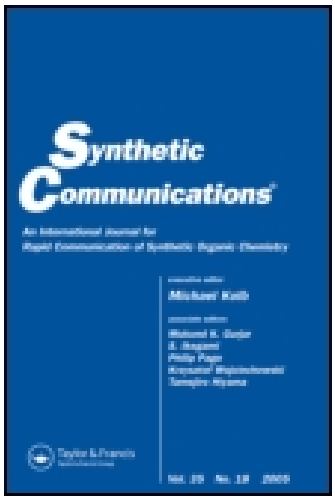

Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

THE DDQ MEDIATED CYCLIZATION PRODUCTS OF SOME 2-HYDROXY-3-(1′-ALKENYL)-1,4-NAPHTHOQUINONES

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Published online: 16 Aug 2006.

To cite this article: Farouk Ameer , Robin G. F. Giles , Ivan R. Green & Kyatanahalli S. Nagabhushana (2002) THE DDQ MEDIATED CYCLIZATION PRODUCTS OF SOME 2-HYDROXY-3-(1′-ALKENYL)-1,4-NAPHTHOQUINONES, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 32:3, 369-380

To link to this article: http://dx.doi.org/10.1081/SCC-120002120

SYNTHETIC COMMUNICATIONS, 32(3), 369–380 (2002)

THE DDQ MEDIATED CYCLIZATION PRODUCTS OF SOME 2-HYDROXY-3-(1′-ALKENYL)-1,4-NAPHTHOQUINONES

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ABSTRACT

The DDQ mediated cyclisation products derived from 2-hydroxy-3-(1′-alkenyl)-1,4-napthoquinones viz. 17 were found to be temperature dependent. At 60°C the naphthofuranquinone 19 was the predominant isomer whereas at 8°C, the naphthopyranquinone 18 was exclusively formed.

The synthesis of alkenylnaphthoquinones has been undertaken to study both their medicinal properties[1] as well as their potential as starting materials for naturally occurring biologically active compounds.[2,3] In our previous preparation of the 1′-hexenyl-1,4-naphthoquinone **17** we established the best conditions for its synthesis.[4] The prime aim of the exercise

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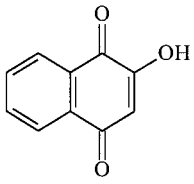
was to develop a methodology in which an aliphatic aldehyde can be condensed with 2-hydroxy-1,4-naphthoquinone **1** under basic conditions to form molecules that could be transformed into naphthopyrans having similar structural features to the biologically active erythrostominone **2**.[5,9]

In this paper, the condensation between acid labile aldehydes and lawsone **1** as well as the consequent cyclisation products formed upon treatment of these products with dichlorodicyanobenzoquinone (DDQ) will be presented.



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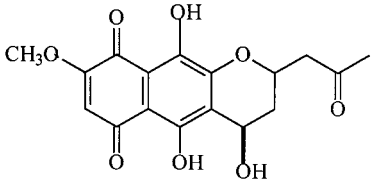

2

Transformation of the six-carbon ketoester **3** into the corresponding dioxolan **4** was accomplished in 91% yield by heating in benzene under reflux in the presence of ethylene glycol and para-toluenesulphonic acid.[6] Reduction of ester **4** to the corresponding alcohol **5** was effected with lithium aluminium hydride in ether at 0°C in a yield of 97%. Finally, oxidation of alcohol **5** to the desired aldehyde **6** was achieved by the use of pyridinium chlorochromate in a yield of 61%. In the same way the five-carbon keto-ester **7** was transformed into the dioxolane **8** (89%), then into the alcohol **9** and finally into the odoriferous aldehyde **10** (65%) (Scheme 1).

Condensation between lawsone **1** and aldehyde **6** in acetonitrile at 75°C in the presence of triethylamine lead to the isolation of the desired alkenyl condensation product **11** in 56% yield after flash chromatography. It was found that prolonged exposure of the reaction mixture to column chromatography lead to a lower yield and the recovery of 2–3% of the deprotected ketone **12**. The *trans* configuration of the double bond in quinone **11** is clearly evident from the ^{1}H-n.m.r. spectrum. Evidence supporting the assignment of structure **12** to the fraction isolated after longer column exposure is also found in the ^{1}H-n.m.r. spectrum which shows a deshielding effect for the CH_3 from 1.36 ppm in **11** to 2.19 ppm for **12** as well as the disappearance of the O-CH_2-CH_2-O signal at 3.97 ppm in **11**. Similar condensation between lawsone **1** and aldehyde **10** afforded, after flash chromatography, the desired quinone **14** in 60% yield.

