SYNTHETIC INVESTIGATIONS IN THE FIELD OF ATTRACTIVE SUBSTANCES (SEX ATTRACTANTS) OF INSECTS

cis-9,10-EPOXYHENEICOSA-1, cis-6-TRIENE — A COMPONENT OF THE SEX PHEROMONE OF Hyphantia cunea

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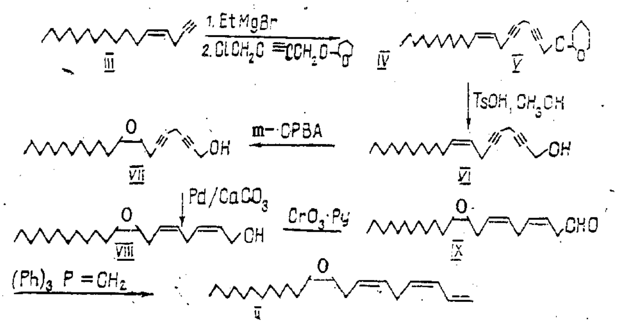
UDC 547.594:632.936.2

A new synthesis of cis-9,10-epoxyheneicosa-1,cis-3,cis-6-triene has been developed.

Four substances have been identified in an extract of the sex pheromone of females of the American fall webworm moth Hyphantira cunea Drury: linoleic and linolenic aldehydes, cis-9,10-epoxyheneicosa-cis-3,cis-6-diene (I), and cis-9,10-epoxyheneicosa-1,cis-3,cis-6-triene (II) [1-3]. The synthesis has been described of enantiomers of (I) and (II) [4-6] and of racemic (I) [7].

In the present communication we describe a synthesis of the racemic trienic epoxide (II).



The alkylation of the bromomagnesium derivative of hexadec-cis-4-en-1-yne (III) with 1-(tetrahydropyran-2-yloxy)-1-chlorobut-1-yne (IV) led to 1-(tetrahydropyran-2-yloxy)eicos-cis-8-ene-2,4-diyne (V); this was converted by acid hydrolysis into eicos-cis-8-ene-2,5-diyn-1-ol (VI), and the epoxidation of the latter with m-chloroperbenzoic acid (m-CPBA) yielded cis-8,9-epoxyeicosa-2,5-diyn-1-ol (VII).

The hydrogenation of the epoxyalcohol (VII) in methanol in the presence of Lindlar catalyst gave cis-8,9-epoxyeicos-cis-2,cis-5-dien-1-ol (VIII), and MnO$_2$ was initially used for the oxidation of this dienic epoxyalcohol (VIII)] to the aldehyde (IX). However, the oxidation of (VIII) by this reagent took a long time and was incomplete.

In a model experiment, according to the results of IR and PMR spectroscopies and capillary chromatography, the oxidation of tetradec-cis-2-en-1-ol by the CrO$_3$·Py complex took place with no cis-trans isomerization of the double bond.

Oxidation of the dienic epoxyalcohol by the complex CrO$_3$·Py gave an epoxyaldehyde which was converted by the Wittig reaction with methylenetriphenylphosphorane into the final cis-9,10-epoxyheneicosa-1,cis-3,cis-6-triene (II). The overall yield of the epoxide (II) was 3.4%, calculated on the hydrocarbon (III).

Field trials showed that, in admixture with linoleic and linolenic aldehydes, the racemic dienic and trienic epoxides (I) and (II) were attractants for H. cunea males.

All-Union Scientific-Research Institute for Biological Methods of Plant Protection, Kishinev. Translated from Khimiya Prirodnykh Soedeninii, No. 1, pp. 141-144, January-February, 1993. Original article submitted March 27, 1992.

0009-3130/93/2901-0120 $12.50

EXPERIMENTAL

IR spectra of substances in CCl_4 were taken on a Specord-75 IR instrument with NaCl and KBr prisms and a NaCl cell. High-resolution PMR spectra were obtained on a Tesla BS-467 spectrometer in CCl_4. The working frequency was 60 MHz, and the internal standard tetramethylsilane. The gas-chromatographic investigation of the compounds obtained was conducted on a Chrom-5 chromatograph using glass columns (3 mm × 1.2 m) filled with 5% of SE-30 on the support Chromaton 100-120 mesh and with 5% of cyclohexanedimethyl succinate on the same support. Isomeric purities were determined on a Varian Vista 6000 chromatograph with a quartz capillary column (0.3 mm × 25 m) coated with SE-54. Mass spectra were taken on a HP 5890 instrument with a HP 5970 mass-selective detector.

