Liebigs Ann. Chem. **1982**, 1766 – 1774

Synthesis of Insect Juvenile Hormone Analogs, II [1]

Synthesis of Juvenoids with 2,4-Dienoic Ester Function

Lucjan Borowiecki, Aleksander Kazubski,* and *Elżbieta Reca*

Department of Organic Chemistry, Institute of Chemistry, Nicolaus Copernicus University, Gagarina 7, 87 – 100 Toruń, Poland

Received April 1, 1982

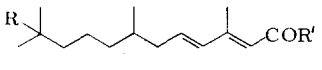
This article reports the synthesis of some 2,4-dienoic ester insect juvenile hormone analogs with a cyclohexene, pinene, or methoxycyclohexane ring in the terminal position.

Synthese von Juvenilhormon-Analogen von Insekten, II [1]. – Synthese von Juvenoiden mit einer 2,4-Dienestergruppe

Es wird die Synthese von 2,4-Dienester-Analogen von Insekten-Juvenilhormonen, die einen Cyclohexen-, Pinen- oder Methoxycyclohexan-Ring in der terminalen Stellung enthalten, beschrieben.

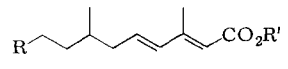
The *S*-enantiomers of (2*E*,4*E*)-3,7,11-trimethyl-2,4-dodecadienoates [2,3] **1** – **4** possess uncommon activity among the hitherto synthesized insect juvenile hormone analogs.

Scheme 1



1-4

	R	R'
1	OMe	OiPr
2	H	OCH_2–C≡CH
3	H	OEt
4	H	SEt



5-11

	R	R'
5	H	H
6		Et
7		Et
8		Et
9		iPr
10		iPr
11		iPr

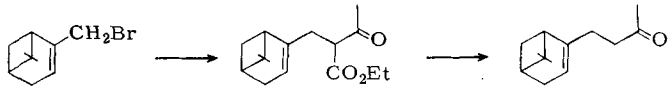
0170 – 2041/82/1010 – 1766 $ 02.50/0

So far, there are only a few papers[4-6] which concern the synthesis of 2,4-dienoate insect juvenile hormone analogs with a carbocyclic ring in the terminal position. We have undertaken syntheses of some derivatives **6** – **11** of 3,7-dimethyl-2,4-nonadienoic acid (**5**) with a cyclohexene, pinene, and methoxycyclohexane ring in the terminal part of the molecule.

The literature data show the high probablility of juvenile hormone activity of these compounds. They have for such type of analogs the optimum of nine carbon atoms in the side chain[5], and due to the carbocyclic ring in the terminal position they may act specifically.

In the syntheses of the above mentioned analogs **6** – **11** two ketones, i. e. 4-(1-cyclohexenyl)-2-butanone (**15**) and (2-pinen-10-yl)propanone (**14**), were the key intermediates. The ketone **15** was prepared on two different ways which we have described previously[1]. Compound **14** was obtained from myrtenyl bromide (**12**) according to Scheme 2.

Scheme 2

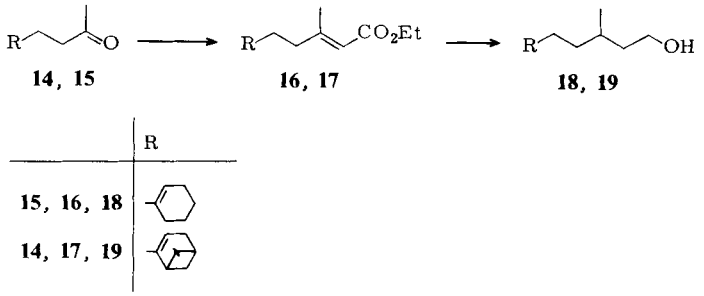


12 **13** **14**

The bromo derivative **12** was subjected to a condensation reaction with ethyl acetoacetate to give ethyl 3-oxo-2-(2-pinen-10-yl)butyrate (**13**) in 78% yield, the structure of which was confirmed by IR and NMR spectra. The absorption bands at 1720, 1750, and 1645 cm^{-1} presented in the IR spectrum are characteristic for C=O (ketone), C=O (ester), and C=C (double bond), respectively. On the other hand, in the NMR spectrum, besides the typical signals of the pinene ring protons at δ = 0.74 (s), 1.22 (s; CH_3-C-CH_3) and 5.15 (m; C=CH), a singlet (3H) at δ = 2.08 indicates the presence of a methyl group in α-position to the ketone function. A triplet (3H) at δ = 1.20 and a quartet (2H) at δ = 4.07 correspond to an ester ethyl group. Furthermore, a triplet (1H) at δ = 3.37 confirmes the presence of a proton linked with a carbon atom in α-position both to ester and ketone group.

