Synthesis of New Isoxazolylnaphthoquinones as Potential Trypanocidal and Antibacterial Agents†

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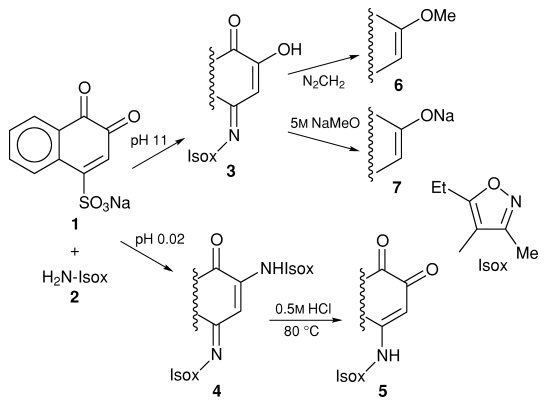
The synthesis of three new isoxazolylnaphthoquinones with an ethyl group on the isoxazole ring is reported.

Previous studies on the biological behavior of isoxazolylnaphthoquinones[1] have demonstrated that some members of the series exhibit important biological activity against the causative agent of Chagas' disease[1] and *Staphylococcus aureus*.[3] These compounds have poor solubility in organic solvents so we focused our synthetic efforts towards more lipophilic compounds. Here we describe the preparation of three new isoxazolylnaphthoquinones with an ethyl group on the isoxazole ring by condensing sodium 1,2-naphthoquinone-4-sulfonate **1** with 3-methyl-5-ethyl-4-aminoisoxazole **2** in aqueous solution (Scheme 1).



Scheme 1

The method proposed is relatively simple and versatile allowing, through variation of the pH of the medium, the reaction to be directed towards the formation of products with a variable degree of lipophilicity. In neutral and alkaline aqueous solutions, the reaction between **1** and **2** yielded 48 and 67% of 2-hydroxy-*N*-(3-methyl-5-ethylisoxazol-4-yl)-1,4-naphthoquinone-4-imine **3** respectively. The reaction between **1** and **2** in acidic aqueous solution gave 90% of the bisisoxazolylnaphthoquinone imine **4**. By hydrolysis with acidic aqueous solutions at 80 °C in EtOH, compound **4** was converted to the diketone derivative **5**, a tautomer of **3** in 99% yield. Reaction of **3** with ethereal diazomethane led to the *O*-methyl derivative **6**, whereas treatment of **5** with diazomethane led to no reaction. The IR spectrum of **3** (KBr) showed one absorption band at 3309 cm^{-1} (O–H) and one band at 1703 cm^{-1} (carbonyl of the quinone ring). The IR spectrum of **5** showed one absorption band at 3283 cm^{-1} (N–H) and two bands at 1689 and 1623 cm^{-1} (two carbonyl stretching vibrations of the quinone ring). The ^1H NMR spectrum of **5** in $CDCl_3$ gave no indication of a second tautomer (see Experimental). For enol **3** a complex ^1H NMR spectrum [δ_H ($CDCl_3$) 1.22–1.29 (t, CH_3), 2.19 (s, CH_3), 2.59–2.77 (m, CH_2), 5.58 (s, H^{3K}), 6.49 (s, H^{3E}), 7.25 (s, OH), 7.66–7.82 (m, $H^{5,6,7K}$, $H^{6,7E}$, 7.94 (br, NH), 8.16–8.22 (m, H^{8K}, H^{5E}), 8.53–8.56 (d, H^{8E}); E = enol, K = keto] indicated the presence of two forms (δ 5.58 for keto and δ 6.49 for enol), 40:60. When CF_3COOD was added to the $CDCl_3$ solution, the tautomeric equilibrium was shifted towards the keto structure: δ_H ($CDCl_3$–CF_3COOD) 1.34 (t, 3H, CH_3), 2.36 (s, 3H, CH_3), 2.85 (q, 2H, CH_2), 4.04 (s, 1H, NH), 6.45 (s, 1H, H^3), 8.00–8.06 (m, 2H, $H^{6,7}$), 8.36–8.45 (m, 2H, $H^{5,8}$). When NaOD was added, the equilibrium was displaced to the tautomeric form **3** to yield its sodium salt **7**: δ_H ($CDCl_3$–NaOD) 0.73 (t, 3H, CH_3), 2.07 (s, 3H, CH_3), 2.18 (q, 2H, CH_2), 5.20 (s, 1H, H^3), 6.99–7.14 (m, 2H, $H^{6,7}$), 7.46 (m, 1H, H^5), 7.93 (m, 1H, H^8). No evidence of a tautomeric equilibrium was found in the ^1H NMR spectrum of **3** in $(CD_3)_2SO$, presumably due to H-bonding of $(CD_3)_2SO$ to OH.

