Chemistry of Natural Compounds, Vol. 31, No. 3, 1995

INSECT PHEROMONES AND THEIR ANALOGS.
XLIX. SYNTHESIS OF TRIDEC-4-EN-1-YL ACETATE — THE SEX PHEROMONE OF *Keiferia lycopersicella*

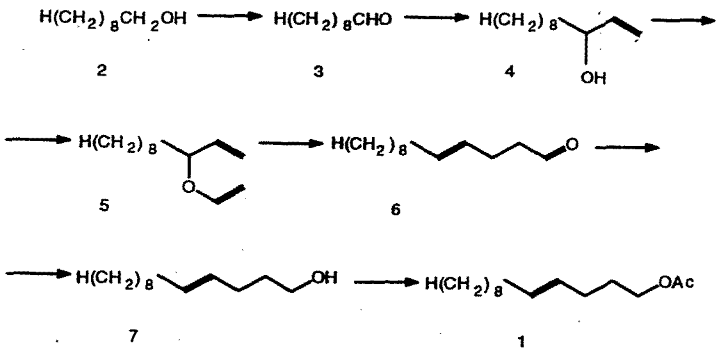
V. N. Odinokov, R. R. Vakhidov, R. N. Shakhmaev,
and N. V. Gil'vanova

UDC 542.91+547.473+632.936.2

Using the Claisen rearrangement at the stage of constructing the double bond, we have synthesized tridec-4E-en-1-yl acetate, the sex pheromone of the tomato pinworm Keiferia lycopersicella.

The *trans* isomer tridec-4E-en-1-1 acetate (**1**) has been identified as the sex pheromone of the tomato moth *Keiferia lycopersicella*, while its *cis* isomer exhibited no pheromonal activity [1]. Several syntheses of the pheromone (**1**) are known in which the double bond with the (E) configuration is constructed via an acetylenic intermediate [2-4], and also by the use of a Knoevenagel condensation [5], the opening of a cyclopropane ring [6], and the isomerization of the *cis*-alkenol to the required *trans* isomer [7].

We have developed a new route for the synthesis of pheromone (**1**), according to which the formation of the double bond makes use of a Claisen rearrangement, which enables Δ^4-alkenes exclusively with the (E) configuration to be obtained from vinyl ethers of secondary allyl alcohols [8]. As the compound necessary for the synthesis of pheromone (**1**) by being subjected to the Claisen rearrangement we used the vinyl ether of undec-3-en-1-ol, obtained from the readily accessible nonan-1-ol in three stages via the intermediate aldehyde (**3**) and the secondary allyl alcohol (**4**). The interaction of the latter with vinyl ethyl ether in the presence of $Hg(OAc)_2$ gave the required compound (**5**). Although the conversion of (**4**) after heating for 15 h did not exceed 40%, the unchanged alcohol (**4**) was easily separated from the product of its vinylation (**5**) for re-use.



The ether (**5**) was smoothly converted (180°C, 0.5 h) into a single reaction product — tridec-4E-enal (**6**), as was confirmed by GLC analysis and IR spectroscopy (ν 965 cm^{-1}). The aldehyde (**6**) was readily converted into the desired pheromone (**1**) by reduction and the subsequent acetylation of the resulting alcohol (**7**). Definitive proof of the (E) configuration

---

a) Institute of Petrochemistry and Catalysis, Academy of Sciences of the Republic of Bashkortostan; b) Scientific–Research Institute of Fine Organic Synthesis, Academy of Sciences of the Republic of Bashkortostan. Translated from Khimiya Prirodnykh Soedinenii, No. 3, pp. 490-493, May-June, 1995. Original article submitted November 9, 1994.

of the Δ^4 bond in acetate (**1**) was provided by the presence in the ^{13}C NMR spectrum of signals at δ 28.92 ppm (C-3) and 32.65 ppm (C-6),while in the spectrum of the analogous compound with the (Z) configuration the corresponding signals are shifted downfield by 4-4.5 ppm [9].

EXPERIMENTAL

IR spectra were taken on a Microlab 620 MX spectrometer (in a film), and PMR spectra were recorded on a Tesla BS-587A instrument (working frequency 80 MHz), solvent $(CD_3)_2CO$, chemical shifts on the δ scale (internal standard hexamethyldisiloxane). The ^1H and ^{13}C NMR spectra of compound (**1**) were recorded on a Bruker AM 300 instrument (working frequencies 300 and 75 MHz), solvent $CDCl_3$, chemical shifts on the δ scale relative to TMS in the JMOD editing scheme. GLC analysis was performed on a Chrom-5 instrument with, as the immobile phase, the silicone liquid SE-30 (5%) on Chromaton N-AW-DMS (0.16-0.20 mm), working temperatures 50-300°C, carrier gas helium; for compound (**6**) we used the stationary phase PEG-20 in a 0.2 mm × 12 m column at working temperatures of 50-200°C. TLC was conducted on Silufol plates with a fixed layer of SiO_2. The analytical results for the compounds synthesized corresponded to the calculated figures.

