 1). The ^{13}C and 1H NMR spectra (Table 1) showed the characteristic resonances of an aldehyde [δ_H 10.23 (*d*) and δ_C 205.9 (*d*)], a ketone [δ_C 201.4 (*s*)], an enone [δ_C 141.7 (*s*), 145.9 (*s*) and 195.1 (*s*)], an acid [δ_C 184.7 (*s*)], a terminal

Scheme 1.

double bond [δ_C 107.9 (*t*) and 147.5 (*s*)], as well as a trisubstituted double bond [δ_C 130.4 (*d*) and 131.5 (*s*)]. The regio- and stereochemistry of 1 was supported by the HMBC and NOESY studies. The HMBC spectrum showed that H-14' (δ 3.15) was correlated to C-12 (δ 195.1) and C-13 (δ 73.3), whereas the NOESY spectrum showed that H-7 (δ 2.82) was correlated to H-20 (δ 1.21) as well as H-5 (δ 2.00) to H-6 (δ 10.23 and H-15' (δ 2.44). The large coupling constant (11 Hz) between H-5 and H-7 was consistent with their *trans* relationship. Compound 1 (namely tai

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Table 1. ^{13}C and ^1H NMR data of compounds **1**, **2m**, **4m** and **5** (CDCl_3)

1	2m		3m		4m		5	
	δ_{C}	δ_{H}	δ_{C}	δ_{H}	δ_{C}	δ_{H}	δ_{C}	δ_{H}
1	35.9	1.52 (m)*	36.6†	*	32.3	*	30.8	1.55 (m), 1.88 (m)
2	18.3	*	18.5	1.54 (m)*	18.1	*	18.1	1.44 (m)*
3	41.0	1.14 (m), 1.44 (m)	43.6	1.06 (m), 1.34 (m)	41.7	1.38 (m)*	41.1	0.96 (m), 1.34 (m)
4	34.4		34.5		32.6		32.8	
5	57.3	2.00 (d, 13.0)†	63.5	2.15 (s)	62.3	2.01 (s)	60.9	1.57 (s)
6	205.9	10.23 (d, 4.4)	202.0	10.02 (d, 1.4)§				
7	55.1	2.82 (dd, 13.0, 4.4)	87.5		204.8		206.5	
8	66.0		73.8		66.6		68.1	
9	145.9		142.2		60.2		55.5	
10	46.8		42.9		46.6		49.9	
11	141.7		144.1		198.6		210.5	
12	195.1		194.5		160.1		92.7	
13	73.3		67.3		143.2		59.4	
14	201.4		201.8		192.9		207.1	
15	26.7	2.34 (m)	27.5	2.16 (m)	25.7	3.21 (sept, 7.0)	34.3	2.23 (sept, 6.8)
16	16.9	1.00 (d, 7.0)	17.8	1.06 (d, 6.9)	19.9	1.17 (d, 7.0)	20.6	1.23 (d, 6.8)
17	18.7	1.01 (d, 7.0)	18.1	1.06 (d, 6.9)	20.6	1.15 (d, 7.0)	21.6	0.88 (d, 6.8)
18	34.1	0.88 (s)	33.1	0.97 (s)	32.6	1.07 (s)	32.6	1.07 (s)
19	21.3	0.90 (s)	23.2	0.88 (s)	21.5	0.95 (s)	21.4	0.89 (s)
20	19.1	1.21 (s)	24.5	1.48 (s)	21.3	0.78 (s)	23.2	1.01 (s)

1'	38.0	2.00 (m), 1.70 (m)	38.1†	*	*	37.1†	1.52 (m)*	39.2	1.64 (m), 0.71 (m)
2'	19.1	*	19.5	*	*	19.0	*	18.6	1.56 (m)*
3'	36.9	*	37.0†	*	*	36.8	1.48 (m), 1.93 (m)	36.0	1.44 (m), 1.58 (m)
4'	47.3		47.7			47.6		47.7	
5'	49.3	1.90 (m)	49.8	1.92 (dd, 12.2, 2.7)		50.1	1.83 (dd, 12.4, 2.7)	48.0	1.35 (m)
6'	26.5	1.34 (m)*	26.5	1.18 (m)*		24.9	1.56 (m)*	21.3	1.06 (m)*
7'	37.4	2.28 (m)*	37.5†	*		37.8†	2.30 (br d, 12.0) ^a	33.8	1.98 (m), 1.60 (m)
8'	147.5		147.8			147.1		53.8	
9'	56.9	1.60 (m)	56.7	1.76 (m)		54.0	1.64 (m)	48.0	1.16 (m)
10'	38.6		38.8			38.8		39.9	
11'	22.5	2.12 (m)*	23.3	*		26.8	*	29.0	2.02 (m), 1.80 (m)
12'	130.4	5.05 (br s)	132.4	5.07 (br t, 5.2)		41.3	3.07 (dd, 11.8, 3.9)	49.2	2.88 (m)
13'	131.5		134.0			143.0		136.1	
14'	45.5	3.15 (dd, 10.6, 6.1)	44.5	3.29 (t, 10.0)		122.0	5.64 (br d, 7.1)	121.6	5.51 (br d, 5.6)
15'	38.0	2.44 (m)*	33.0	2.32 (m)*		30.6	2.17 (br d, 15.0), 2.42 (dd, 15.0, 7.8)	29.9	2.80 (m)
16'	16.1	1.40 (s)	18.8	1.78 (s)		24.3	1.72 (s)	22.2	2.45 (br d, 20.0)
17'	107.9	4.37 (s), 4.77 (s)	108.2	4.37 (s), 4.75 (s)		108.7	4.61 (s), 4.90 (s)	45.4	1.59 (br s)
18'	184.7		179.2			179.2		178.8	2.32 (d, 12.0), 2.77 (d, 12.0)
19'	16.3	1.11 (s)	16.7	1.13 (s)		16.5	1.08 (s)	17.1	1.08 (s)
20'	14.5	0.67 (s)	14.6	0.71 (s)		15.2	0.58 (s)	15.1	0.67 (s)
CO ₂ CH ₃			51.9	3.65 (s)		51.9	3.63 (s)	52.0	3.60 (s)
OCH ₃			60.0	3.99 (s)		60.0	3.86 (s)	55.1	3.47 (s)

