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DIMERIC HYDROANTHRACENES FROM THE UNRIPE SEEDS OF *CASSIA TOROSA**

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Key Word Index—*Cassia torosa*; Leguminosae; physcion-9-anthrone; physcion-10,10′-bianthrone; phlegmacin; anhydrophlegmacin B_2; torosanin; hydroanthracene; phytosterols.

Abstract—From the unripe seeds of *Cassia torosa* three new dimeric hydroanthracene derivatives were isolated along with stigmasterol, sitosterol, campesterol, physcion-9-anthrone, torosachyrsone and the phlegmacins A_2 and B_2. The structures of the new derivatives were established as physcion-10, 10′-bianthrone, anhydrophlegmacin B_2 [2-(6′-methoxy-3′-methyl-3′, 8′, 9′-trihydroxy-1′-oxo-1′, 2′, 3′, 4′-tetrahydroanthracene-10′-yl)-1, 8-dihydroxy-3-methoxy-6-methyl-9-oxo-9, 10-dihydroanthracene] and torosanin [2-(6′-methoxy-3′-methyl-3′, 8′, 9′-trihydroxy-1′-oxo-1′, 2′, 3′, 4′-tetrahydroanthracene-5′-yl)-1, 8-dihydroxy-3-methoxy-6-methyl-9-oxo-9, 10-dihydroanthracene], respectively.

INTRODUCTION

Previously, we reported the isolation of several anthraquinones and a hydroanthracene, torosachrysone (**1**) from the seeds of *Casia torosa* Cavanilles [1]. From the seedlings of this plant, we isolated some hydroanthracenes, germichrysone, germitorosone, methylgermitorosone, the phlegmacins A_2 (**2**) and B_2 (**3**) and the anhydrophlegmacin-9,10-quinones A_2 (**4**) and B_2 (**5**) [2–4]. In this paper, we report the isolation of **1–3**, physcion-9-anthrone (**6**) and phytosterols and the isolation and structural determination of three dimeric anthracene derivatives, physcion-10, 10′-bianthrone (**7**), anhydrophlegmacin B_2 (**8**) and torosanin (**9**) from the unripe seeds of this plant.

RESULTS AND DISCUSSION

The benzene extract of the crushed unripe seeds was treated as described in the Experimental to yield **1**, **3**, **6**, phytosterols and **7–9**.

Compound **6** was identified as physcion-9-anthrone by direct comparison with an authentic sample.

Phytosterols, colourless needles, mp 155–160°, green colour with Liebermann–Burchard reagent, were identified as a mixture of stigmasterol (major component), sitosterol and campesterol by GLC.

Compound **7**, pale yellow needles, mp 192–192.5°, $[\alpha]_D^{22} - 93°$, $C_{32}H_{26}O_8$, gave a positive $FeCl_3$ reaction and a yellow colour which changed to orange with 5% KOH. Its UV and IR spectra suggested the presence of an anthrone having chelated OH groups. The ^1H NMR spectrum showed the presence of two Me groups, two OMe groups, two CH groups, four aromatic protons and four chelated OH groups (Table 1). On pyrolysis, **7** yielded **6** which was converted to physcion (**10**) on oxidation with CrO_3 in HOAc. From these data, **7** was presumed to be physcion-10, 10′-bianthrone. An attempt to synthesize **7** from **6** by oxidation with $FeCl_3$ gave a product which had similar TLC, IR, ^1H NMR and MS properties to **7** but which had no optical rotation. Thus, **7** was a mixture of the isomer having optical activity and the *meso*-isomer of physcion-10, 10′-bianthrone.