Nonanal (3). The alcohol (**2**) (28.8 g; 0.2 mole) was added to a suspension of pyridinium chlorochromate (64.6 g; 0.3 mole) in 400 ml of abs. CH_2Cl_2, the mixture was stirred for 2 h, 500 ml of diethyl ether was added, and the solution was decanted from the resulting precipitate, which was washed with diethyl ether (3 × 100 ml). The combined organic solution was filtered through a layer of silica gel (200 g), the solvent was evaporated off, and the residue was distilled in vacuum. This gave 19.8 g (70%) of the aldehyde (**3**), bp 92-94°C (23 mm), n_D^{22} 1.4276 [10]. IR spectrum (ν, cm^{-1}): 1730, 2700 (CHO). PMR spectrum: 0.85 (t, 3H, J = 6 Hz, CH_3), 1.1-1.3 (m, 12H, CH_2), 2.15-2.45 (m, 2H, H_2CCO), 9.86 (t, 1H, J = 1.5 Hz, HCO).

Undec-1-en-3-ol (4). A little vinyl bromide and a few drops of methyl iodide were added (Ar) to 5.35 g of magnesium turnings in 180 ml of abs. THF and then the remainder of the vinyl bromide to make a total of 23.6 g (0.22 mole), was added dropwise. After the mixture had been stirred for 2 h, 15.62 g (0.11 mole) of the aldehyde (**3**) in 180 ml of abs. THF was added. The resulting mixture was stirred for 4 h and left overnight, after which 30 ml of saturated aqueous NH_4Cl was added, the organic layer was washed with saturated NaCl solution, and the aqueous layer was extracted with diethyl ether. The combined organic solution was dried with Na_2SO_4 and evaporated, and the residue was distilled in vacuum. This yielded 11.95 g (64%) of the alcohol (**4**), bp 126-128°C (20 mm), n_D^{20} 1.4435 [11], R_f 0.34 (hexane–diethyl ether (1:1)). IR spectrum (ν, cm^{-1}); 926, 995 ($H_2C{=}CH$), 1640 (C=C), 3080 ($H_2C{=}C$), 3350 (OH) (cf. [12]). PMR spectrum: 0.87 (t, 3H, J = 6 Hz, CH_3), 1.1-1.5 (m, 14H, CH_2), 3.65 (m, 1H, OH), 3.85-4.05 (m, 1H, HCO), 5.0-5.3 (m, 2H, $H_2C{=}C$), 5.5-6.0 (m, 1H, HC=C).

3-Vinyloxyundec-1-ene (5). To a mixture of 20 ml of diethyl ether and 0.2 g of $Hg(OAc)_2$ was added 6.27 g of the alcohol (**4**), and the reaction mixture was heated with stirring under reflux for 15 h. After cooling to 0°C, 30 ml of a 10% solution Na_2CO_3 was added, the resulting mixture was stirred for 0.5 h, and then the organic layer was washed with water, dried with K_2CO_3, and evaporated. This gave 2.88 g (40%) of the ether (**5**, n_D^{18} 1.4428, R_f 0.8 (hexane–diethyl ether (8:2)), IR spectrum (ν, cm^{-1}): 830, 930, 925, 1615, 1635 ($CH{=}CH_2$). PMR spectrum: 0.85 (t, 3H, J = 6 Hz, CH_3), 1.2-1.5 (m, 14H, CH_2), 4.0-4.2 (m, 1H, HC–O), 5.0-5.3 (m, 4H, $H_2C{=}C$), 5.5-5.8 (m, 1H, HC=C), 6.1-6.4 (m, 1H, O–CH=C). Further elution (hexane–diethyl ether (1:1)) gave 3.25 g (52%) of the unchanged alcohol (**4**).

Tridec-4E-enal (6). Under argon, 1.4 g of the ether (**5**) was heated at 180°C for 0.5 h, and it was then cooled, applied to a layer of Al_2O_3 (10 g), and eluted with pentane. Evaporation of the solution yielded 1.23 g (88%) of the aldehyde (**6**) n_D^{18} 1.4625, R_f 0.6 (hexane–diethyl ether (8:2)). IR spectrum (ν, cm^{-1}: 975 (HC=CH–trans), 1728, 2740 (CHO), m, [13]. PMR spectrum: 0.8 (t, 3H, J = 6 Hz, CH_3), 1.2-1.3 (m, 12H, CH_2), 1.9-2.1 (m, 4H, $H_2CC{=}CCH_2$), 2.2-2.5 (m, 2H, H_2CCO), 5.3-5.5 (m, 2H, HC=CH), 9.78 (t, 1H, J = 1.5 Hz, HCO) (cf. [13]).