3-Methyl-5-ethyl-4-aminoisoxazole **2** was obtained by treatment of 3,5-dimethylisoxazole with *n*-butyllithium[3] in THF at −78 °C and quenching the reaction mixture with MeI followed by nitration[4] and reduction.[5]

Compounds **3**, **4** and **5** were characterized by IR, MS and NMR. The ^1H NMR data of **3**–**7** are shown in Table 1.

We investigated the effects of **7** on the motility and vitality of trypomastigote forms of *Trypanosoma cruzi* on blood samples obtained by bleeding of infected Albino Swiss mice. These bioassays showed that **7** inhibits the motility of flagellated forms (30 h) in a dose-related manner, the more effective blood concentrations being 150, 300 and 400 μg/ml. Furthermore, parasites in blood samples from animals injected with trypomastigote forms immobilized *in vitro* with **7** were not detected.[7]

The evaluation of the antimicrobial properties of **3** and **7** revealed that both compounds show *in vitro* antibacterial activity against *S. aureus* with a MIC of 32 μg ml^{-1}.[8]

Table 1 Proton chemical shifts (δ_H) and coupling constants (J/H_2) calculated by LAOCOON III program

Compd.	**3**	**4**	**5**	**6**	**7**
H-3[c]	5.23[a]	–	5.32[a]	6.26[a]	5.29[a]
	–	5.64[b]	5.62[b]	6.21[b]	–
H-5	8.04[a]	–	7.94[a]	8.08[a]	7.88[a]
	–	8.23[b]	8.09[b]	8.22[b]	–
H-6	7.75[a]	–	7.78[a]	7.76[a]	7.52[a]
	–	7.67[b]	7.70[b]	7.66[b]	–
H-7	7.89[a]	–	7.85[a]	7.84[a]	7.61[a]
	–	7.76[b]	7.76[b]	7.74[b]	–
H-8	8.22[a]	–	8.06[a]	8.44[a]	8.36[a]
	–	8.53[b]	8.12[b]	8.49[b]	–
rms[d]	0.092[a]	–	0.034[a]	0.077[a]	0.001[a]
	–	0.218[b]	0.167[b]	0.118[b]	–
J_{56}	7.43[a]	–	7.94[a]	8.08[a]	7.86[a]
	–	7.92[b]	8.60[b]	6.98[b]	–
J_{57}	1.83[a]	–	2.51[a]	1.46[a]	1.05[a]
	–	1.39[b]	1.64[b]	1.18[b]	–
J_{58}	0.75[a]	–	1.88[a]	1.63[a]	1.81[a]
	–	0.61[b]	1.35[b]	1.11[b]	–
J_{67}	7.54[a]	–	7.24[a]	7.25[a]	8.63[a]
	–	7.38[b]	8.65[b]	7.39[b]	–
J_{68}	0.81[a]	–	1.87[a]	1.03[a]	0.99[a]
	–	1.11[b]	1.74[b]	1.22[b]	–
J_{78}	8.01[a]	–	7.46[a]	8.21[a]	8.20[a]
	–	8.23[b]	8.75[b]	7.70[b]	–

[a]Recorded in $(CD_3)_2SO$. [b]Recorded in $CDCl_3$. [c]Experimental data ±0.01 ppm. [d]Errors in Hz.