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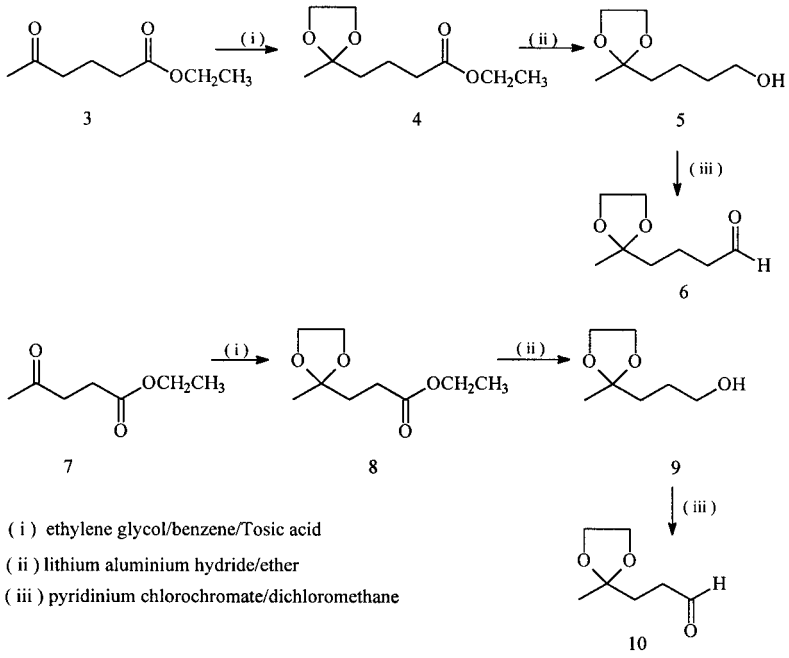

Scheme 1.

Again the ^{1}H-n.m.r. spectrum clearly demonstrated the *trans* nature of the double bond.

Previously, it has been shown that base catalysed condensations between lawsone **1** and aldehydes lead to 2-hydroxy-3-(1′-alkenyl)-1,4-naphthoquinones but in addition on array of naphthopyran products were also isolated.[4,7] The effectiveness of using DDQ to catalyse the cyclisation of 2-hydroxy-3-(1′-alkenyl)-1,4-naphthoquinones had been demonstrated earlier[8] and this prompted us to apply similar reaction conditions to the systems we had in hand.

A mixture of quinone **17**[4] and 1.2 mol equivalents of DDQ in benzene was heated at 60°C for 2 h to afford two products. The major isomer (70%) was assigned the naphthofuranquinone structure **19** whilst the desired minor product (5%) was assigned the dehydronaphthopyranquinone structure **18**. Assignment of structure **19** to the major isomer is based on the ^{1}H-n.m.r. spectrum which showed a singlet at 6.61 ppm for 3-H as the only olefinic proton, a triplet at 2.81 ppm with J 7.0 Hz, for 1′-H of the butano side chain and for aliphatic C signals at 13.7, 22.2, 28.1 and 29.5 ppm in the ^{13}C-n.m.r. spectrum. On the other hand assignment of structure **18** to the

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minor isomer is also based on the ^{1}H-n.m.r. spectrum which shows a multiplet at 5.19 ppm for 2-H. A COSY spectrum clearly demonstrated coupling between 2-H and 3-, 4- and the 1′-H. A doublet of a doublet at 5.80 ppm with *J* 10.2 and 3.8 Hz is assigned to 3-H while a doublet of a doublet at 6.71 ppm with *J* 10.2 and 1.4 Hz is assigned to 4-H. In the ^{13}C-n.m.r. spectrum only three aliphatic signals are observed at 13.8, 17.4 and 37.7 ppm.

Repeating the reaction at 25°C lead to the formation of the naphthofuranquinone **19** in 43% yield and the dehydronaphthopyranquinone **18** in 42% yield but with a time period of 18 h. By lowering the temperature to 7–8°C and extending the stirring period to 36 h, the sole product isolated was the desired naphthopyranquinone **18** in 78% yield. It may be speculated that thermodynamic factors are of greater significance than kinetic ones at this temperature.

