NOTE

Electrochemical Behavior of 5,5'-Biguaiazulene-3,3' (5*H*,5'*H*)-dione and Its Four Unique Autoxidation Products

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Abstract : The redox potentials of 5,5'-biguaiazulene-3,3' (5*H*,5'*H*)-dione (a dimer of the monomeric 3-guaiazulenedione radical) and its four unique autoxidation products were determined by cyclic voltammetry for a comparative study. The electrochemical behavior of these compounds is discussed.

Key words : redox potential, cyclic voltammetry, biguaiazulenedione, guaiazulenequinones, 6-formylindene

1 Introduction

5,5'-Biguaiazulene-3,3' (5*H*,5'*H*)-dione (**1**, biguaiazulenedione) obtained exclusively by the peracid oxidation of guaiazulene in hexane has been found to be a highly important key intermediate for the various autoxidation products of guaiazulene^{1)~3)}. For example, autoxidation of **1** in pyridine at 25°C provides as high as 46 % yield of 3,5-guaiazulenedione (**2**, guaiazulenequinone)²⁾, along with 2,2'-bi(3,5-guaiazulenedione) (**3**, biguaiazulenequinone) (1.0 %)^{3),4)}, whereas autoxidation of **1** in CHCl₃ (or CH₂Cl₂) at 25°C affords 5-isopropylidene-3,8-dimethyl-1(5*H*)-azulenone (**4**, guaiazulenequinonemethide) as a major product (~30 % yield)^{1),3)}. When crystals of **4** were allowed to stand at room temperature (25°C) for a week, they were converted almost quantitatively into 6-formyl-3,7-dimethyl-1*H*-inden-1-one (**5**, 95

Structural Formulas 1

% yield)^{3),5)~7)}. The primary autoxidation step of **1** was presumed to be an equilibration, in organic solvents, of biguaiazulenone **1** with the monomeric 3-guaiazulenone radical **1a**, from which various types of the autoxidation products are derived. This is because, on setting aside a CHCl_3 (or CH_2Cl_2) solution of biguaiazulenone **1** at 25°C under anaerobic conditions, a well-resolved, hyperfine ESR spectrum became observable^{1),8)}. Moreover, the reactions of **1** with several radical trapping reagents also quantitatively gave the corresponding 3-guaiazulenone derivatives⁹⁾. We wish to report herein on the electrochemical behavior of this unique biguaiazulenone **1** and its structurally interesting autoxidation products **2~5** having a conjugate, fused-cyclopentenone system for a comparative study of their redox potentials (stabilities) by the use of cyclic voltammetry (CV).

2 Results and Discussion

Biguaiazulenone **1** is insoluble in CH_3CN , a generally used solvent for CV measurements. Thus, the CV of **1** was conducted in CH_2Cl_2 ¹⁰⁾. The cyclic voltammogram showed one irreversible reduction at -1.55 V (see Fig. 1). An electron transfer mechanism for **1** is illustrated in Scheme 1: the monomeric 3-guaiazulenone radical **1a**, derived from **1** in an equilibrium, undergoes one electron reduction, giving the hitherto unisolated guaiazulene-3-oxido anion **1b**. This anion is presumed to be highly unstable and thus shows an irreversible voltammogram, since 3-hydroxyguaiazulene has been shown¹¹⁾ too unstable to be isolated as a pure form at room temperature.

The reduction potentials of the autoxidation products **2~5** were then measured and the values are summarized in Table-1.

Guaiazulenequinones **2** and **3** give relatively stable di- and tetra-anions **2c** and **3c**, respectively, by stepwise reductions, whereas quinonemethide **4** and its rearranged product **5** afford unstable radical anions **4a** and **5a**, which do not undergo further reductions to dianions but decompose, as shown in their electron transfer mechanisms (Scheme-2). It should be noted that the reduction potential of the dimer **1** has been found appreciably higher than those of **2~5**. This is most likely because 3-guaiazulenone radical **1a** derived from **1** is

Fig. 1 Cyclic Voltammogram of **1** Showing One Irreversible Reduction at -1.55 V .
Conditions: E/V vs SCE, $0.1\text{ mol}\cdot\text{dm}^{-3}\text{ n-Bu}_4\text{NBF}_4$ in CH_2Cl_2 , Pt wire electrodes, Scan rate 100 mV/s , at 25°C .

Scheme 1 One Irreversible Electron Transfer Mechanism with Biguaiazulenone **1**.