Tridec-4E-en-1-ol (7). At 0°C, 0.39 g (10.3×10^{-3} mole) of $NaBH_4$ was added to a solution of 1.02 g (5.15×10^{-3} mole) of the aldehyde (**6**) in 15 ml of abs. ethanol, and the mixture was stirred for 10 min, warmed to room temperature, treated with 15 ml of 5% HCl, and extracted with diethyl ether (3 × 30 ml). The extract was washed with saturated NaCl solution, dried with $MgSO_4$, and evaporated. This yielded 0.80 g (78%) of the alcohol (**7**), n_D^{18} 1.4556, R_f 0.41 (hexane–diethyl ether (1:1)). Its IR and PMR spectra were identical with those given in [6].

Tridec-4E-en-1-yl Acetate (1). A mixture of 0.6 g (3.0×10^{-3} mole) of the alcohol (7), 6 ml of abs. pyridine, and 2.6 ml of Ac_2O was held at room temperature,* and, after the addition of 15 ml of diethyl ether, it was washed with 10% HCl and with saturated NaCl solution and was dried with $MgSO_4$. The residue after evaporation was chromatographed (SiO_2, hexane–diethyl ether (9:1)). This gave 0.58 g (81%) of the acetate (1), n_D^{18} 1.4438, R_f 0.69 (hexane–diethyl ether (7:3)). Its IR and PMR spectra were identical with those given in the literature [5, 6]. ^{13}C NMR spectrum (δ, ppm): 171.26 (s, C=O), 131.67 (d, C–4), 128.66 (d, C–5), 64.02 (t, C–1), 32.65 (t, C–6), 31.98 (t, C–11), 29.61, 29.59, 29.39, 29.25 (t, C–7, C–8, C–9, C–10), 28.92 (t, C–3), 28.55 (t, C–2), 22.75 (t, C–12), 21.06 (q, CH_3CO), 14.19 (q, C–13).

REFERENCES

1. K. Ogawa and A. Yamamoto, GFR Patent 3814465 (1989); Chem. Abstr., **112**, 114214u (1990).
2. J. W. Patterson, Synthesis, No. 3, 337 (1985).
3. T. Fukumoto and A. Yamamoto, Japanese Patent 2101028 (1990); Chem. Abstr., **113**, 112635t (1990).
4. G. G. Melikyan, G. Kh. Aslanyan, K. A. Atanesyan, D. A. Mkrtchyan [sic], and Sh. O. Badanyan, Khim. Prir. Soedin., 102 (1990).
5. L. M. Bikulova, G. G. Verba, and A. A. Abduvakhabov, Khim. Prir. Soedin., 444 (1991).
6. A. M. Moiseenkov, B. A. Czeskis, N. M. Ivanova, and O. M. Nefedov, J. Chem. Soc., Perkin Trans. I, No. 11, 2639 (1991).
7. W. Seufert, E. Buschamann, R. Becker, W. Seppelt, and W. Mackenroth, FRG Patent 4,006,919 (1991): Chem. Abstr., **115**, 255619n (1991).
8. O. P. Vig, M. L. Sharma, N. K. Varma, and N. Malik, Indian J. Chem., **B20**, No. 10, 860 (1981).
9. V. N. Odinokov, R. S. Bakeeva, R. I. Galeeva, V. R. Akhunova, Ya. G. Mukhtarov, G. A. Tolstikov, L. M. Khalilov, and A. A. Panasenko, Zh. Org. Khim., **15**, No. 10, 2017 (1979).
10. V. A. Rabinovich and Z. Ya. Khavin, Concise Chemical Handbook [in Russian], Khimiya, Leningrad (1977), p. 170.
11. Nii Hiromichi, Furukawa Kiyoshi, Ivakiri Mitsuo, J. Chem. Soc. Jpn., Pure Chem. Sec., **92**, No. 12, 1214 (1971).
12. A. V. Rama Rao, E. Rajarathanam Reddy, A. V. Purandure, and Ch. V. N. S. Varaprasad, Tetrahedron, **43**, No. 19, 4385 (1987).
13. K. Oshima, H. Takahashi, H. Yamamoto, and H. Nozaki, J. Am. Chem. Soc., **95**, No. 8, 2693 (1973).

---

*No time given — Translator.