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Experimental

Melting and boiling points were determined by the capillary method on a Buchi 510 melting point apparatus and are uncorrected. The IR spectra were recorded for potassium bromide discs on a Nicolet 5 SXC FT IR spectrophotometer and only selected absorptions are reported. ^1H and ^{13}C NMR spectra were recorded at 200.1 and 50.3 MHz in $CDCl_3$ and $(CD_3)_2SO$ on a Bruker AC 200E spectrometer; chemical shifts are given in ppm (δ) with Me_4Si as internal standard. The proton spectra were simulated using the LAOCOON III program. The mass spectra at 70 eV of **3** and **4** were recorded and the analyses were performed by UMYMFOR Laboratories, Buenos Aires, Argentina. The mass spectra of **2** and **5** were recorded on a Finnigan Model 3300 F-100 Quadrupole Mass Spectrometer. UV spectra were recorded for solutions in ethanol (95%) on a Shimadzu UV-160 A UV-VIS spectrometer. A Chromatotron model 7924 T was used for preparative radial chromatography (PRC). Column chromatography was performed on silica gel 60 (Macherey Nagel 0.05–0.2 mm). Precoated silica gel (Merck) was used for thin layer chromatography (TLC). All chemicals and reagents were of analytical grade. THF was freshly distilled over Na wire and $LiAlH_4$. Organic extracts were dried over anhydrous Na_2SO_4. *n*-Butyllithium in diethyl ether solution was prepared and the concentration was determined by Gilman's procedure.[6] 3,5-Dimethylisoxazole was purchased from Aldrich.

3-*Methyl*-5-*ethylisoxazole*.—Bp 159–160 °C, prepared by treatment of 3,5-dimethylisoxazole (47.9 mmol) with *n*-butyllithium (1.33 M; 36 ml) followed by addition of CH_3I (47.9 mmol) (70%).[3] δ_H ($CDCl_3$) 1.27 (t, 3H, CH_3), 2.25 (s, 3H, CH_3), 2.72 (q, 2H, CH_2), 5.80 (s, 1H, 4-H).

3-*Methyl*-5-*ethyl*-4-*nitroisoxazole*.—Bp 121 °C (30 mmHg) (lit. 50 °C at 0.7 mmHg), obtained in 76% yield by treatment of 3-methyl-5-ethylisoxazole with a 1:3 mixture of HNO_3 (65%) and H_2SO_4 (96%).[4] δ_H ($CDCl_3$) 1.38 (t, 3H, CH_3), 2.56 (s, 3H, CH_3), 3.22 (q, 2H, CH_2).

3-*Methyl*-5-*ethyl*-4-*aminoisoxazole* **2**.—To 3-methyl-5-ethyl-4-nitroisoxazole (0.493 g, 3.16 mmol) magnetically stirred at 0–5 °C (ice bath), 16 ml of distilled water and 4.01 g of NH_4Cl were added. The reaction mixture was stirred for an additional 5 min and subsequently zinc dust (1.76 g) was added in portions with stirring. After the mixture had been stirred at 0 °C for 10 min, EtOAc (18 ml) was added and the mixture was filtered through Celite. The layers were separated and the aqueous layer extracted with EtOAc (3 × 20 ml). Removal of solvent under reduced pressure provided an oil (0.277 g, 70% yield) of suitable purity, bp 184–185 °C, for the next reaction: δ_H ($CDCl_3$) 125 (t, 3H, CH_3), 2.19 (s, 3H, CH_3), 2.51–2.58 (br s, 2H, NH_2), 2.65 (q, 2H, CH_2); ν_{max}/cm^{-1} (KBr) 3406–3238, 2981, 2944, 1668, 1485, 1434, 1389, 1339, 1273, 1053, 1023; *m*/*z* (%) 126 (3, $M^{\bullet+}$), 111 (100), 85 (23), 70 (21), 69 (16), 57 (94), 56 (31), 42 (34), 29 (36), 28 (35).

