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Spectral Assignments and Reference Data

Structure of an unexpected trimer from the reaction of ageratochromene II with aluminum chloride

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A new trimer from the reaction of ageratochromene [1] (6,7-dimethoxy-2,2-dimethyl-1-benzopyran) with anhydrous aluminum chloride was shown to be 3,4-dihydro-6,7-dimethoxy-2,2-dimethyl-3-(6′,7′-dimethoxy-2′,2′-dimethyl-2*H*-1-benzopyran-4′-yl)-4-(3″,4″-dihydro-6″,7″-dimethoxy-2″,2″-dimethyl-2*H*-1-benzopyran-3″-yl)-2*H*-1-benzopyran. Its structure was confirmed by NMR (^{1}H, ^{13}C, DEPT-135. COSY, HMBC, HSQC, TOCSY and NOESY), IR, mass spectra and elemental analysis. Copyright © 2002 John Wiley & Sons, Ltd.

KEYWORDS: NMR; ^{1}H NMR; ^{13}C NMR; trimer; ageratochromene II; assignment

INTRODUCTION

The ageratochromenes I (**1**) and II (**2**) have been shown to induce precocious metamorphosis when applied to larval stages of insects.[1,2] Both the synthesis of dimers (**3** and **4**) by dimeric reaction and isolation of dimer (**3**) of ageratochromene II from the essential oil of *Ageratum conyzoides* have been reported.[3,4] Fraga and co-workers reported the dimeric reaction of ageratochromene II in 1983; different Lewis acids such as iron(III) chloride, zinc bromide and silver nitrate supported in silica gel were used as dimeric agents to obtain these dimers.[5–9]

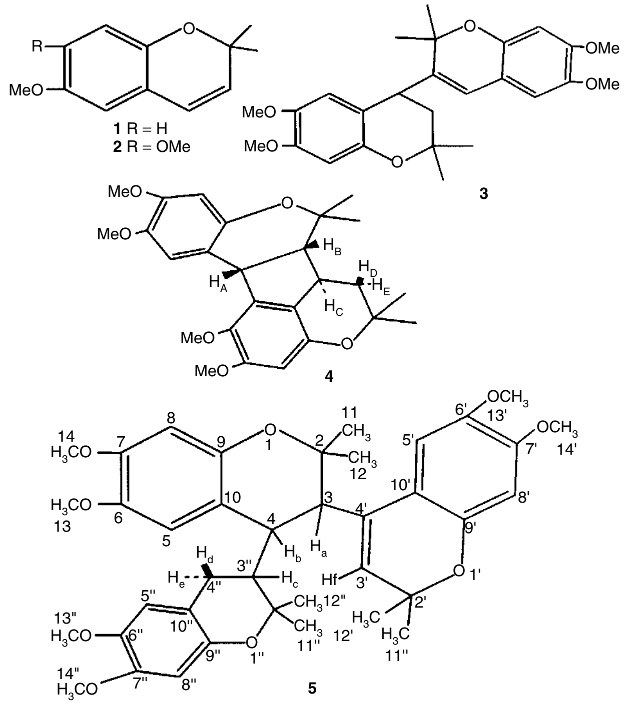
Studies of some dimeric and trimeric ageratochromene I analogs have been reported.[10] However, the synthesis of trimer **5** has not been reported previously and may prove to be of potential interest as an antijuvenile hormone. Furthermore, neither the reaction of ageratochromene II (**2**) with anhydrous aluminum chloride nor a detailed structural description of this type of compounds has been reported. We describe here the reaction of ageratochromene II with aluminum chloride and discuss the structure of the trimer **5** in detail.

DISCUSSION

In addition to the dimers **3** and **4**, an unexpected solid was isolated from the reaction of aluminum with ageratochromene II (**2**). The ^{1}H and ^{13}C NMR spectra data in CDCl3 of 5 are shown in Table I.

This solid is a trimer of ageratochromene II based on the following facts: (1) the molecular formula of the solid was elucidated to be $C_{39}H_{48}O_9$ from its mass spectrum (EI, 70 eV, M^+ 660) and elemental analyses; (2) the ^{1}H NMR spectrum showed the presence of six aromatic protons (sharp singlets at δ 6.90, 6.87, 6.47, 6.34 and 6.29). The DEPT spectrum showed only one negative signal at δ 24.13, which can be attributed to a CH_2 group. Based on the facts mentioned above, this solid may be one of the structures **A, B, C** and **5** (Scheme 2).