Treatment of the alkenyl quinone **14** with 1.2 mol equivalent of DDQ in benzene at 60°C for 2.5 h followed by very careful chromatographic separation afforded two products. The major product has been assigned the naphthofuranquinone structure **15** (54%) and the minor product has been assigned the dehydronaphthopyranquinone structure **16** (24%). The ^{1}H-n.m.r. spectrum of quinone **15** exhibited three well defined single peaks *viz*., a 3-proton peak at 1.43 ppm, a 2-proton peak at 3.16 and a 1-proton peak at 6.80 ppm assigned to 3′-, 1′- and the olefinic 3-H respectively. On the other hand the ^{1}H-n.m.r. spectrum of quinone **16** showed a doublet of a doublet at 5.08 ppm with *J* 3.6 and 1.8 Hz assigned to 2-H, a doublet of a doublet at 5.87 ppm with *J* 10.4 and 3.6 Hz, assigned to 3-H and a doublet of a doublet at 6.82 ppm with *J* 10.4 and 1.8 Hz, assigned to 4-H of the dehydropyran ring.

Repeating the reaction at lower temperatures *viz*., 25 and 8°C and stirring for longer times resulted in an improved relative yield of the dehydronaphthopyranquinone **16**. However, the best relative yields were obtained at 8°C where the isolated ratio of quinones **15**:**16** was 38:32. The near proximity of the dioxolane ring to the tricyclic ring system may have an effect on the relative ratio.

Finally, treatment of the alkenylquinone **11** with 1.2 mol equivalents of DDQ in benzene at 25°C for 12 h yielded a single product in 68% yield to which structure **13** has been assigned. In the ^{1}H-n.m.r. spectrum a multiplet at 5.37 ppm is assigned to 2-H on the basis that a COSY spectrum shows coupling to 3-, 4- and 1′-H. In addition a doublet of a doublet at 5.90 ppm with *J* 10.0 and 3.8 Hz is assigned to 3-H while a doublet of a doublet at 6.69 ppm with *J* 10.0 and 1.6 Hz is assigned to 4-H of the dehydropyran ring. An interesting observation was made in that the signals of the two enantiotopic 1′-hydrogens appear as a doublet of a

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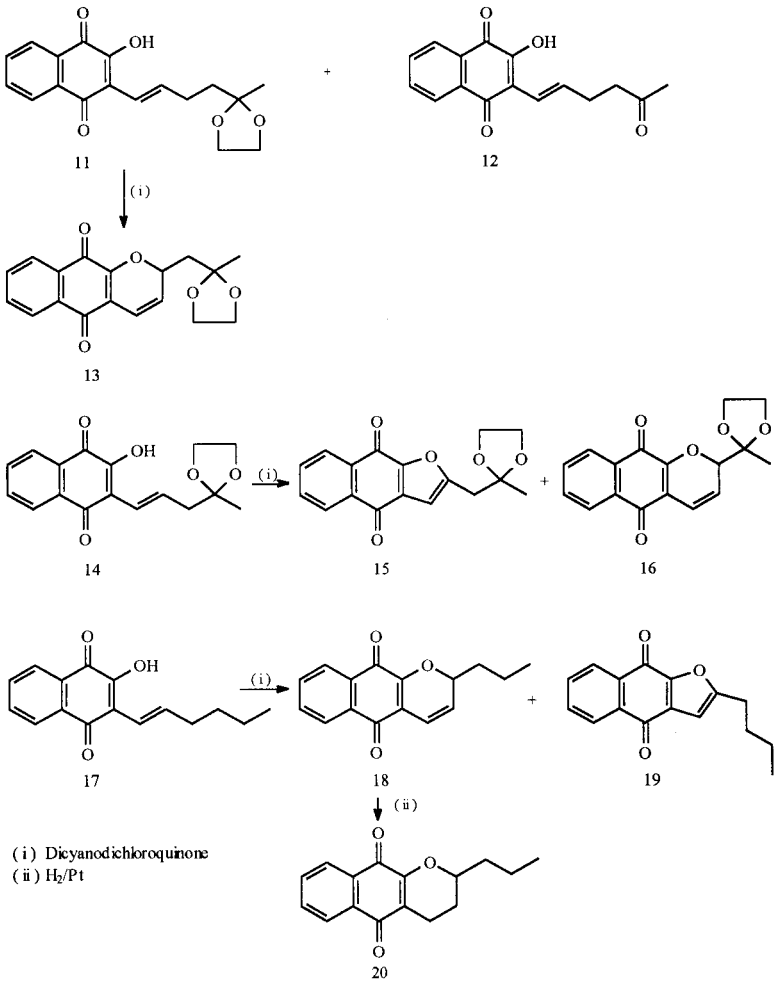

Scheme 2.

doublet at 2.05 ppm with J 14.80 and 6.0 Hz and 2.37 ppm with J 14.80 and 6.8 Hz.

Repeating the reaction at 60°C for 2 h in benzene afforded the same dehydronaphthopyranquinone **13** in 60% yield. In this case t.l.c did show a very minor fraction running just ahead of the product. However, the quantity was so insignificant that it was not pursued further.