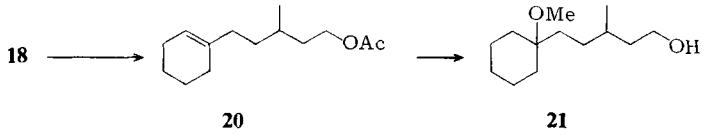
In the next synthetic step the keto ester **13** was decarboxylated according to the method described by *Ohki* and co-workers[7]. It was refluxed for 18 h with barium hydroxide in aqueous ethanol to give (2-pinen-10-yl)propanone (**14**) in 85% yield. Wittig-Horner reaction of the ketones **15** and **14** with ethyl diethoxyphosphorylacetate in the presence of NaH in anhydrous dimethoxyethane solution gave the appropriate α,β-unsaturated esters **16** and **17** in 89 and 86% yield as mixtures of 2*E* and 2*Z* isomers. In the NMR spectra of these compounds the signals at δ = 5.58 and 5.60 for compound **16**, and at δ = 5.50 and 5.52 for **17** correspond to the absorption of the C-2 protons of the 2*Z* and 2*E* isomers, respectively[8,9]. Greater differences in chemical shifts were observed for the protons of the C-3 methyl groups. With regard to the shielding effect of an ester group[9], the signals of the methyl groups of the 2*Z* isomers appear as doublets at δ = 1.80, i. e. about 0.3 ppm higher than for the 2*E* isomers (δ = 2.09 for compound **16** and 2.05 for compound **17**). Comparision of these two signals showes the predominance of the 2*E* isomer.

Scheme 3



In the next synthetic step the C-2 double bonds in the aliphatic chains of the compounds **16** and **17** were reduced with lithium in liquid ammonia[10]. Using an excess of lithium and methanol as a proton source we did not achieve a selective hydrogenation of the C-2 olefinic bond but also a simultaneous reduction of the ester group and obtained 5-(1-cyclohexenyl)-3-methylpentanol (**18**) and 3-methyl-4-(2-pinen-10-yl)-butanol (**19**).

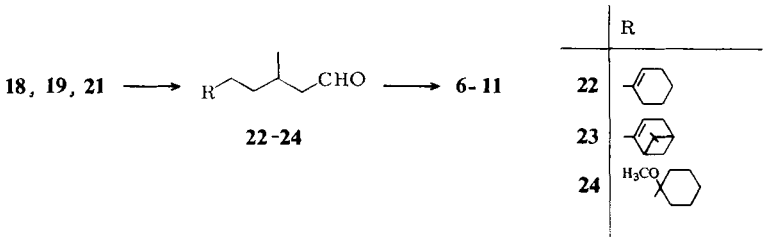
Scheme 4



The alcohol **18** was esterified with acetic anhydride in pyridine to yield the acetate **20** which was subsequently subjected to a methoxymercuration-demercuration reaction[11] to give 5-(1-methoxycyclohexyl)-3-methylpentanol (**21**).

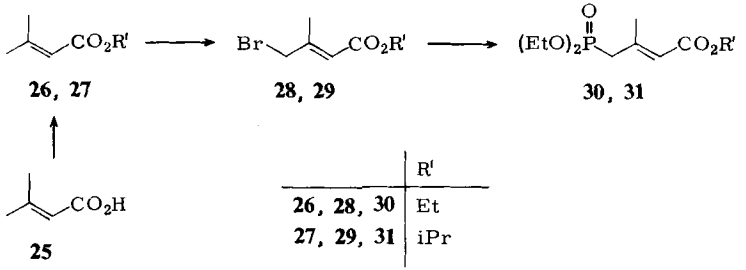
In the next step the alcohols **18**, **19**, and **21** were oxidized with a twofold excess of pyridinium dichromate[12] in dichloromethane to afford 5-(1-cyclohexenyl)-3-methylpentanal (**22**), 3-methyl-4-(2-pinen-10-yl)butanal (**23**), and 5-(1-methoxycyclohexyl)-3-methylpentanal (**24**) in 64, 52, and 82% yield, respectively.