Compound **8**, yellow prisms, mp 199–200°, $C_{32}H_{28}O_9$, gave a positive $FeCl_3$ reaction and a yellow colour which changed to red after a short time with methanolic NaOH. The UV and IR spectra suggested the presence of a hydroxyanthracene skeleton. The ^1H NMR spectrum indicated four phenolic OH groups, an alcoholic OH group, two Me groups, three $-CH_2-$ groups, two OMe groups and five aromatic protons. In the high resolution MS $[M]^+$ was at *m/z* 556 and the base peak at *m/z* 270, corresponding to physcionanthrone. The spectral data indicated that the plane structure of **8** was identical to that of anhydrophlegmacin A_1, which had been reported as the constituent of the fungus *Cortinarius odorifer* Britz (Agaricales) [5]. On treatment with methanolic NaOH, **8** gave anhydrophlegmacin-9, 10-quinone B_2 (**5**), which was identical to an authentic sample obtained from the seedlings of this plant [3]. Thus, the structure of **8** was determined as anhydrophlegmacin B_2.

Compound **9**, yellow needles, mp 267–268°, $C_{32}H_{28}O_9$, gave a positive $FeCl_3$ reaction and a yellow colour which changed to red after a short time with

*Part 13 in the series "Studies of the Constituents of Purgative Crude Drugs". For Part 12 see Takido, M., Kitanaka, S., Takahashi, S. and Tanaka, T. (1982) *Phytochemistry* **20**, 425.

Table 1. ^{1}H NMR spectral data of **1** and **6–11** (100 Mz, $CDCl_3$, TMS as internal standard, J in Hz)

Position of H	1	6	7	8	9	10	11
			Torosachrysone moiety				
2	2.83 *s*(br)			2.70 *s*(*br*)	2.79 *s*(*br*)		2.80 *s*(*br*)
3-Me	1.45 *s*			1.33 *s*	1.38 *s*		1.38 *s*
3-OH	1.68 *s*(*br*)			2.10 *s*(*br*)	1.62 *s*(*br*)		
4	3.03 *s*(*br*)			2.73 *d* (*J* = 17) 2.93 *d* (*J* = 17)	2.83 *d* (*J* = 17) 3.03 *d* (*J* = 17)		2.91 *s*(*br*) → 33% → 6.42 *s*
10	6.86 *s*				6.48 *s*		
5	6.54 *s*			6.15 *d* (*J* = 2.4) → 37%			
6-OMe	3.88 *s*			3.70 *s* → 35% → 6.51 *d* (*J* = 2.4)	3.82 *s* → 34% → 6.69 *s*		3.82 *s* → 35% → 6.70 *s*
7	6.47 *s*						
8-OH	9.79 *s*			10.23 *s*	10.21 *s*		10.24 *s*
9-OH	16.10 *s*			16.69 *s*	16.39 *s*		16.39 *s*
			Physcion-9-anthrone or physcion moiety				
2		6.36 *d* (*J* = 2.4)	6.35 *d* 6.37 *d* (*J* = 2.4)			6.69 *d* (*J* = 2.4)	
3-OMe		3.85 *s*	3.81 *s* 3.83 *s*	3.77 *s* → 30%	3.77 *s* → 22%	3.94 *s*	3.87 *s* → 29% → 7.55 *s*
4		6.39 *d* (*J* = 2.4)	5.96 *d* 5.99 *d* (*J* = 2.4)	6.61 *s* → 22%	6.58 *s* → 17%	7.37 *d* (*J* = 2.4)	
10		4.16 *s*(*br*)	4.33 *s*(2H)	4.38 *s*(*br*) → 17%	4.37 *s*(*br*) → 27%		
5		6.67 *s*(*br*)	6.10 *m*(2H)	6.74 *s*(*br*)	6.72 *d*-like	7.64 *d*-like	7.66 *d*-like
6-Me		2.34 *s*	2.28 *s* 2.30 *s*	2.39 *s*	2.38 *s*	2.46 *s*	2.47 *s*
7		6.67 *s*(*br*)	6.68 *m*(2H)	6.74 *s*(*br*)	6.72 *d*-like	7.09 *d*-like	7.08 *d*-like
8-OH		12.62 *s*	12.11 *s* 12.16 *s*	12.77 *s*	12.64 *s*	12.32 *s*	12.35 *s*
1-OH		12.31 *s*	11.80 *s* 11.86 *s*	12.21 *s*	12.64 *s*	12.12 *s*	12.08 *s*