The ease with which the double bond of the dehydropyran ring can be reduced was demonstrated by the quantitative catalytic hydrogenation of

dehydronaphthopyranquinone **18** into the corresponding naphthopyranquinone **20**.

Thus a new strategy has been developed for the synthesis of intermediates *viz*., **13**, **16**, and **20** which can be transformed into trideoxyerythrostominone analogues[9] to be used for biological evaluations currently being investigated in our laboratories.

EXPERIMENTAL

^{1}H- and ^{13}C-n.m.r. spectra were recorded using a Varian 200 MHz instrument at 20°C in deutereochloroform. Infrared spectra were measured as Nujol mulls unless otherwise stated and recorded on a Perkin Elmer FT-IR 1000 pc spectrometer. Melting points were recorded on a Fischer-John apparatus and are uncorrected. C and H analyses were performed on a Carlo Erba NA 1500 Nitrogen analyser and GC-MS were performed on a Finnigan-Matt GCQ instrument. Column chromatography was carried out using Merck Kielselgel 60 (35–230 mesh) as dry columns. Hexane refers to that fraction boiling between 60–75°C. Residue obtained upon workup refers to the material obtained from the dried ($MgSO_4$) organic extract after filtration and removal of solvent.

Ethyl 5-Dioxolan Hexanoate 4[6]

As solution of benzene (400 mL), ethylene glycol (29.8 g; 0.480 mol) and *p*-toluene sulphonic acid (1.03 g; 5.4 mmol) were stirred and heated under reflux in a Dean-Stark apparatus to ensure all reagents were dry. To this mixture was added ethyl 4-acetyl butyrate **3** (50 g; 0.316 mol) and the resulting solution was stirred under reflux with water being removed *via* the Dean-Stark separator for 18 h. The cooled benzene layer was washed with saturated aqueous sodium hydrogen carbonate (150 ml) and then water (100 mL). The residue obtained upon workup was distilled to afford the ester **4** (58 g; 91%) as a light olive-coloured oil, b.p. 98–102°C (1 mmHg); ν_{max} 1744 cm^{-1}; δ_H 1.25 (t, 3H, *J* 7.2 Hz, OCH_2CH_3), (1.32 (s, 3H, 6-H), 1.73–1.68 (m, 4H, 3- and 4-H), 2.32 (t, 2H, *J* 7.2 Hz, 2-H), 3.93 (sharp m, 4H, OCH_2CH_2O), 4.12 (q, *J* 7.2 Hz, OCH_2CH_3), δ_C 14.2 (OCH_2CH_3), 19.6 (6-C), 23.7 (3-C), 34.3 (4-C), 38.3 (2-C), 60.3 (OCH_2CH_3), 64.6 (OCH_2CH_2O), 109.9 (5-C) and 173.7 (C=O). (Found: C, 59.2; H, 8.7%; M^+, 202. Calc. for $C_{10}H_{18}O_4$: C, 59.4; H. 8.9%; *M*, 202).

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5-Dioxolane Hexan-1-ol 5

To a slurry of lithium aluminium hydride (3.98 g; 0.105 mol) in dry ether (100 mL) at 0°C was added dropwise a solution of ester **4** (20.14 g; 0.099 mol) in dry ether (50 mL) over a period of 30 min. The resulting slurry was stirred at 25°C for a further 2 h after which time the reaction was quenched by the careful addition of saturated aqueous ammonium chloride. The residue obtained upon workup afforded the alcohol **5** as an oil (15.48 g; 97%); ν_{max} 3412 cm^{-1}; δ_H 1.31 (3H, s, 6-H), 1.60 (7H, m, 2-, 3-, 4-H and C-1 OH), 3.64 (2H, t, *J* 6.2 Hz, 1-H), and 3.93 (4H, sharp m, OCH_2CH_2O); δ_C 20.2 (6-C), 23.8 (3-C), 32.8 (4-C), 38.8 (2-C), 62.8 (1-C), 64.7 (OCH_2CH_2O), and 110.2 (5-C). (Found: C, 59.9; H, 10.1%; M^+, 160. Calc. for $C_8H_{16}O_3$: C, 60.0; H, 10.0%; *M*, 160).