Scheme 5



Our goal compounds, the insect juvenile hormone analogs **6** – **11**, have been obtained by Wittig-Horner reaction between the aldehydes **22**, **23**, and **24** and ethyl and isopropyl 4-diethoxyphosphoryl-3-methyl-2-butenoate (**30**) and (**31**), respectively. **30** and **31** were prepared from 3-methyl-2-butenoic acid (**25**) according to Scheme 6[13-15].

Scheme 6



The ethyl and isopropyl esters **26** and **27** were transformed into the bromo esters **28** and **29** by allylic bromination with NBS. **28** and **29** were mixtures of geometric isomers (*2E:2Z* in 1.2:1 ratio; GC, NMR). *Arbuzow* reaction[16,17] of these bromo esters with triethyl phosphite gave the phosphonates 30 and 31 as mixtures of *2E* and *2Z* isomers in 1.2:1 (GC, NMR) ratio.

The condensation reactions of the aldehydes **22, 23,** and **24** with **30** and **31** were carried out in dimethoxyethane using sodium hydride for the generation of the appropriate phosphonate anion and occured in about 65% yield. The obtained compounds **6 – 11** possessed exclusively *E* configuration of the C-4 double bond which was in accordance with the literature data[15,19,20]. However, they were mixtures of *2E* and *2Z* isomers as a consequence of using the (*E,Z*) phosphonates **30** and **31**.

In the NMR spectra of all analogs the signals of the C-2 methyl groups are presented as characteristic doublets (J = 1 Hz) at δ = 1.9 and 2.2. The signals at lower field (δ = 2.2) represent the *2E* isomers, the C-2 methyl groups of which are less shielded by an ester function[9]. For the same reason similar shifts are observed for the C-2 olefinic protons of the *2E* isomers which in all spectra appear as broad singlets at $\delta \approx 5.6$. Analogous signals of *2Z* isomers appear at $\delta \approx 5.5$. The broad multiplets at $\delta \approx 6$ presented in all spectra correspond to the absorptions of the C-4 and C-5 protons of the *2E* isomers and C-5 protons of the *2Z* isomers[2,15]. Finally, a doublet at $\delta \approx 7.5$ with a characteristic *trans*-coupling constant of J = 16 Hz is assigned to the most exposed C-4 proton of the *2Z* isomers. Using GC analysis we have determined contest of the individual geometric isomers of the analogs **6 – 11**. For the ethyl esters **6, 7,** and **8** the isomeric ratio *2E:2Z* is 1.3:1 and in the case of the isopropyl esters **9, 10,** and **11** it is a 1:1 ratio.

The analogs **6 – 11** were subjected to preliminary biological tests. The details concerning the juvenile hormone activity will be published later.

This work was done within the project MR I-12.1.5.3/2. Miss *Elżbieta Michalska* co-operated in the experiments.

Experimental

IR spectra: Specord 71 IR spectrometer. – ^{1}H NMR spectra: Tesla BS 487C 80 MHz spectrometer, internal standard was hexamethyldisiloxane (HMDSO). – GC: Perkin-Elmer 990 chromatograph; stationary phases: SE 30 (2.5%), PEG 4000 (5%); carrier: Chromosorb G AW DMCS (80–100 mesh). – TLC: Merck silica gel 60 F_{254}; pre-coated plates. – Column chromatography: Macherey-Nagel & Co. silica gel and Merck GF_{254} silica gel. – Optical rotations: Polamat A polarimeter. – Melting points: Boetius apparatus, without correction.