Hexadec-cis-4-en-1-yne (III). Over 1 h, the Grignard reagent obtained from 3.84 g of Mg and 17.4 g of ethyl bromide in 75 ml of absolute THF was added dropwise at −78°C to 100 ml of absolute THF that had been saturated with acetylene for 30 min, and then acetylene was passed through the reaction mixture at 20°C for 6 h. After the end of the passage of $CH{=}CH$, 0.1 g of CuCl, and after another 15 min, 15 g of 1-chlorotetradec-cis-2-ene [7] were added. The reaction mixture was left overnight, and was then stirred at 55°C for 10 h, and with the THF boiling for 2 h. The reaction mixture was cooled and was decomposed with 2 N HCl and extracted with ether, and the ethereal solution was washed with water, sodium metabisulfite, and water, and was dried with anhydrous Na_2SO_4. The solvent was evaporated off. The product was purified on a column of SiO_2, with hexane as the eluent. This gave 13 g (90.7%) of the hydrocarbon (II). bp 129°C (1mm), n_D^{20} 1.4558. IR spectrum (cm^{-1}) 3300, 3012. PMR spectrum (δ, ppm): 0.86 t (3H, CH_3), 1.30 br.s (18H, $(CH_2)_9$), 2.03 m, (3H, $\equiv C\underline{H}$, $C\underline{H}_2C\equiv$) 2. 89 m (2H, $\equiv CC\underline{H}_2C\equiv$), 5.5 m (2H, $C\underline{H}{=}C\underline{H}$). Found %: C 86.94; H 12.89. $C_{16}H_{28}$. Calculated %: C 87.19; H 12.80.

1-(Tetrahydropyran-2-yloxy)eicos-cis-8-ene-3,4-diyne (V). The Grignard reagent obtained from 2.67 g of Mg and 11 g of ethyl bromide in 75 ml of absolute THF was added dropwise to 23 g of hydrocarbon (III) in 50 ml of absolute THF cooled with ice water, and the reaction mixture was then stirred at 20°C for 1 h, and at 50°C for 1 h. Then it was cooled, and 1 g of CuCl and, after 30 min, the chloroacetal (IV) were added. The reaction was conducted in a current of dry argon for 72 h, and the resulting mixture was decomposed with 75 g of $(NH_4)_2SO_4$ in 250 ml of water and then with 2 N HCl; it was extracted with ether, and the ethereal solution was washed with water and dried with anhydrous Na_2SO_4. The solvent was evaporated off, and the product was purified on a column of Al_2O_3 with hexane as eluent. This gave 10.64 g (49%) of the acetal (V). n_D^{20} 1.4830. IR spectrum (cm^{-1}): 3032, 1110, 1020, 900 (oxypyran). PMR spectrum (δ, ppm): 0.92 t (3H, CH_3), 1.21 br.s (18H, $(CH_2)_9$), 1.6 br.s (6H, $CH_2)_3$), 2.01 m (2H, $\equiv CCH_2C\equiv$), 3.02 m (2H, $=CHCH_2C\equiv$), 4.06 m (2H, $C\underline{H}_2O$), 4.57 m (1H, OCHO), 5.33 m (2H, $C\underline{H}=C\underline{H}$).

Eicos-cis-8-ene-2,5-diyn-1-ol (VI). A mixture of 4.2 g of (V) in 45 ml of methanol and 1.05 g of p-toluenesulfonic acid was stirred until the acetal (V) had completely disappeared (18 h). Monitoring by TLC on SiO_2 in the hexane−ether (1:1) system. After the end of the reaction, the methanol was evaporated off, and the residue was diluted with ether, washed with potassium bicarbonate and with water, and dried with anhydrous Na_2SO_4. The solvent was evaporated off, and the residue was purified by chromatography on SiO_2 (100-160 mesh) with the eluents hexane and hexane−acetone (5% and 10% of acetone). This gave 2.5 g (76.9%) of the diacetylenic alcohol (VI) IR spectrum (cm^{-1}): 3610, 3020, 2220. PMR spectrum (δ, ppm): 0.81 t (3H, CH_3), 1.18 br.s (18H, $(CH_2)_9$), 2.01 m (2H, $\equiv CC\underline{H}_2C\equiv$), 2.54 m (2H, $=CHC\underline{H}_2C\equiv$), 3.33 m (2H, $\equiv CC\underline{H}_2$), 4.06 s (1H, $O\underline{H}$), 5.36 m (2H, $C\underline{H}=C\underline{H}$).

cis-8,9-Epoxyeicosa-2,5-diyn-1-ol (VII). Slowly, 4.3 g of the alcohol (VI) in 20 ml of methylene chloride was added to a cooled solution of 3.6 g of m-chloroperbenzoic acid in 50 ml of methylene chloride. The reaction mixture was stirred at 20°C until the enynic alcohol (VI) had disappeared (36 h). The progress of the reaction was monitored by thin-layer and gas-liquid chromatographies (TLC and GLC). The reaction mixture was diluted with a two-fold volume of ether, decomposed with 10% aqueous Na_2CO_3, and extracted with ether, and the extract was dried with anhydrous Na_2SO_4. The solvent was evaporated off, and the product was purified by chromatography on a column of SiO_2 with elution by mixtures of hexane with ethyl acetate (5, 10, and 15% of ethyl acetate). This gave 1.43 g (31.5%) of the epoxide (VII) as a light yellow crystalline product. mp 62-63°C. IR spectrum (cm^{-1}): 3610. PMR spectrum (δ, ppm): 0.92 t (3H, CH_3), 1.3 br.s (18H, $(CH_2)_9$), 2.01 m (2H, $\equiv CC\underline{H}_2\equiv$) 2.80 m (2H, $\underset{\diagdown O \diagup}{CH{-}CH}C\underline{H}_2C\equiv$), 3.03 m (2H, $\underset{\diagdown O \diagup}{CH{-}CH}$) 4.03 s (1H, $O\underline{H}$).