5-Dioxolan Hexanol 6

To a stirred suspension of pyridinium chlorochromate (10.13 g; 47 mmol) in dichloromethane (50 mL) was added dropwise a solution of alcohol **5** (5.0 g; 31 mmol) in dichloromethane (20 mL) at 25°C and stirring was maintained at this temperature for an additional 3 h. Ether (100 mL) and magnesium sulphate (5 g) were added and the resultant slurry was vigorously stirred and then filtered through celite using additional ether as the wash solvent. The residue obtained was further purified by flash chromatography using hexane-ether (4 : 1) as eluent to afford hexanal **6** (3.0 g; 61%) as a mobile liquid, ν_{max} 1735 cm^{-1}; δ_H 1.32 (3H, s, 6-H), 1.72 (4H, m, 3- and 4-H), 2.47 (2H, dt, *J* 6.3 and 1.8 Hz, 2-H), and 3.94 (4H, sharp m, OCH_2CH_2O) and 9.77 (1H, t, *J* 1.8 Hz, 1-H); δ_C 16.7 (6-C), 23.8 (3-C), 38.3 (4-C), 43.9 (2-C), 64.8 (OCH_2CH_2O), 109.9 (5-C) and 202.7 (C=O). (Found: C, 60.6; H, 8.7%; M^+, 158. Calc. for $C_8H_{14}O_3$: C, 60.8; H, 8.9%; *M*, 158).

Ethyl 4-Dioxolan Pentanoate 8

By a similar methodology employed for the synthesis of dioxolane **4** the dioxolane **8** was obtained from ketoester **7** as an oil (89%), b.p. 87–91°C at 1 mmHg; ν_{max} 1744 cm^{-1}; δ_H 1.24 (3H, t, *J* 7.2 Hz, OCH_2CH_3), 1.21 (3H, s, 5-H), 2.01 (2H, t, *J* 8.0 Hz, 3-H), 2.38 (2H, t, *J* 8.0 Hz, 2-H), 3.93 (4H, sharp m, OCH_2CH_2O), and 4.12 (2H, q, *J* 7.2 Hz, OCH_2CH_3), δ_C 14.3 (OCH_2CH_3), 19.8 (5-C), 34.2 (3-C), 38.5 (2-C), 59.4 (OCH_2CH_3), 64.6 (OCH_2CH_2O), 109.4 (4-C) and 174.2 (C=O). (Found: C, 58.1; H, 8.8%; M^+, 188. Calc. for $C_9H_{16}O_4$: C, 57.45; H, 8.5%; *M*, 188).

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4-Dioxolan Pentan-1-ol 9

By a similar methodology employed for the synthesis of dioxolane **5** the alcohol **9** was obtained as an oil in 90% yield; ν_{max} 3420 cm^{-1}; δ_H 1.33 (3H, s, 5-H), 1.74 (4H, m, 2- and 3-H), 1.95 (1H, brs, 1-OH), D_2O exchangeable) 3.64 (2H, t, *J* 6.2 Hz, 1-H), and 3.96 (4H, sharp m, OCH_2CH_2O), δ_C 23.7 (5-C), 27.2 (3-C), 35.9 (2-C), 63.1 (1-C), 64.7 (OCH_2CH_2O) and 110.1 (4-C). (Found: C, 57.4; H, 9.5%; M^+, 146. Calc. for $C_7H_{14}O_3$: C, 57.5; H, 9.6%; *M*, 146).

4-Dioxolan Pentanal 10

By similar methodology employed for the synthesis of aldehyde **6** the pentanal **10** was obtained as an odoriferous oil in 65% yield; ν_{max} 1738 cm^{-1}; δ_H 1.33 (3H, s, 5-H), 2.07 (2H, t, *J* 7.0 Hz, 3-H), 2.47 (2H, dt, *J* 7.0 and 2.0 Hz, 2-H), 3.91 (4H, sharp m, OCH_2CH_2O), and 9.72 (1H, t, *J* 2.0 Hz, 1-H), δ_C 24.2 (5-C), 31.8 (3-C), 38.5 (2-C), 64.8 (OCH_2CH_2O), 109.2 (4-C) and 202.4 (1-C). Found: C, 58.4; H, 8.2%; M^+, 144. Calc. for $C_7H_{12}O_3$: C, 58.3; H, 8.3%; *M*, 144).

2-Hydroxy-3-(*E*-5′-dioxolano-1′-hexenyl)-1,4-naphthoquinone 11 and 2-Hydroxy-3-(*E*-5′-oxo-1′-hexenyl)-1,4-naphthoquinone 12