* The signal of one or both protons was too weak to be assigned.

† Assignments may be exchanged.

‡ Coupling constants (*J* in Hz) in parentheses.§ Coupled with 7-OH (δ 4.24).

adduct F) is a regioisomer of taiwaniadduct E which is a cycloadduct between taiwaniaquinone and *trans*-ozic acid with the linkages at C-8–C-14' and C-13–C-15'.

Compound **2** was not readily purified. It was, therefore, subjected to methylation (CH₂N₂, Et₂O) and purified as its methyl ester **2m**. Ester **2m** (C₄₁H₅₈O₇), [M]⁺ *m/z* 662.4184, showed ¹H and ¹³C resonances similar to those in taiwaniadduct E methyl ester [5], except lack of the H-7 signal. The C-7 resonance of **2m** appeared at δ 87.5 (s), indicating the presence of a tertiary hydroxyl group at this position. Compound taiwaniadduct G was thus a [5+2] cycloadduct between taiwaniaquinone C and *trans*-ozic acid with linkages at C-8–C-14' and C-13–C-15' (Scheme 2). C-10 methyl group (δ 1.48) and the C-7 aldehyde (δ 10.02) had to be on the same face as they showed NOE correlation in the NOESY spectrum of **2m**. The HMBC spectrum of **2m** also showed the correlation of C-12 (δ 194.5) with H-15' (δ 2.32), supporting the regiochemistry of the C-13–C-15' linkage. Compound **3** was treated with CH₂N₂ to give a dimethylated product **3m**, in which the two new methyl groups appeared at δ 3.63 and 3.99 attributable to an ester and enol ether moieties. Compound **3m** had the characteristic resonances for two carbonyl groups [δ _C 200.0 (s) and 205.1 (s)], a terminal double bond [δ _C 108.7 (t) and 147.1 (s)], a trisubstituted double bond [δ _C 122.0 (d) and 143.0 (s)], as well as a secondary hydroxyl group [δ _C 77.3 (d)]. Compound **3m** gave rise to a molecular ion [M]⁺ at *m/z* 48.4394 consistent with the molecular formula C₃₀O₆. Based on the above spectral data, the parent compound **3** (taiwaniadduct H) was deduced to be a [4+2]

cycloadduct of a norditerpene alcohol **6** and *trans*-ozic acid (Scheme 3). The structure was finally deduced from the HMBC spectrum of **3m**, in which the correlation of C-7 (δ 77.3) to C-15' (δ 30.6) was confirmed. The stereochemistry was established by the NOESY spectrum, in which H-5 (δ 1.42) was correlated with H-12' (δ 3.07) and H-7 (δ 4.35) with H-20 (δ 0.69). The large coupling constant (12 Hz) for H-5 and H-7 was in agreement with their *trans* relationship. Thus, **3** is formed by combination of two components with the linkages at C-8–C-15' and C-9–C-12'.

Treatment of compound **4** with CH₂N₂ gave a bismethylated product **4m** (C₄₁H₅₈O₈), [M]⁺ at *m/z* 646.4240. Compound **4m** yielded a crystalline compound **5** on standing at room temperature for three weeks (Scheme 4). The structure of **5** was unambiguously determined by X-ray crystallography (Fig. 1). Thus, **5** (taiwaniadduct J) is derived from **4m** via an intramolecular [2+2] cycloaddition with the linkages at C-12–C-8' and C-13–C-17'. Compound **4** (taiwaniadduct I) is a [4+2] cycloadduct of the norditerpene **7** and *trans*-ozic acid with the linkages at C-8–C-12' and C-9–C-15'. The cycloaddition occurs on the less hindered face of **7** to give **4** having the (8*R*, 9*R*, 12'*R*)-configuration.

EXPERIMENTAL

General. HPLC: Hibar Lichrosorb Si 60 column (10 μ m, 25 cm $\times$ 1 cm i.d.); TLC: Merck silica gel 60F sheets.

Plant material. The dried leaves (1.75 kg) of *T. cryptomerioides* were exhaustively extracted with