2-*Hydroxy*-N-(3-*methyl*-5-*ethylisoxazol*-4-*yl*)-1,4-*naphthoquinone* 4-*Imine* **3**.—To **1** (1.037 g, 3.98 mmol) in 38 mL of buffer consisting of 7.4×10^{-3} M Na_3PO_4 and 8.0×10^{-2} M Na_2HPO_4, pH 11, cooled with an ice–NaCl bath was added a suspension of **2** (0.227 g, 1.81 mol) in 6 ml of distilled water. The reaction mixture was stirred (0 °C, 30 min) and then acidified with HCl until precipitation of product was complete. The resulting orange precipitate was collected, washed with water until neutral and dried in vacuum to give 0.343 g (67%) of **3** as an orange solid. The product was chromatographed on silica gel. Elution with benzene–ethyl acetate (40:60) gave 0.251 g (49%) of **3**, mp (decomp.) 225–226 °C, δ_H [$(CD_3)_2SO$] 1.18 (t, 3H, CH_3), 2.14 (s, 3H, CH_3), 2.73 (q, 2H, CH_2), 5.23 (s, 1H, 3H), 7.74 (m, 1H, 6-H), 7.90 (m, 1H, 7-H), 8.04 (m, 1H, 5-H), 8.22 (m, 1H, 8-H), 9.27 (s, 1H, OH); δ_C [$(CD_3)_2SO$] 8.8 (CH_3), 10.6 (CH_3), 18.2 (CH_2), 100.1 (C-3), 112.9 (C), 123.5 (C), 128.0 (C), 129.1 (C), 130.0 (C), 131.0 (C), 131.3 (C), 134.2 (C), 155.2 (C), 157.6 (C), 175.8 (COH), 180.6 (CO); ν_{max}/cm^{-1} (KBr) 3309 (OH), 1703 (C=O, 1598 (C=N); λ_{max}/nm 239, 269, 446; *m*/*z* (%) 282 (4, $M^{\bullet+}$), 241 (5), 199 (5), 186 (10), 185 (92), 156 (7), 102 (24), 101 (18), 77 (20), 57 (100) (Found: C, 68.31; H, 5.19; N, 9.64. $C_{16}H_{14}N_2O_3$ requires C, 68.09; H, 4.96; *N*, 9.93%).

2-(3-*Methyl*-5-*ethylisoxazol*-4-*ylamino*)-N-(3-*methyl*-5-*ethylisoxazol*-4-*yl*)-1,4-*naphthoquinone* 4-*Imine* **4**.—To **2** (0.301 g, 2.39 mmol) suspended in 0.5 M HCl (20 ml) and cooled with an ice–NaCl bath was added **1** (0.654 g, 2.51 mmol) in 15 ml of distilled water. The reaction mixture was stirred (0 °C, 30 min) and then extracted with CH_2Cl_2 (5 × 35 ml). The organic extract was washed with 5 M NaOH (3 × 35 ml), dried (Na_2SO_4) and the solvent removed to give 0.420 g (90%) of **4** as a red solid. Crystallization from H_2O–EtOH (1:1) gave 0.339 g (72.9%) of red crystals, mp 115–116 °C; δ_H ($CDCl_3$) 1.12 (t, 3H, CH_3), 1.18 (t, 3H, CH_3), 2.10 (s, 3H, CH_3), 2.11 (s, 3H, CH_3), 2.46 (q, 2H, CH_2), 2.61 (q, 2H, CH_2), 5.64 (s, 1H, 3-H), 6.47 (br, s, 1H, NH), 7.68 (m, 1H, 6-H), 7.76 (m, 1H, 7-H), 8.23 (m, 1H, 5-H); 8.53 (m, 1H, 8-H); δ_C [$(CD_3)_2SO$] 8.7 (CH_3), 9.1 (CH_3), 10.3 (CH_3), 10.5 (CH_3), 18.0 (CH_2), 18.3 (CH_2), 95.0 (C-3), 113.3 (C), 124.7 (C), 125.2 (C), 125.6 (C), 129.6 (C), 130.8 (C), 133.5 (C), 134.5 (C), 144.0 (C), 154.6 (C), 157.0 (C), 157.7 (C), 157.8 (C), 168.2 (CNH), 180.3 (CO); ν_{max}/cm^{-1} (KBr) 3335 (NH), 1662 (C=O), 1616 (C=N); λ_{max}/nm 239, 300, 350, 442; *m*/*z* (%) 390 (3, $M^{\bullet+}$), 333 (28), 307 (17), 293 (20), 236 (70), 225 (10), 209 (16), 195 (60), 169 (6), 139 (15), 57 (100) (Found: C, 67.99; H, 5.78; N, 14.59. $C_{22}H_{22}N_4O_3$ requires C, 67.69; H, 5.64; N, 14.36%).