The following reagents were prepared according to the literature: *4-(1-cyclohexenyl)-2-butanone* (**15**): b. p. 81–83 °C/6 Torr, n_D^{20} = 1.4778 (lit.[1] b. p. 81–83 °C/6 Torr, n_D^{20} = 1.4778). – *Myrtenyl bromide* (**12**): b. p. 76–78 °C/2 Torr, n_D^{20} = 1.5237, $[\alpha]_D^{27}$ = –29.3 ° (lit.[21] b. p. 81 °C/1 Torr, n_D^{20} = 1.5234, $[\alpha]_D$ = –29.25 °). – *Pyridinium dichromate:* m. p. 143–145 °C (lit.[12] 144–146 °C). – *Ethyl 4-diethoxyphosphoryl-3-methyl-2-butenoate* (**30**): b. p. 124–128 °C/0.2 Torr, n_D^{20} = 1.4585 for the isomeric mixture (*E*:*Z* = 1.2:1) [lit.[6] b. p. 100–110 °C/0.4 Torr for the isomeric mixture (*E*:*Z* = 1.5:1)]. – *Isopropyl 4-diethoxyphosphoryl-3-methyl-2-butenoate* (**31**): b. p. 124–128 °C/0.1 Torr, n_D^{20} = 1.4550 for the isomeric mixture (*E*:*Z* = 1.2:1) [lit.[6] b. p. 100–110 °C/0.3 Torr for the isomeric mixture (*E*:*Z* = 1.5:1)].

Ethyl 3-oxo-2-(2-pinen-10-yl)butyrate (**13**): 58.5 g (0.45 mol) of ethyl acetoacetate was added dropwise to the solution of sodium ethoxide prepared from 9.2 g (0.4 mol) of sodium in 600 ml of dry ethanol. After refluxing for 3 h 86.0 g (0.4 mol) of **12** was added to the cooled reaction mixture and stirring and boiling were continued for additional 4 h. The precipitated sodium bromide was filtered off, the excess of ethanol was removed, and the residue was poured into water and extracted with ether. The extract was washed with brine and dried with $MgSO_4$. Removal of the solvent under reduced pressure and distillation gave 82.5 g (78%) of **13**, b. p. 127–130 °C/2 Torr, n_D^{20} = 1.4810, $[\alpha]_D^{24}$ = +9.45 ° (*c* = 2.028 in methanol). – GC: One peak. – IR (film): 1645 (C=C), 1720 (C=O), 1750 cm^{-1} (CO_2). – ^{1}H NMR (CCl_4): δ = 0.74 (s; 3H, CH_3–C–CH_3), 1.20 (t, *J* = 7 Hz; 3H, CH_2–CH_3), 1.22 (s; 3H, CH_3–C–CH_3), 2.08 (s; 3H, CH_3CO), 3.37 (t, *J* = 7 Hz; 1H, CH), 4.07 (q, *J* = 7 Hz; 2H, CH_2CH_3), 5.15 (m; 1H, C=CH).

$C_{16}H_{24}O_3$ (264.3) Calc. C 72.69 H 9.15 Found C 72.51 H 9.02

(2-Pinen-10-yl)propanone (**14**): The solutions of 79.2 g (0.3 mol) of **13** in 200 ml of ethanol and 156.0 g (0.5 mol) of $Ba(OH)_2 \cdot 8\,H_2O$ in 600 ml of water were mixed and refluxed for 18 h unter nitrogen. The cooled reaction mixture was poured into water with ice containing hydrochloric acid in order to dissolve barium carbonate. The solution was extracted with ether. The extract was washed with water, $NaHCO_3$ solution, brine, and dried with $MgSO_4$. After removing of the solvent the residue was distilled under reduced pressure giving 48.9 g (85%) of **14**, b. p. 104–106 °C/3 Torr, n_D^{20} = 1.4860, $[\alpha]_D^{17}$ = +26.1 ° (*c* = 2.081 in methanol). – GC: One peak. – IR (film): 1660 (C=C), 1720 cm^{-1} (C=O). – ^{1}H NMR (CCl_4): δ = 0.76 (s; 3H, CH_3–C–CH_3), 1.22 (s; 3H, CH_3–C–CH_3), 2.00 (s; 3H, CH_3CO), 5.09 (m; 1H, C=CH).

$C_{13}H_{20}O$ (192.3) Calc. C 81.20 H 10.48 Found C 81.41 H 10.35

Semicarbazone of **14**: m. p. 172–173 °C (ethanol).