To solution of lawsone **1** (655 mg; 3.76 mmol) and aldehyde **6** (850 mg; 5.38 mmol) in acetonitrile (20 mL) was added triethylamine (1.51 g; 15 mmol) and the resulting ruby red solution was stirred at 75°C (oil bath) under nitrogen for 6 h. The cooled solution was diluted with ether (100 mL) and briefly washed with sulphuric acid (40 mL of a 1 M solution) and water (2 × 40 mL). The residue obtained upon workup was flash chromatographed using hexane–ethyl acetate (7 : 3) as eluent to yield the quinone **11** (662 mg; 56%) as yellow crystals, m.p. 114–116°C (from hexane), ν_{max} 3350 and 1646 cm^{-1}; δ_H 1.36 (3H, s, 6′-H), 1.86 (2H, m, 4′-H), 2.40 (2H, m, 3′-H), 6.64 (1H, dt, *J* 16.2 and 1.6 Hz, 1′-H), 7.08 (1H, dt, *J* 16.2 and 7.0 Hz, 2′-H), 7.70 (2H, m, 6- and 7-H), 7.77 (1H, s, D_2O exchangeable, 2-OH), and 8.30 (2H, m, 5- and 8-H). δ_C 24.1, 29.7, 38.3, 64.8 (x2), 109.9, 118.7, 118.8, 126.1, 127.2, 129.6, 133.2, 135.1, 143.5, 181.6 and 184.5. (Found: C, 68.9; H, 5.6%; M^+, 314. Calc. for $C_{18}H_{18}O_5$: C, 68.8; H, 5.7%; *M*, 314). Further slow elution of the column with the same solvent afforded the ketone **12** (24 mg; 24%) as dark brown crystals, m.p. 125–126°C (from hexane), ν_{max} 3344, 1723 and 1659 cm^{-1}; δ_H 2.19 (3H, s, 6′-H), 2.58–2.65 (4H, m, 4′- and

3′-H), 6.60 (1H, dt, *J* 16.3 and 1.6 Hz, 1′-H), 7.04 (1H, dt, *J* 16.3 and 7.1 Hz, 2′-H), 7.75 (2H, m, 6- and 7-H), 7.80 (1H, s, D_2O exchangeable, 2-OH), and 8.10 (2H, m, 5- and 8-H). δ_C 28.9, 30.1, 42.8, 118.3, 119.6, 126.2, 127.2, 129.5, 132.8, 133.3, 135.2, 141.5, 151.7, 181.6, 184.4 and 208.1. (Found: C, 71.0; H, 5.3%; M^+, 270. Calc. for $C_{16}H_{14}O_4$: C, 71.1; H, 5.2%; *M*, 270).

2-Hydroxy-3-(*E*-4′-dioxolano-1′-pentenyl)-1,4-naphthoquinone 14

To a solution of lawsone **1** (2.03 g; 11.7 mmol) and aldehyde **10** (2.4 g; 16.7 mmol) in acetonitrile (25 mL) was added triethylamine (4.72 g; 46.7 mmol) and the resulting ruby red solution was stirred at 75°C (oil bath) for 6 h under nitrogen. After similar workup as for quinone **11** and flash chromatography using hexane–ethyl acetate (7 : 3) as eluent the quinone **14** was isolated (2.11 g; 60%) as yellow crystals, m.p. 115–116°C (from hexane), ν_{max} 3471, 1672 and 1640 cm^{-1}; δ_H 1.39 (3H, s, 5′-H), 2.64 (2H, dd, *J* 7.4 and 1.4 Hz, 3′-H), 3.99 (4H, s, OCH_2CH_2O), 6.68 (1H, dt, *J* 16.4 and 1.4 Hz, 1′-H), 7.06 (1H, dt, *J* 16.4 and 7.4 Hz, 2′-H) 7.72 (2H, m, 6- and 7-H), 7.81 (1H, s, D_2O exchangeable, 2-O*H*), and 8.10 (2H, m, 5- and 8-H). δ_C 24.3, 45.0, 65.0 (×2*C*), 109.7, 118.4, 121.9, 126.1, 127.2, 129.6, 132.8, 133.3, 135.2, 138.0, 151.7, 181.6 and 184.3. (Found: C, 67.8; H, 5.5%; M^+, 300. Calc. for $C_{17}H_{16}O_5$: C, 68.0; H, 5.3%; *M*, 300).

2-Propyl-3,4-dehydronaphtho[2,3-*b*]pyran-5,10-dione 18 and 2-Butylnaphtho[2,3-*b*]furan-4,9-dione 19