The ^{1}H NMR spectra of this solid showed a singlet at δ 5.38(1H). This is not consistent with structure **C**, since the olefinic proton should appear at a frequency higher than δ 6.00. The chemical shift of the olefinic proton H_f in **5** is close to the experimental data (the chemical shift of the olefinic proton in **5** can be estimated using the empirical equation[11] $\delta_H = 5.25 + 0.45 - 0.25 - 0.07 = 5.38$, which is identical with the experiment value δ 5.38).



Scheme 1

The DEPT-135 spectrum of the trimer displayed six positive signals between δ 21.46 and 28.81 arising from the six methyl groups. The HSQC and HMBC correlation exhibited the connections of C2, C2′ and C2″ to the attached methyl groups.

The DEPT-135 spectrum showed a negative signal at δ 24.13 ppm, which corresponds to C4″. From the HSQC correlation from C4″ to H_d (δ 2.73) and H_e (δ 2.50) and the COSY correlation from H_d to H_e, the connection of H_d and H_e to C4″ was deduced.

The DEPT spectrum displayed three saturated CH (C3, C4 and C3″) groups at δ 47.56, 40.63 and 43.49. From the HSQC correlation from C3 (δ 47.56) to H_a (δ 3.17), from C4 (δ 40.63) to H_b (δ 3.35) and from C3″ (δ 43.49) to H_c (δ 2.02), the connections of H_a to C3, H_b to C4 and H_c to C3″ were obtained.

By analysis of the COSY and NOESY correlation from H_a to H_b and from H_c to H_d and H_e, and the NOESY correlation from H_c to H_a and H_b, the connections among C3, C4, C3″ and C4″ can be described as shown.

These connections coincide with the TOCSY correlation from H_c to H_b and it precludes the structures **A** and **B**, because H_c cannot arise from a benzyl proton. Hence **5** is the only reasonable structure which is consistent with all spectral data.

Based on the TOCSY correlation from H_f to H12′ (δ 1.19), it was deduced that C2′ (δ 77.00) is adjacent to the olefinic link. Similarly, from the TOCSY correlation from H_a to H11 (δ 1.53) and H12 (δ 1.26), it can be deduced that C3 is close to C2. It is also seem likely that C2″ is adjacent to C3″.

The DEPT spectrum showed that these unsaturated CH groups give ^{13}C signals at δ 126.24, 113.32, 111.54, 107.35, 101.55, 101.32 and 101.19. From the HSQC correlation δ 126.24 to olefinic proton H_f, the signal at δ 126.24 was assigned to the olefinic carbon C3′. Based on the empirical formula[11] for ^{13}C chemical shifts in substituted benzenes, the signals at δ 113.32, 107.35 and 111.54 were assigned to C5, C5′ and C5″ and the signals at δ 101.32, 101.55 and 101.19 were assigned to C8, C8′ and C8″, respectively. The differences among C5, C5′ and C5″ are due to their adjacent groups (CH, —C=CH— and CH_2, respectively). Additionally, empirical estimates for the chemical, shifts indicate that C5 is at highest frequency (δ 113.32), C5′ is at lowest frequency (δ 111.54) and the middle one is C5″ (δ 107.35). The TOCSY correlation from H5 to H8 and from H5′ to H8′

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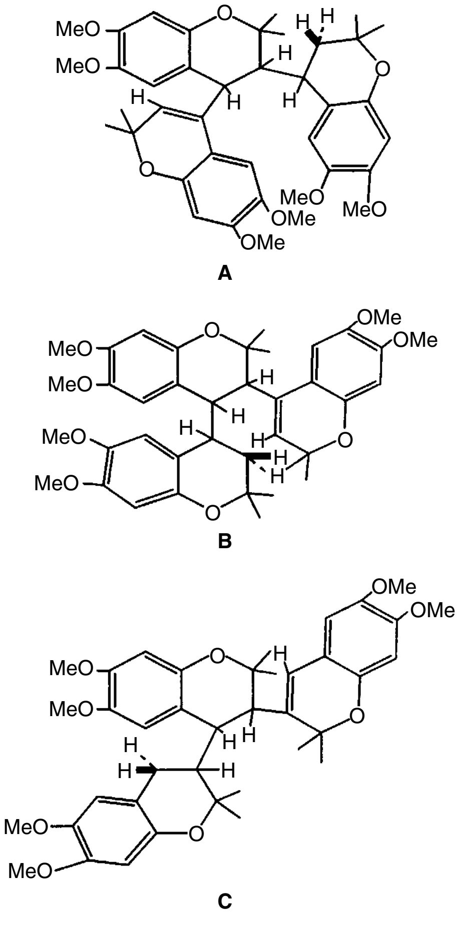
Table 1. ^{13}C and ^{1}H NMR spectral data for **5**