cis-8,9-Epoxyeicosa-cis-2,cis-5-dien-1-ol (VIII). In a hydrogenation flask, 1.43 g of the epoxyalcohol (VII) was dissolved in 4.5 g of methanol, and 150 mg of Lindlar catalyst and 3 drops of quinoline were added. Hydrogenation was monitored by GLC. After the absorption of the equivalent amount of hydrogen and the disappearance of the acetylenic alcohol, the reaction mixture was filtered, and the methanol was distilled off. The dienic epoxyalcohol was purified on a column of SiO_2 (40-100 mesh) with hexane–ether (5:1) as eluent. This gave 1.23 g (82.5%) of the epoxyalcohol (VIII). IR spectrum (cm^{-1}): 3610, 3020.

PMR spectrum (δ, ppm): 0.85 t (3H, CH_3), 1.33 br.s (18H, $(CH_2)_9$), 2.21 m (2H, $\underset{O}{CH—CH}C\underline{H}_2$), 2.76 m (4H, $\underset{O}{C\underline{H}—C\underline{H}}$, $=CHC\underline{H}_2CH=$) 3.63 m (2H, $=CHCH_2$), 4.06 s (1H, $O\underline{H}$), 5.43 m (4H, $C\underline{H}=C\underline{H}$).

cis-8,9-Epoxyeicosa-cis-2,cis-5-dien-1-al (IX). At −10°C, in an atmosphere of dry nitrogen, 2.7 g of CrO_3 was added in small portions to a solution of 4.2 g of pyridine in 60 ml of absolute methylene chloride, and after 15 min 1.2 g of (VIII) in 6 ml of methylene chloride was added. The reaction mixture was stirred in an atmosphere of nitrogen at 20°C for 5 h. The progress of oxidation was monitored by TLC and GLC. The reaction mixture was diluted with ether and was passed through SiO_2 (100-250 mesh), and the ether was evaporated off. The product was purified by column chromatography on SiO_2 (100-250 mesh), with elution by mixtures of hexane and ethyl acetate (10, 20, and 30% of ethyl acetate). This gave 0.5 g (42%) of the epoxyaldehyde (IX) with a purity of 78%. IR spectrum (cm^{-1}): 3020, 2725, 1680, 1610. PMR spectrum (δ, ppm): 0.86 t (3H. CH_3), 1.03 br.s (18H, $CH_2)_9$), 2.0 m (2H, $=CHC\underline{H}_2CH=$), 2.76 m (2H, $\underset{O}{CH—CH}—C\underline{H}_2CH=$), 3.6 m (2H, $\underset{O}{CH—CH}$), 5.43 m (2H, $C\underline{H}=CH$), 7.4 m (2H, $CH=CHCHO$), 9.66 s (1H, CHO). Mass spectrum (m/z): 302 $(M)^+$, 280 $(M-18)^+$. 197 $(C_{13}H_{25}O)^+$, 184 $(C_{11}H_{23}$-$CHO)^+$, 133 $(C_9H_9O)^+$.

cis-9,10-Epoxyheneicosa-1,cis-3,cis-6-triene (II). In an atmosphere of nitrogen, 0.5 g of the epoxyaldehyde (IX) in 10 ml of absolute THF was added over 30 min at 0°C to a solution in 20 ml of absolute THF of the methyltriphenylphosphorane obtained from 0.86 g of methyltriphenylphosphonium bromide and 2.2 ml of a 2.3 N hexane solution of butyllithium. The reaction mixture was stirred at 20°C for 2 h and it was then diluted with ether, decomposed with water, and extracted with ether. The extract was dried with anhydrous Na_2SO_4, and the solvent was evaporated off. The product was purified by two passages through a column of SiO_2 (40-100 mesh) with elution by 2% ethyl acetate in n-hexane. This gave 0.25 g (51%) of the epoxide (II) with a purity of 92%, n_D^{20} 1.4620. IR spectrum (cm^{-1}): 3080, 3010, 1460, 1280, 900. PMR spectrum (δ, ppm): 0.9 t (3H, CH_3), 1.22 br.s (20H, $(CH_2)_{10}$), 2.0 m (2H, $=CHC\underline{H}_2CH=$), 2.66 m (2H, $\underset{O}{CH—CH}C\underline{H}_2CH=$), 3.3 m (2H, $\underset{O}{CH—CH}$), 4.83 (1H, $C\underline{H}=CH_2$), 5.0 (2H, $C\underline{H}=C\underline{H}$), 5.4 m (1H), 5.8 m (1H). Mass spectrum (m/z): 187 $(C_{13}H_{25}O)^+$, 183 $(C_{11}H_{23}CO)^+$, 106 $(C_8H_{10})^+$, 91, 79.

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