Table 1 Reduction Potentials of 1, 2, 3, 4, and 5 Obtained by Cyclic Voltammetry^{a)}.

Compound	Reduction potentials (E/V)		
	E_1	E_2	$E_{3,4}$
1b),d),g)	-1.55 (-1.40) ^{h)}		
2c),e),g)	-1.14 (-1.13) ¹²⁾	-1.53 (-1.52) ¹²⁾	
3c),f),g)	-1.02 ⁴⁾	-1.18 ⁴⁾	-1.47 ⁴⁾
4c),d),g)	-1.13		
5c),d),g)	-1.08		

a) Conditions : E/V vs SCE, Pt wire electrodes, Scan rate 100 mV/s, at 25°C.

b) In CH₂Cl₂ with 0.1 mol·dm⁻³ n-Bt₄NBF₄.

c) In CH₃CN with 0.1 mol·dm⁻³ Et₄NClO₄.

d) One irreversible electron transfer.

e) Two reversible electrons transfer.

f) Four reversible electrons transfer.

g) No oxidation potential was observed between 0 and +2.0 V.

h) A conjectural value in CH₃CN (see Ref. 10).

Scheme 2 Electron Transfer Mechanisms with 2, 3, 4, and 5.

much less susceptible to reduction compared with the other related neutral species 2~5, which turn out to possess similar, first reduction potentials (E_1).

On the other hand, the EI mass fragmentations of 1 determined in detail with a B/E constant linked scan method¹³⁾ and the exact mass of each fragment ion peak has shown that the primary step occurs by one electron oxidation of equilibrated 1a to give 3-guaiazulenone cation (m/z 213), which is then quantitatively converted into guaiazulenequinonemethide cation-radical (m/z 212) and 3-hydroxyguaiazulene cation-radical (m/z 214) by disproportionation as illustrated in **Scheme 3**. It is noteworthy that the EI mass fragmentations of 1¹³⁾ follow pathways similar to the autooxidation mechanisms of 1¹³⁾.

Electrochemical reactions of biguaiazulene 1 under various conditions to induce a specific product are currently under intensive investigation.

Scheme 3 Possible EI Mass Fragmentations from 1. Conditions: Direct injection method, Accelerating voltage 5000 V, Electron energy 70 eV, Ion source temperature 200°C, Ionization current 300 μ A. () : Intensity of the fragment ion peak.

3 Experimental

3.1 Materials

5,5'-Biguaiazulene-3,3' (5*H*,5'*H*)-dione (1)¹⁾, 3,5-guaiazulenedione (2)²⁾, 2,2'-bi (3,5-guaiazulenedione) (3)³⁾, 5-isopropylidene-3,8-dimethyl-1(5*H*)-azulenone (4)¹⁾, and 6-formyl-3,7-dimethyl-1*H*-inden-1-one (5)³⁾ were prepared from guaiazulene¹⁴⁾ by the author's methods.

3.2 The CV (cyclic voltammetry) measurements of compounds 1~5

The CV measurements of compounds 1~5 were performed by Dr. Takanori Suzuki (Tohoku Univ.) ; see the measurement conditions summarized in Table 1.

3.3 The EI mass measurements of compound 1

The EI-MS spectra of compound 1 were taken on JEOL JMS-HX 100 (with a JEOL JMA-DA 5000 mass data system) high-resolution instrument, and given in terms of *m/z* (relative intensity) compared with the base peak¹³⁾ ; see the measurement conditions summarized in Scheme 3.

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- 6) Compound 5 is more stable than 1*H*-inden-1-one 6, which has not been isolated at room tempera-

ture under aerobic conditions, because **6** possesses a $4n\pi$ ($n=2$) system. The electron affinity (corresponding to π -LUMO in relation to redox potential) and ionization potential (corresponding to π -HOMO) for **6** were calculated to be -1.07 and -9.50 eV, respectively, by the MNDO-PM3 method [kindly performed by Dr. Tomoaki Endo (Sumitomo Chemical Co. Ltd.)]; the detailed data will be reported elsewhere.