Position	^{13}C	^{1}H	Position	^{13}C	^{1}H	Position	^{13}C	^{1}H
2	76.19		2′	77.00		2″	75.34	
3	47.56	3.17 (1H, d, 8.8, Ha)	3′	126.24	5.38 (1H, s, Hf)	3″	43.49	2.02 (1H, br, Hc)
4	40.63	3.40 (1H, d, 8.8, Hb)	4′	133.01		4″	24.13	2.73 (1H, dd, 8.4, Hd) 2.50 (1H, dd, 4, He)
5	113.32	6.90 (1H, s)	5′	107.35	6.87 (1H, s)	5″	111.54	6.29 (1H, s)
6	142.35		6′	142.98		6″	142.98	
7	147.51		7′	147.95		7″	146.51	
8	101.32	6.34 (1H, s)	8′	101.55	6.47 (1H, s)	8″	101.19	6.29 (1H, s)
9	148.13		9′	148.13		9″	149.93	
10	115.50		10′	112.19		10″	113.42	
11	26.08	1.54 (3H, s)	11′	28.81	1.29 (3H, s)	11″	26.92	1.38 (3H, s)
12	28.50	1.26 (3H, m)	12′	21.46	1.19 (3H, s)	12″	27.47	1.43 (3H, s)
13	55.84	3.61 (3H, s)	13′	55.61	3.86 (3H, s)	13″	56.18	3.70 (3H, s)
14	55.71	3.77 (3H, s)	14′	56.90	3.86 (3H, s)	14″	55.71	3.79 (3H, s)



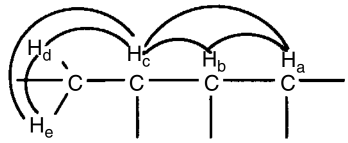
Scheme 2

showed that C5 and C8, C5′ and C8′, and C5″ and C8″ are in three different aromatic rings. The signals at δ 101.32, 101.55 and 101.19 were assigned to C8, C8′ and C8″, respectively.

The chemical shifts of C10, C10′ and C10″ should be at the lowest frequency among all aromatic quaternary carbon atoms. The DEPT spectrum and empirical chemical shift showed that the signals at δ 115.50, 112.19 and 113.42 corresponded to C10. C10′ and C10″, respectively.

The HMBC correlation from C4′ to H_f, H5′ and H_a showed that this signal at δ 133.01 arises from C4′. From the empirical chemical shifts of C6, C6′ and C6″, and the HMBC correlation, the C6, C6′ and C6″ resonances were assigned.

Based on the DEPT spectrum and the HMBC correlation from C to H and the estimated chemical shifts of C7, C7′ and C7″ from the empirical formula,[11] these signals at δ 147.51, 147.95 and 146.51 are attributed to C7, C7′ and C7″, respectively. In the same way, it was deduced that C9, C9′ and C9″ correspond to the signals at δ 148.13, 148.13 and 149.93, respectively.



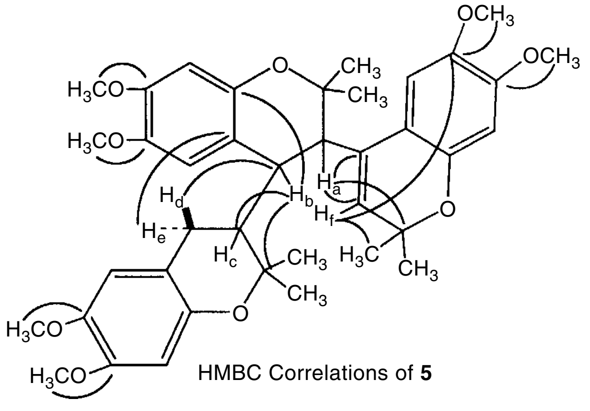
EXPERIMENTAL

Melting-points were determined on a Kofler melting-point apparatus and are uncorrected. Elemental analyses were carried out on a Yanaco CHN Corder MT-3 analyzer. IR spectra were obtained in KBr discs on a Nicolet FT-IR 170SX spectrometer. Mass spectra were measured on an HP-5988A spectrometer (EI at 70 eV). ^{1}H NMR spectra ($CDCl_3$) were recorded on a JEOL FX-200X, spectrometer: ^{13}C and all two-dimensional NMR spectra were recorded on a Bruker-DRX400, instrument in 5 mm tubes at room temperature, with TMS as an internal standard at a concentration of 40 mg ml^{-1}. The pulse conditions were pulse width H 10 μs and C 14 μs, flip angle 90°, recycling delay (RD), 1.5 s and number of data points 219.