*Arrows and figures in % indicate enhancement in NOE experiment.

methanolic NaOH. Its UV and IR spectra suggested the presence of a hydroanthracene skeleton as in **8**, and the ^{1}H NMR spectra indicated the presence of four phenolic OH groups, an alcoholic OH group, two Me groups, three $-CH_2-$ groups, two OMe groups and five aromatic protons. Comparison of ^{1}H NMR spectra with those of **1** and **6** indicated that **9** contained both torosachrysone and physcion-9-anthrone moieties. Compared with **1**, the signal of H-10 was shifted upfield by 0.18 ppm and the signal of H-7 was shifted downfield by 0.24 ppm, while the signal of H-5 had disappeared. Thus the physcion-9-anthrone moiety was linked to C-5 of the torosachrysone moiety. The linkage position in the physcion-9-anthrone moiety of **9** was at C-7 since the chemical shifts were similar to those of the physcion-9-anthrone moiety in **8**. The C-5 to C-7 linkage was confirmed by NOE. The high resolution MS showed $[M]^+$ at m/z 556 ($C_{32}H_{28}O_9$), and major fragment ions were observed at m/z 538 and 270 (base peak). On treatment with methanolic NaOH, **9** gave torosanin-9, 10-quinone (**11**). Thus, the structure of **9**, which we have named torosanin, was determined.

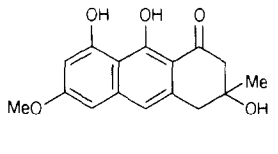
Compounds **2** and **3** were identified as phlegmacins A_2 and B_2 by direct comparison with authentic samples isolated from seedling of this plant.

In a previous study we found a tetrahydroanthracene, torosachrysone, and large amounts of anthraquinones in the ripe seeds, whereas in this study, anthrones instead of quinones were found in the unripe seeds. These findings suggest that the anthrones are oxidized to quinones as the seeds mature. Torosanin (**9**) represents a new combination-type of dimeric anthracene derivative.

EXPERIMENTAL

Plant material was obtained from the Drug Plant Garden of the College of Science and Technology, Nihon University.

Extraction and isolation. The crushed unripe seeds (3 kg) were extracted with C_6H_6 (3 × 6 l.) and torosachyrsone (**1**) (12 g) was extracted from the extract (47.4 g) with $CHCl_3$. The filtrate was evapd to dryness and the residue (45.3 g) chromatographed on a silicic acid column using C_6H_6–EtOAc (4:1, 6 fractions collected). Fraction 1 was rechromatographed with C_6H_6 to give **6** (600 mg) and **7** (230 mg). Fractions 2, 3 and 4 gave phytosterols (200 mg), **8** (1.7 g) and **1** (5.5 g), respectively. Fraction 5 was rechromatographed with *n*-hexane–EtOAc (1:1) to give **9** (125 mg), and fraction 6 was rechromatographed with C_6H_6–EtOAc (7:3) to give phlegmacins A_2 (**2**) (3 g) and B_2 (**3**) (4.5 g).



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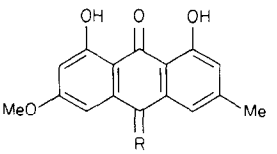

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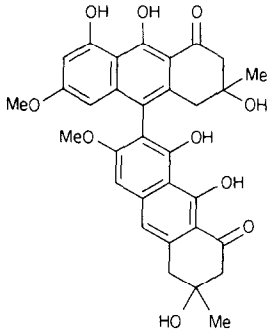
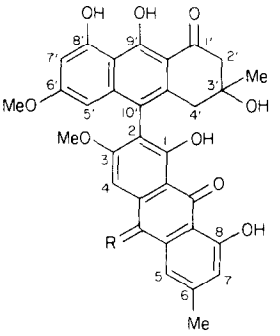
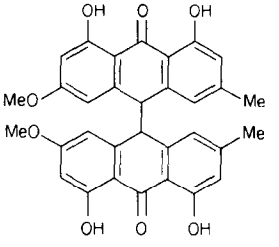
10 R = O