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Structural Formula 2

- 7) Anticarcinogenic activity of **5** against P388 : ID₅₀ values ($\mu\text{g/mL}$) obtained by *in vitro* screening was approximately 1/50 that of adriamycin (kindly measured by Sumitomo Pharmaceutical Co. Ltd.)⁹⁾. In the case of guaiazulenequinone **2**, it was approximately 1/10 that of adriamycin : Y. Matsubara, *J. Synth. Org. Chem. Jpn.*, **50**, 963 (1992) ; the detailed data will be reported elsewhere.
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- 9) Unpublished results.
- 10) For a comparative purpose, the oxidation potentials (at 25°C with CV) using ferrocene as a standard material showed $+0.38$ V in CH_3CN with 0.1 M- Et_4NClO_4 and $+0.53$ V in CH_2Cl_2 with 0.1 M- $n\text{-Bu}_4\text{NBF}_4$, indicating that the value in CH_2Cl_2 shifts $+0.15$ V from that in CH_3CN .
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- 13) **1** : EI-MS m/z 214 ($[\text{M}/2+\text{H}]^{+\bullet}$, 87 %), 213 ($[\text{M}/2]^+$, 100), 212 ($[\text{M}/2-\text{H}]^{+\bullet}$, 74), 199 (67), 197 (89), 183 (22), 171 (50), 165 (11), 155 (33), 153 (22), 143 (27), 141 (28), 128 (33), 115 (26), 91 (10), 77 (11), 63 (6), 51 (6), 39 (6), 28 (4), and 18 (11). The molecular ion peak ($\text{M}^{+\bullet}$) of **1** was not observed, although its $[\text{M}+\text{H}]^+$ ion peak was shown by the FAB-MS spectroscopy¹⁾.
- 14) We are grateful to Konan Kako Co. (Osaka) for a generous gift of guaiazulene.

[報文] 各種微生物リパーゼのエステル化反応における脂肪酸選択性

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四種類の微生物リパーゼの脂肪酸選択性を種々の脂肪酸とグリセリンのエステル化反応において検討した。リパーゼOF(*Candida cylindracea*起源), リポザイム(*Mucor miehei*起源), リパーゼF(*Rhizopus* sp. 起源)およびリパーゼM(*Mucor javanicus*起源)は以下の脂肪酸選択性を示すことが判明した。ステアリン酸, オレイン酸, リノール酸およびリノレン酸の炭素数18の脂肪酸に対し, リパーゼOF, リポザイムおよびリパーゼFは $C_{18:1} \geq C_{18:2} \geq C_{18:3} > C_{18:0}$ の順にエステル化しやすい傾向を示したが, リパーゼMは $C_{18:3} \geq C_{18:2} \geq C_{18:1} > C_{18:0}$ の傾向を有していた。

また, リパーゼOFは長鎖の飽和脂肪酸より中鎖の脂肪酸を優先的に, すなわち $C_{12:0} > C_{14:0} > C_{16:0} > C_{18:0}$ の順に, グリセリンに組み込む傾向を有していたが, リポザイムはこれらの飽和脂肪酸に対する選択性は示さなかった。

イコサペンタエン酸(EPA, $C_{20:5}$)やドコサヘキサエン酸(DHA, $C_{22:6}$)のような高度不飽和脂肪酸に対し, 使用したいずれのリパーゼも $C_{18:1}$ と比較して, 特にDHAをグリセリンに組み込み難かったが, リパーゼMを用いた場合のみはDHAが比較的高い割合でグリセリンとエステル化されることが判明した。

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[ノート] 食用キノコ7種の主なセブレロシドの同定

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マイタケ(*Glifola frondosa*)子実体から主要な糖脂質としてセブレロシドを分離し, その代表的な構成セラミド種をN-hydroxypalmitoyl-9-methyl-trans-4, trans-8-sphingadienineと特徴づけた。このタイプのセブレロシドは, *G. frondosa*菌糸体ならびに他の6種の担子菌子実体中にも主要分子種として存在していた。また, 担子菌セブレロシドの構成スフィンゴイド塩基として, 微量ながら C_{18} , C_{19} および C_{20} の飽和直鎖のトリヒドロキシ塩基ならびにトランス-4-スフィンゲニンとトランス-4, トランス-8-スフィンガジエニンの存在も確認された。

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[ノート] 5, 5'-ビグアイアズレン-3, 3' (5H, 5'H)-ジオンの電気化学的挙動とその4種の特異な自動酸化生成物

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5, 5'-ビグアイアズレン-3, 3' (5H, 5'H)-ジオン(3-グアイアズレノンラジカルの二量体)とその4種の特異な自動酸化生成物の酸化還元電位について, サイクリックボルタンメトリー(CV)を用いて比較検討した。これらの化合物の電気的挙動について述べる。

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