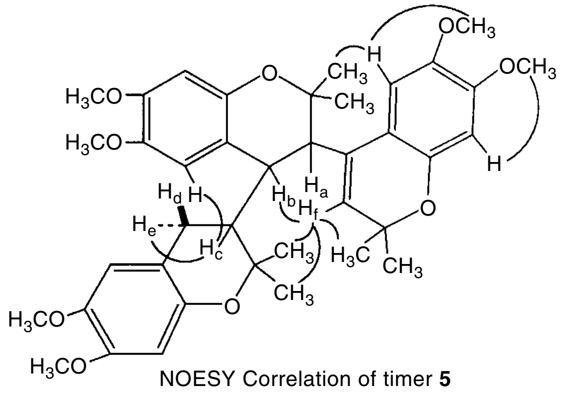
Reaction of ageratochromene II with anhydrous aluminum chloride

A mixture of ageratochromene II (2.2 g) and anhydrous aluminum chloride (4 g) in untreated diethyl ether (50 ml) was stirred at −5 °C for 15–20 min. The reaction mixture was diluted with 50 ml of ice–water and filtered, and the water layer was extracted with diethyl ether (3 × 50 ml). The organic layer was collected, washed well with brine, dried with anhydrous sodium sulfate and chromatographed on silica gel using light petroleum–diethyl ether (4 : 1 to 1 : 1) as eluent. Pure dimers **3** and **4** were obtained by recrystallization from methanol and pure trimer **5** was obtained by recrystallization from light petroleum–diethyl ether (2 : 1).

Dimer **3**, m.p. 155 °C (lit.,[5] 154 °C); yield, 12%; ^{1}H NMR ($CDCl_3$–TMS, 200 MHz), δ 1.24, 1.34, 1.40 and 1.49 (s, each 3H,



HMBC Correlations of **5**



NOESY Correlation of timer **5**

CH_3), 1.85 (m, 2H, 3-H), 3.48–3.60, (t, 1H, $J = 7$ Hz, 4-H), 3.75, 3.77 and 3.90 (s, each 3H, MeO), 6.00 (s, 1H, 4′-H), 6.36, 6.39 and 6.41 (s, each 1H, ArH).

Dimer **4**, m.p. 203–204 °C (lit.,[5] 198–199 °C); yield, 72%; ^{1}H NMR ($CDCl_3$–TMS, 200 MHz), δ 1.24, 1.34, 1.40 and 1.47 (s, each 3H, CH_3), 1.3–1.6 (m, 1H, H_e), 2.10–2.28 (m, 2H, H_b and H_d), 3.08–3.20 (m, 1H, H_c), 4.45 (d, 1H, $J = 7$ Hz, H_a), 6.21, 6.34 and 7.28 (s, each 1H, ArH).

Trimer **5**, m.p. 88–89 °C; yield, 14%; (found, C 70.87, H 7.37; $C_{39}H_{48}O_9$ requires C 70.89, H 7.32%); MS (EI, 70 eV), 660 (M^+, 12), 645 (3), 440 (22), 439 (26), 425 (14), 409 (10), 383 (15), 323 (25), 260 (18), 259 (100), 221 (18), 219 (18), 212 (17), 207 (10), 205 (25), 195 (20), 167 (39); IR, 2920–2970, 1640, 1520, 1200, 1010 cm^{-1}.

REFERENCES

1. Bowers WS, Ohta T, Cleere JS, Marsella PA. *Science* 1976; **193**: 542.
2. Burt ME, Kuhr RJ, Bowers WS. *Pestic. Biochem. Physiol.* 1978; **9**: 300.
3. Kasturi TR, Thomas M, Abraham EM. *Indian J. Chem.* 1973; **11**: 91.
4. Kasturi TR, Abraham EM. *Tetrahedron Lett.* 1967; **27**: 2573.
5. Kasturi TR, Abraham EM, Brown P. *J. Chem. Soc., Perkin Trans. 1* 1973; 2468.
6. Fraga BM, Garcia VP, Gonzalez AG, Hernandez MG, Hanson JR, Hitchcock PB. *J. Chem. Soc., Perkin Trans. 1* 1983; **1**(11): 2687.
7. Fraga BM, Garcia VP. *J. Chem. Res. (S)* 1986; **3**: 94.
8. Fraga BM, Garcia VP. *J. Org. Chem.* 1987; **52**: 5032.
9. Fraga BM, Cabrea I, Garcia VP. *Heterocycles* 1999; **51**: 2747.
10. Vyas AV, Mulchandani NB. *J. Chem. Res. (S)* 1987; **4**: 98.
11. Hu JH. *Nuclear Magnetic Resonance Spectroscopy*. Hydrocarbon Processing Press: Beijing, China, 1988; 65–68 (in Chinese).