4-(3-*Methyl*-5-*ethylisoxazol*-4-*ylamino*)-1,2-*naphthoquinone* **5**.—After refluxing **4** (0.098 g, 0.25 mmol) in EtOH (10.05 ml) for 5 min, 0.5 M HCl (5 ml) was added. The mixture was heated at 80 °C for 40 min. After cooling to room temp. the organic solvent was evaporated under reduced pressure and the aqueous phase was extracted with CH_2Cl_2 (5 × 10 ml). The organic extract was dried (Na_2SO_4) and the solvent removed to give 0.064 g (90%) of **5** as an orange solid. The crude product was purified by PRC (benzene 100%, benzene–CH_2Cl_2 90:10, 80:20, 60:40), mp 130–131 °C; δ_H ($CDCl_3$) 1.29 (t, 3H, CH_3), 2.24 (s, 3H, CH_3), 2.70 (q, 2H, CH_2), 5.62 (s, 1H, 3-H), 6.63 (br s, 1H, NH), 7.68–7.81 (m, 2H, 6-, 7-H), 8.08–8.14 (m, 2H, 5-, 8-H); δ_H [$(CD_3)_2SO$], 1.18 (t, 3H, CH_3), 2.10 (s, 3H, CH_3), 2.66 (q, 2H, CH_2), 5.32 (s, 1H, 3-H), 7.73–7.95 (m, 3H, 5-, 6-, 7-H), 8.03–8.06 (d, 1H, 8-H), 8.70 (br s, 1H, NH); δ_c [$(CD_3)_2SO$] 8.9 (CH_3), 10.6 (CH_3), 18.2 (CH_2), 99.6 (C), 102.3 (C-3), 113.01 (C), 125.1 (C), 125.8 (C), 130.3 (C), 132.4 (C), 134.6 (C), 142.4 (C), 148.4 (C), 157.7 (C), 168.2 (CO), 182.0 (CO); ν_{max}/cm^{-1} (KBr) 3283 (N–H), 1689 (C=O), 1623 (C=O), 1597 (C=O), 1597 (C=N); λ_{max}/nm 218, 264, 325, 435; *m*/*z* (%) 283 (27, $M^{\bullet+}+1$), 253 (29), 241 (31), 227 (9), 199 (6), 185 (100), 157 (16), 129 (21), 101 (23), 89 (1), 75 (9), 57 (19) (Found: C, 68.48; H, 5.18; N, 10.19. $C_{16}H_{14}N_2O_3$ requires C, 68.09; H, 4.96; N, 9.93%).

2-*Methoxy*-N-(3-*methyl*-5-*ethylisoxazol*-4-*yl*)-1,4-*naphthoquinone* 4-*Imine* **6**.—Obtained in 85% yield by reaction of **3** with an ethereal solution of diazomethane.[9] Mp 148–149 °C; δ_H ($CDCl_3$) 1.26 (t, 3H, CH_3), 2.21 (s, 3H, CH_3), 2.65 (q, 2H, CH_2), 3.79 (s, 3H, OCH_3), 6.21 (s, 1H, 3-H), 7.62–7.78 (m, 2H, 6-, 7-H), 8.22 (m, 1H, 5-H), 8.49 (m, 1H, 8-H); δ_H [$(CD_3)_2SO$] 1.16 (t, 3H, CH_3), 2.16 (s, 3H, CH_3), 2.65 (q, 2H, CH_2), 3.78 (s, 3H, OCH_3), 6.26 (s, 1H, 3-H), 7.71–7.88 (m, 2H, 6-, 7-H), 8.07 (m, 1H, 5-H), 8.44 (m, 1H, 8-H); ν_{max}/cm^{-1} (KBr) 2977 (CH_3), 1667 (C=O); λ_{max}/nm 236, 292, 340, 438; *m*/*z* (%) 296 (2.88, $M^{\bullet+}$), 239 (5.82), 213 (14), 199 (100), 184 (34), 172 (11), 156 (17), 127 (19), 101 (17), 57 (44).

Sodium 4-(3-*Methyl*-5-*ethylisoxazol*-4-*ylimino*)-1-*oxo*-1,4-*dihydronaphthalene*-2-*olate* **7**.—Obtained in 82% yield by reaction of **3** with a methanolic solution of NaMeO (5 M).[10] δ_H [$(CD_3)_2SO$] 1.12 (t, 3H, CH_3), 1.99 (s, 3H, CH_3), 2.56 (q, 2H, CH_2), 5.29 (s, 1H, 3-H), 7.46–7.66 (m, 2H, 6-, 7-H), 7.68 (m, 1H, 5-H), 8.36 (m, 1H, 8-H); ν_{max}/cm^{-1} (KBr) 1636 (C=N), 1648 (C=O).

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