2 and **3**



4 and **5** R = O
8 R = H_2



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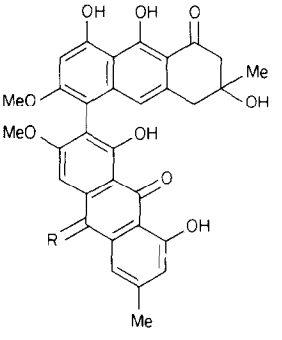

9 R = H_2
11 R = O

Physcion-9-anthrone (**6**). Recrystallization (C_6H_6) gave pale yellow needles, mp 192–192.5°. High resolution MS: 270.0888 $[M]^+$, calc. for $C_{16}H_{14}O_6$: 270.0890; UV $\lambda_{max}^{dioxane}$ nm (log ϵ): 211 (sh, 4.28), 218 (4.30), 254 (3.79), 270 (3.82), 300 (3.80), 352 (4.08); IR ν_{max}^{KBr} cm^{-1}: 3450, 2950, 1650, 1620, 1595. **6** was found to be identical with an authentic sample by spectral comparison.

Phytosterols. Recrystallization (MeOH) gave colourless needles, mp 155–160°. IR ν_{max}^{KBr} cm^{-1}: 3550, 2900, 1640, 1460, 1370, 1050, 970, 960. GLC (isothermally at 250° on 3% SE-30/Chromosorb W, N_2, FID) showed the presence of compesterol, stigmasterol and sitosterol.

Physcion-10,10'-bianthrone (**7**). Recrystallization (C_6H_6) gave very pale yellow needles, mp 273–274°, $[\alpha]_D^{22} - 93°$ ($CHCl_3$; *c* 0.11). High resolution MS: 538.1619 $[M]^+$, calc. for $C_{32}H_{26}O_8$: 538.1625; UV $\lambda_{max}^{dioxane}$ nm (log ϵ): 211 (4.80), 222 (sh, 4.67), 256 (sh, 4.17), 277 (4.32), 358 (4.47); IR ν_{max}^{KBr} cm^{-1}: 1640, 1620, 1600, 1570, 1490. MS 70 eV, *m/z* (rel. int.): 538 $[M]^+$ (1), 269 $[M/2]^+$ (100), 241 $[M/2 - CO]^+$ (36).

Anhydrophlegmacin B_2 (**8**). Crude crystals was recrystallized ($CHCl_3$) to give yellow prisms, mp 273–274°. High resolution MS: 556.1707 $[M]^+$, calc. for $C_{32}H_{28}O_9$: 556.1731; UV $\lambda_{max}^{dioxane}$ nm (log ϵ): 228 (4.75), 267 (4.76), 303 (sh, 4.19), 310 (sh, 4.23), 352 (4.34), 402 (sh, 3.99); IR ν_{max}^{KBr} cm^{-1}: 3500, 2950, 1620, 1595, 1485; MS 70 eV, *m/z* (rel. int): 556 $[M]^+$ (2), 538 $[M - H_2O]^+$ (75), 270 $[M - H_2O/2 + H]^+$ (100), 269 $[M - H_2O/2]^+$ (14), 255 $[M - H_2O/2 + H - Me]^+$ (13), 227 $[M - H_2O/2 + H - Me - CO]^+$ (27); ORD $[\alpha] \times 10^{-2}$ (nm): 0° (326), +11.5° (336), +2.5° (349), +16° (372), 0° (395), −8.8° (424).

Torosanin (**9**). Crude crystals were recrystallized (C_6H_6) to give yellow needles, mp 267–268°. High resolution MS: 556.1691 $[M]^+$, calc. for $C_{32}H_{28}O_9$: 556.1731; UV $\lambda_{max}^{dioxane}$ nm (log ϵ): 226 (4.69), 275 (4.70), 312 (4.18), 326 (sh, 4.22), 354 (4.35), 4.02 (sh, 4.08), 420 (sh, 4.02); IR ν_{max}^{KBr} cm^{-1}: 3400, 2950, 1620, 1595, 1485; MS 70 eV, *m/z* (rel. int.): 556 $[M]^+$ (44), 538 $[M - H_2O]^+$ (100); ORD $[\alpha] \times 10^{-2}$ (nm): +21.1° (311), 0° (331), −10.7° (340), 0° (349), +4.5° (356), 0° (380), −7.3° (429).

