Potent Army Worm Antifeedants from the East African *Warburgia* Plants

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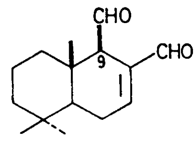
Summary Chemical investigation of antifeedant compounds from *Warburgia* plants has led to the isolation and characterization of polygodial, ugandensidial, and the unknown warburganal, which exhibit very strong antifeedant activity against the African army worm.

The East African genus *Warburgia* (Canellaceae) consists of two species, *W. stuhlmannii* and *W. ugandensis*, the barks of which are employed widely in folk medicine and as spices in food. Preliminary tests had indicated that the bark extract possessed antifeedant activity against army worms,‡ *Spodoptera littoralis* and *S. exempta*, widely occurring African crop pests. Accordingly, the extracts were fractionated by using leaf disk bioassay with *Zea mays* (or corn), containing sucrose and adenosine as feeding stimulants.[1] The test consists of dipping 2 cm diameter leaves into acetone solutions of fractionated extracts for 2 s§ and giving them to insects, with or without control leaves. This has led to the isolation of the known polygodial[2] (**1**), ugandensidiol[3] (**2**), and the new warburganal (**3**), which exhibit very strong antifeedant activities against African army worms.¶

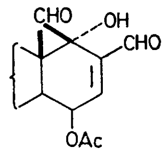
Leaves which had been dipped into 0·1 p.p.m. solutions for 2 s were not eaten by the insects and led to insect starvation.[4] It is conceivable that with proper development, some potent antifeedants such as the current series may provide another method for controlling pest insects in the field or during crop storage.[5] The antifeedant activity of compounds (**1**)—(**3**) was suppressed upon addition of equimolar quantities of L-cysteine to test solutions, thus strongly suggesting that SH groups on the receptors are involved in the taste sense of these insects.[1]

Extraction of the ground barks with 60% aqueous methanol followed by n-hexane extraction and chromatography on silica gel (twice) afforded the antifeedant fractions.[6] The fraction from *W. stuhlmanni* was further fractionated by high pressure liquid chromatography (h.p.l.c.) using a μ-Bondapak-C_{18} 30 cm column, and methanol–water (55:45 v/v), to give polygodial (**1**) and the lactones cinnamolide (4)[7] and bemadienolide (**5**).[7] In the case of *W. ugandensis*, preparative t.l.c. of the antifeedant fraction from the column gave ugandensidial (**2**) and the two lactones; the fourth constituent warburganal (**3**) was eluted from the t.l.c. plate and was separated with difficulty from a contaminant upon h.p.l.c. employing a deactivated μ-Porasil 30 cm column, and ether–n-hexane (15:85 v/v).

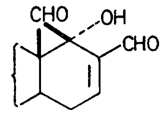
The structures of known compounds were established through spectral data and comparisons with published physical constants. The structure of warburganal (**3**) is based on the following evidence: $C_{15}H_{22}O_3$, chemical ionisation (isobutane) mass spectrum 251 (MH^+); u.v. (MeOH) 224 (ϵ, 6300); c.d. (MeOH) $\Delta\epsilon_{285}$ −2·3 (overlapping n,π^* extrema of the two aldehydes) and $\Delta\epsilon_{228}$ −1·54 (π,π^* Cotton effect of enal), i.r. ($CHCl_3$) 3460 (intramol. H-bonded OH), 2850 (CHO), 1722 (CHO), 1687, and 1650 cm^{-1} (enal). The ^{13}C n.m.r. spectrum showed the presence of 3 CH_3, 4 CH_2, 1 CH, 3 quaternary C, 2 olefinic C, and 2 carbonyl C atoms. Pertinent ^1H n.m.r. ($CDCl_3$) data are: δ 9·41 (s, 8-CHO), 9·72 (d, J 1 Hz, 9-CHO), 7·21 (dd, J 4 and 2 Hz, 7-H), 4·04 (d, J 1 Hz, intramol. H-bonded OH coupled to 9-CHO), and 0·96, 1·00, and 1·10 (all 3H s, Me). The 10-Me singlet at δ 1·10 was not shifted upon addition of lanthanide shift reagents and hence the 9-OH group is α-oriented.



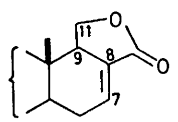
(1) polygodial



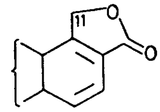
(2) ugandensidial



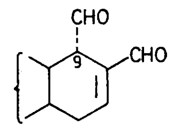
(3) warburganal



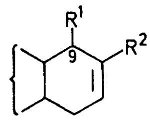
(4)



(5)



(6)



(7) $R^1 = R^2 = CH_2OH$
(8) $R^1 = CH_2OH, R^2 = CHO$
(9) $R^1 = R^2 = CO_2H$
(10) $R^1 = R^2 = CO_2Me$

It should be noted that the antifeedant activity of polygodial (**1**) was destroyed upon epimerization at C-9 by treatment with base; the lactones (**4**) and (**5**), and other polygodial conversion products (**7**)—(**10**) were all devoid of activity. These results together with the inhibitory action of L-cysteine suggest that the enal unit acts as a nucleophile (SH) acceptor, and that the 9β-CHO acts as a hydrogen bond or nucleophile acceptor which is located at a critical distance from the enal. Interestingly, the army worm antifeedants taste 'hot' to humans while nonactive compounds (**4**)—(**10**) do not.

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‡ Antifeedants are defined as substances which when tasted can result in cessation of feeding either temporarily or permanently depending upon potency.

§ If the leaves are soaked for longer periods, the palatability for insects decreases owing to extraction of constituents.

¶ The antifeedant level of polygodial and warburganal were not significant when tested against *Manduca sexta* (with tomato leaves) and *Schistocerca Vaga* (with corn seedlings). Hence, they are not universal antifeedants. Tests were kindly carried out by Drs. G. B. Staal and K. J. Judy, Zoecon Corporation.

[1] W.-C. Ma and I. Kubo, unpublished work.
[2] C. S. Barnes and J. W. Loder, *Austral. J. Chem.*, 1962, **15**, 322. *Cf.* also A. Ohsuka, *Nippon Kagaku Zasshi*, 1962, **83**, 757. For synthesis see T. Kato, T. Suzuki, M. Tanemura, A. S. Kumanireng, N. Ototani, and Y. Kitahara, *Tetrahedron Letters*, 1971, 1961.
[3] C. J. W. Brooks and G. H. Draffan, *Tetrahedron*, 1969, **25**, 2887.
[4] This aspect has been studied in more detail by electrophysiological methods: W. C. Ma, unpublished work.
[5] Another antifeedant of similar or slightly lower activity level as tested against the desert locust and army worm is azadirachtin: P. R. Zanno, I. Miura, K. Nakanishi, and D. L. Elder, *J. Amer. Chem. Soc.*, 1975, **97**, 1975. However, the molecule, $C_{35}H_{44}O_{16}$, is far too complex to be synthesized on a practical level.
[6] I. Kubo and A. Chapya, unpublished work.
[7] L. Canonica, A. Corbella, P. Gariboldi, G. Jommi, J. Krepinsky, G. Ferrari, and C. Casagrande, *Tetrahedron*, 1969, **25**, 3895, 3903.