To a solution of quinone **17**[4] (786 mg; 3.0 mmol) in benzene (40 mL) was added a solution of DDQ (820 mg; 3.6 mmol) in benzene (40 mL) and the resulting solution was stirred at 25°C for 18 h. The precipitated quinol was filtered and the filtrate evaporated and the residue obtained was chromatographed and eluted with hexane–ethyl acetate (7 : 3) to afford firstly the furanquinone **19** (327 mg; 43%) as yellow crystals, m.p. 102–103°C (from hexane), ν_{max} 1684 cm^{-1}; δ_H 0.95 (3H, t, *J* 7.0 Hz, 4′-H), 1.42 (2H, hextet, *J* 7.0 Hz, 3′-H), 1.75 (2H, pentet, *J* 7.0 Hz, 2′-H), 2.81 (2H, t, *J* 7.0 Hz, 1′-H), 6.61 (1H, s, 3-H), 7.74 (2H, m, 6- and 7-H), and 8.17 (2H, m, 5- and 8-H). δ_C 13.7, 22.2, 28.1, 29.5, 77.7, 104.3, 126.9, 127.0, 128.4, 132.0, 132.8, 133.7, 134.0, 165.1, 181.2 and 183.1. (Found: C, 75.4; H, 6.4%; M^+, 254. Calc. for $C_{16}H_{14}O_3$: C, 75.6; H, 6.3%; *M*, 254). Further very careful elution with the same solvent afforded the pyranquinone **18** (320 mg; 42%) as yellow crystals, m.p. 70–72°C (from hexane); ν_{max} 1672 and 1640 cm^{-1}; δ_H 0.96 (3H, t, *J* 7.2 Hz, 3′-H), 1.70 (4H, m, 1′- and 2′-H), 5.19 (1H, m, 2-H), 5.80 (1H, dd,

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J 10.2 and 3.8 Hz, 3-H), 6.71 (1H, dd, *J* 10.2 and 1.4 Hz, 4-H), 7.70 (2H, m, 7- and 8-H), and 8.09 (2H, m, 6- and 8-H). δ_C 13.8, 17.4, 37.7, 77.7, 117.0, 118.6, 126.2 (× 2), 126.3, 128.4, 131.5, 133.5, 134.0, 153.0, 179.7 and 181.8. (Found: C, 75.3; H, 6.4%; M^+, 254. Calc. for $C_{16}H_{14}O_3$: C, 75.6; H, 6.3%; *M*, 254).

2-Propylnaphtho[2,3-*b*]pyran-5,10-dione 20

The quinone **18** (30 mg; 0.12 mmol) in ethyl acetate (10 mL) containing Pd-C (10%) catalyst (5 mg) was hydrogenated for 2 h and the resulting solution passed through a short column to give the pyran **20** (30 mg; 100%) as yellow crystals, m.p. 61–63°C (from hexane); ν_{max} 1678 cm^{-1}; δ_H 0.99 (3H, t, *J* 6.8 Hz, 3′-H), 1.70 (6H, m, 1′-, 2′- and 3-H), 2.60 (2H, m, 4-H), 4.18 (1H, m, 2-H), 7.68 (2H, m, 7- and 8-H), and 8.07 (2H, m, 6- and 9-H). δ_C 14.1, 18.4, 18.6, 25.5, 29.8, 36.5, 78.0, 117.1, 121.4, 126.1, 126.4, 132.2, 133.6, 134.0, 155.6, 179.9 and 184.5. (Found: C, 75.3; H, 6.3%; M^+, 256. Calc. for $C_{16}H_{16}O_3$: C, 75.0; H, 6.25%; *M*, 256).

2-(2′-Dioxolanopropyl)-naphtho[2,3-*b*]furan-4,9-dione 15 and 2-(1′-Dioxolano-ethyl)-3,4-dehydronaphtho[2,3-*b*]pyran-5,10-dione 16

To solution of quinone **14** (1.06 g; 3.53 mmol) in benzene (40 mL) was added a solution of dichlorodicyanoquinone (962 mg; 4.24 mmol) in benzene (40 mL) and the mixture was stirred and heated at 60°C (oil bath) under nitrogen for 2.5 h. The cooled reaction mixture was filtered and the residue obtained after removal of the solvent was chromatographed and eluted with hexane–ethyl acetate (3 : 7) as eluent to afford the naphthofuranquinone **15** (568 mg; 54%) as orange crystals, m.p. 142–143°C (from hexane–ethyl acetate); ν_{max} 1666 and 1634 cm^{-1}; δ_H 1.43 (3H, s, 3′-H), 3.16 (2H, s, 1′-H), 3.97 (4H, m, OCH_2CH_2O), 6.80 (1H, s, 3-H), 7.73 (2H, m, 6- and 7-H), and 8.19 (2H, m, 5- and 8-H). δ_C 24.5, 38.4, 65.1 (x2), 107.0, 108.4, 126.4, 127.0, 127.1, 131.9, 132.7, 133.3, 133.7, 133.9, 159.7, 173.2 and 181.0. (Found: C, 68.6; H, 4.5%; M^+, 298. Calc. for $C_{17}H_{14}O_5$: C, 68.5; H, 4.7%; *M*, 298). Further elution with the same solvent afforded the naphthopyranquinone **16** (252 mg; 24%) as orange crystals, m.p. 124–126°C (from hexane–ethyl acetate); ν_{max} 1670 and 1640 cm^{-1}; δ_H 1.44 (3H, d, *J* 1.8 Hz, 2′-H), 4.00 (4H, m, OCH_2CH_2O), 5.08 (1H, dd, *J* 3.6 and 1.8 Hz), 2-H), 5.87 (1H, dd, *J* 10.4 and 3.6 Hz, 3-H), 6.82 (1H, dd, *J* 10.4 and 1.8 Hz), 4-H), 7.70 (2H, m, 7- and 8-H), 8.09 (1H, m, 6-H) and 8.19 (1H, m, 8-H). δ_C 20.6, 24.4,