Phlegmacins A_2 (**2**) *and* B_2 (**3**). Recrystallization (C_6H_6) gave **2**, yellow powder, mp 195°, and **3**, yellow powder, mp 200°. Identified as phlegmacins A_2 and B_2 by comparison with authentic samples.

Physcion-9-anthrone (**6**) *from* **7**. **7** (10 mg) was heated *in vacuo* at 330° and the sublimate chromatographed on silicic acid using C_6H_6 to give pale yellow needles (2.5 mg), mp 192°, which crystallized from C_6H_6, and **7** (3 mg). The crystals were identified as physcion-9-anthrone by comparison with an authentic sample.

CrO_3 *oxidation of* **7**. **7** (10 mg) was dissolved with 1% CrO_3 in HOAc (40 ml). After standing 1 hr at 20°, the reaction mixture was chromatographed on silicic acid using C_6H_6 to give yellow needles (3 mg), mp 203–205° which crystallized from MeOH. The crystals were identified as physcion (**11**) by comparison with an authentic sample.

Synthesis of physcion-10, 10'-bianthrone. To a soln of physcion-9-anthrone (**2**) (40 mg) in C_6H_6 (30 ml) under reflux in a N_2 atmosphere in the dark, 1% $FeCl_3$–EtOH soln (11 ml) was added over 1 hr. The reaction mixture was poured into H_2O and extracted with Et_2O. The extract was chromatographed on silicic acid using C_6H_6 to give physcion and very pale yellow needles (25.4 mg), mp 286–286.5°, $[\alpha]_D^{22}$ 0°, which crystallized from C_6H_6. The crystals had the same properties (TLC, UV, IR, ^1H NMR and MS) as those of natural physcion-10, 10'-bianthrone, except that they exhibited no optical rotation.

Anhydrophlegmacin-9, 10-quinone B_2 (**5**) *from anhydrophlegmacin* B_2 (**8**). A soln of **8** (10 mg) in 1% NaOH–MeOH (3 ml) was left for 5 min at room temp. H_2O (10 ml) was then added and the mixture was neutralized with 5% HCl and extracted with C_6H_6. The soln was concd *in vacuo*, and the residue was chromatographed on silicic acid using C_6H_6–EtOAc (9:1). The product was recrystallized (C_6H_6) to give dark red prisms of **5** (3 mg), mp 191–193°. High resolution MS: 552.1431 $[M]^+$, calc. for $C_{32}H_{24}O_9$: 552.1419. **5** was identified as anhydrophlegmacin-9, 10-quinone B_2 by direct comparison with an authentic sample.

Torosanin-9, 10-quinone (**11**) *from torosanin* (**9**). **9** (10 mg) was dissolved in 1% NaOH–MeOH (5 ml) and left to stand for 10 min at room temp. The soln was then acidified with 1% HCl and extracted with C_6H_6. The C_6H_6 extract was chromatographed on silicic acid using C_6H_6–EtOAc (19:1). The product was crystallized (Et_2O) as yellow orange needles (2 mg), mp 230–231°. High resolution MS: 570.1520 $[M]^+$, calc. for $C_{32}H_{26}O_{10}$: 570.1524; UV $\lambda_{max}^{dioxane}$ nm (log ϵ): 224 (4.55), 278 (4.69), 308 (sh, 4.16), 342 (3.73), 395 (sh, 4.16), 416 (421), 463 (sh, 3.96); IR ν_{max}^{KBr} cm^{-1}: 3450, 2950, 1670, 1610, 1595, 1470, MS 70 eV, *m/z* (rel. int.): 570 $[M]^+$ (100), 552 $[M - H_2O]^+$ (57).

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