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A NOVEL ENOLIC β-KETOALDEHYDE IN THE DEFENSE SECRETION OF THE TERMITE RHINOTERMES HISPIDUS

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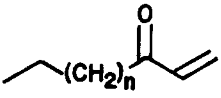
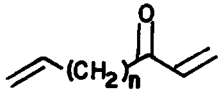
Abstract: The identity of 3-oxo-13-tetradecenal as a major component of the Rhinotermes hispidus defense secretion is established by MS, ^1H and ^{13}C-NMR, and total synthesis.

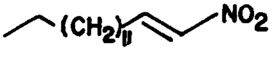
Chemical defense by soldier termites in the advanced subfamilies of the Rhinotermitidae (Isoptera) is executed by the topical application of a copious amount of a lipophilic contact poison to the surface of an attacker.[1,2] Simple vinyl ketones (e.g.,1) and α,ω-dienones (e.g.,2) have been described for two species of Schedorhinotermes[3,4] and a nitro olefin (3) has been determined for Prorhinotermes simplex.[5] Each of these contact poisons presumably acts by the Michael addition of a biological nucleophile to the chemically reactive α,β-unsaturated nitro or keto group,[1] and autodetoxication occurs by glutathione alkylation.[6] We now report that the minor soldiers of Rhinotermes hispidus Emerson possess the pungent-smelling β-ketoaldehydes 4 and 7 as the major constituents of their defense secretion.



1, n= 7,9,11



2, n= 7,9,11



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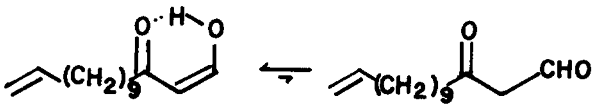
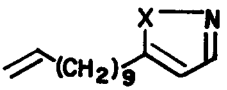
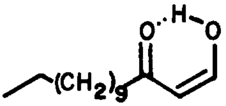


4a 4b



5, X = O
6, X = NH

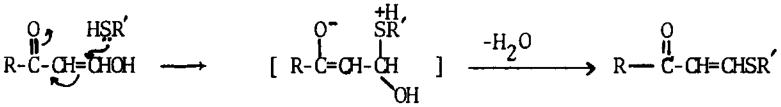


7

Hexane extraction of 80 R. hispidus minor soldiers afforded 50 mg of crude secretion.[7] The major component (>70%) showed the following spectral data: EI-MS (70eV), base peaks m/z 71 ($HOCH{=}CHC{\equiv}O^+$) and 86 ($HOCH{=}CHC(CH_2\cdot)(=OH+)$); λ_{max}^{hexane} 272nm (ε=6200); ^1H-NMR($CDCl_3$)δ7.92(d,J=4.3 Hz, H-1a), 5.52(d,J=4.3 Hz, H-2a), 5.8-5.5 and 5.0 - 4.85 (vinyl ABC, H-13,14), 2.33 (t,J=6.5Hz,H-4); ^{13}C-NMR($CDCl_3$), δ199.89(s,C-3), 175.76(d,C-1a), 139.26(d,C-13), 114.21 (t,C-14), 101.80(d,C-2a). Reaction of the crude secretion with hydroxylamine ($H_2NOH \cdot HCl$, K_2CO_3, C_2H_5OH, 0-20° then 80°, 1hr) afforded the isoxazole 5 which was purified by flash chromatography: EIMS (70ev), m/z 83 (100%, • H_2C-CH=CH-CH=N-OH+), parent peak absent, ^1H-NMR($CDCl_3$), δ8.12 (d,J=1.6 Hz, H-1), 5.95 (d,J=1.6 Hz, H-2), 5.8-5.5 and 5.0-4.85 (vinyl ABC, H-13,14), 2.76(t, 7.4 Hz, H-4); ^{13}C-NMR($CDCl_3$), δ173.19 (s,C-3), 150.24(d,C-1), 139.27 (d,C-13), 114.24 (t,C-14), 99.89(d,C-2). Reaction with hydrazine (H_2NNH_2, C_2H_5OH, 2N NaOH, 0-20° 1 hr) gave the pyrazole 6 which exhibited a parent peak at m/z 220; HRMS, 220.1919 ($C_{14}H_{24}N_2$ requires 220.1938);^1H-NMR($CDCl_3$) δ7.47 (d,J = 1.9 Hz,H-1) 6.06 (d,J=1.8 Hz, H-2), 5.8 - 5.5 and 5.0-4.85 (vinyl ABC), 2.67 (t,J=7.7 Hz, H-4); ^{13}C-NMR ($CDCl_3$), 147.88 (s, C-3), 139.31 (d,C-13), 135.10 (d,C-1), 114.22(t,C-14), 103.34(d,C-2).

An authentic sample of 4 was prepared from 12-dodecenal[9] by methyllithium addition, Jones oxidation to 12-tridecen-2-one and formylation [10] ($HCO_2C_2H_5$, C_6H_6, Na). The isoxazole and pyrazole derivatives were prepared and were identical (capillary GC, MS, ^1H-NMR) to those obtained from the authentic termite-derived material. Corresponding derivatives of 7 (from formylation of 2-tridecanone) were also prepared. Capillary GC and ^1H-NMR of the isoxazole and pyrazole derivatives of the termite secretion clearly show a 3:4 ratio of 13-unsaturated (from 4) to saturated derivatives (from 7) (HRMS of the pyrazole of 7, m/z 222.2081; $C_{14}H_{26}N_2$, 222.2094).

The discovery of β-ketoaldehydes (hydroxymethylene ketones) in a termite more evolutionarily advanced than those which make vinyl ketones is consistent with our hypothesis of the trend for increased reactivity and toxicity of defense secretions with evolutionary advancement. The insecticidal activity of this defense secretion is tentatively attributed to its reaction with cysteinyl sulfhydryl groups via 1,4-addition and elimination.[11]



References and Notes

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5. J. Vrkoč and K. Ubik, Tetrahedron Lett., 1463 (1974).
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7. Rhinotermes hispidus Emerson colonies were obtained from rotten woody litter in rainforest at Kartabo,Guyana. Minor soldiers were removed and crushed in Fisher HPLC hexanes to obtain the defense secretion, which was located in cephalic and abdominal reservoirs of the frontal gland. As reported[8] for 7, this secretion was found to be unstable to Florisil or silica gel purification. However the presence of the ketoaldehydes was readily apparent from ^1H and ^{13}C-NMR of crude secretions (CFT-20 instruments at 80 MHz for ^1H and 20 MHz for ^{13}C).
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11. The biochemical bases for toxication and detoxication are under investigation. We thank the NSF (Grant DEB-7823257) for financial support and C. Iden for mass spectra.

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