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65.8, 66.3, 80.5, 109.9, 118.7, 122.7, 126.4, 127.1, 131.6, 131.9, 133.4, 134.2, 159, 179.3 and 181.9. (Found: C, 68.6; H, 4.6%; M^+, 298. Calc. for $C_{17}H_{14}O_5$: C, 68.5; H, 4.7%; *M*, 298).

2-(2′-Dioxolanopropyl)-3,4-dehydronaphtho[2,3-*b*]pyran-5,10-dione 13

To a solution of quinone **11** (1.12 g; 3.57 mmol) in benzene (40 mL) was added a solution of dichlorodicyanoquinone (972 mg; 4.28 mmol) in benzene (40 mL) and the resulting mixture was stirred under nitrogen at 25°C for 12 h and then filtered. Evaporation of the filtrate afforded a residue that was chromatographed using hexane–ethyl acetate (7 : 3) as eluent to given the naphthopyranquinone **13** (757 mg; 68%) as bright orange crystals, m.p. 115–116°C (from hexane); ν_{max} 1700 cm^{-1}; δ_H 1.42 (3H, s, 3′-H), 2.05 (1H, dd, *J* 14.8 and 6.0 Hz, 1′-H), 2.37 (1H, dd, *J* 14.8 and 6.8 Hz, 1′-H), 3.99 (4H, sharp m, OCH_2CH_2O), 5.37 (1H, m, 2-H), 5.90 (1H, dd, *J* 10.0 and 3.8 Hz, 3-H), 6.69 (1H, dd, *J* 10.0 and 1.6 Hz, 4-H), 7.70 (2H, m, 7- and 8-H) and 8.09 (2H, m, 6- and 8-H). δ_C 25.1, 44.3, 64.7, 64.8, 74.2, 108.2, 116.8, 119.2, 126.4, 126.5, 126.9, 131.6, 131.7, 133.4, 134.2, 152.8, 179.7 and 182.0. (Found: C, 69.3; H, 5.0%; M^+, 312. Calc. for $C_{18}H_{16}O_5$: C, 69.2; H, 5.1%; *M*, 312).

ACKNOWLEDGMENTS

We wish to thank the Council of the University of the Western Cape and the National Research Foundation for financial support and Mr. James Beukes for laboratory assistance.

REFERENCES

1. Papageoriou, V.P.; Assimopoulou, A.N.; Couladouros, E.A.; Hepworth, D.; Nicolaou, K.C. Angew. Chem. Int. Ed. **1999**, *38*, 270–300.
2. Aso, M.; Kanematsu, K. Chem. Pharm. Bull. **1993**, *41*(9), 1549–1556.
3. Ferreira, V.F.; Coutada, L.C.; Pinto, M.C.F.R.; Pinto, A.V. Synth. Commun. **1992**, *12*(3), 195–199.
4. Ameer, F.; Green, I.R.; Nagabhushana, K.S. Synth. Commun. **2001**, *31*(5), 719–724.
5. Cross, B.E.; Edinberry, M.N.; Turner, W.B. J. Chem. Soc. Perkin Trans. 1 **1973**, 380–390.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

6. Benchikh-Le-Hocine, M.; Do Khac. D.; Fetizon, M. Synth. Commun. **1992**, *22*, 1871.
7. Bock, K.; Jacobsen, N.; Terem, B. J. Chem. Soc. Perkin Trans. 1 **1986**, 659.
8. Giles, R.G.F.; Roos, G.H.P. J. Chem. Soc. Perkin Trans. 1 **1976**, 1632.
9. Giles, R.G.F.; Green, I.R.; Hugo, V.I.; Ireland, J.L. Synth. Commun. **1998**, *28*, 4589.

Received in the USA March 19, 2001

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