Ethyl 5-(1-cyclohexenyl)-3-methyl-2-pentenoate (**16**): To a suspension of 3.96 g (0.132 mol) of 80% sodium hydride in 100 ml of dry dimethoxyethane, 29.6 g (0.132 mol) of ethyl diethoxyphosphorylacetate was added under argon, and the mixture was stirred for 1 h at room temperature. Then a solution of 16.7 g (0.11 mol) of the ketone **15** in 20 ml of dimethoxyethane was added dropwise at 20–30 °C, and the mixture was stirred at 50–60 °C for 7 h. The reaction mixture was cooled down, poured into water and extracted with ether. The extract was washed with brine and dried with $MgSO_4$. After removing of the solvent the residue was distilled under reduced pressure giving 21.8 g (89%) of **16**, b. p. 96–99 °C/0.1 Torr, n_D^{20} = 1.4822. – GC: Two peaks (2*E* and

2*Z* isomers, 11 : 1, respectively). – TLC: R_F = 0.79 (*n*-hexane/acetone 15 : 1). – IR (film): 1660 (C = C), 1720 cm^{-1} (C = O). – ^{1}H-NMR ($CDCl_3$): δ = 1.19 (t, *J* = 7 Hz; 3H, CH_2-CH_3), 1.80 (d, *J* = 1 Hz; 3-CH_3, 2*Z*), 2.09 (d, *J* = 1 Hz; 3-CH_3, 2*E*), 1.32 – 2.15 (m; 12H, CH_2), 4.05 (q, *J* = 7 Hz; 2H, CH_2-CH_3), 5.34 (bs; 1H, C = CH), 5.58 (bs; 2*Z*-H), 5.60 (bs; 2*E*-H).

$C_{14}H_{22}O_2$ (222.3) Calc. C 75.63 H 9.97 Found C 75.79 H 9.82

Ethyl 3-methyl-4-(2-pinen-10-yl)-2-butenoate (**17**) was prepared from 38.4 g (0.20 mol) of **14** as described for **16**. Thus 45.5 g (87%) of **17** was isolated, b. p. 122 – 123 °C/1 Torr, n_D^{20} = 1.4916, $[\alpha]_D^{21}$ = +20.8° (*c* = 2.301 in methanol). – GC: Two peaks (2*E* and 2*Z* isomers, 15 : 1, respectively). – IR (film): 1645 (C = C), 1710 cm^{-1} (C = O). – ^{1}H NMR ($CDCl_3$): δ = 0.75 (s; 3H, CH_3-C-CH_3), 1.16 (t, *J* = 7 Hz; 3H, CH_2-CH_3), 1.20 (s; 3H, CH_3-C-CH_3), 1.79 (d, *J* = 1 Hz; C-3 CH_3, 2*Z*), 2.05 (d, *J* = 1 Hz; 3-CH_3, 2*E*), 3.98 (q, *J* = 7 Hz; 2H, CH_2-CH_3), 5.13 (m; 1H, C = CH), 5.50 (bs; 2*Z*-H), 5.52 (bs; 2*E*-H).

$C_{17}H_{26}O_2$ (262.4) Calc. C 77.82 H 9.99 Found C 78.01 H 10.15

5-(1-Cyclohexenyl)-3-methyl-1-pentanol (**18**): The solution of 19.98 g (0.09 mol) of **16** in 130 ml of dry methanol and 130 ml of dry ether was added to 2000 ml of liquid ammonia at −78 °C. Then finely cut lithium (13.68 g, 1.98 mol) was added slowly during 1 h. The reaction mixture was stirred for 1 h at −78 °C, quenched with 500 ml of water and left to stand ca. 12 h at room temperature. After evaporating the ammonia the residue was extracted with ether. The extract was washed with water, brine, and dried with $MgSO_4$. After removing of the solvent the residue was purified by column chromatography: elution with *n*-hexane/acetone 4 : 1. Destillation under reduced pressure gave 12.41 g (76%) of **18**, b. p. 84 – 86 °C/0.05 Torr, n_D^{20} = 1.4840. – GC: One peak. – TLC: R_F = 0.38 (*n*-hexane/acetone 4 : 1). – IR (film): 1670 (C = C), 3340 cm^{-1} (OH). – ^{1}H NMR ($CDCl_3$): δ = 0.81 (d, *J* = 6 Hz; 3H, CH_3), 1.0 – 2.0 (m; 14H, CH_2), 3.10 (m; 1H, OH), 3.53 (t, *J* = 6.5 Hz; 2H, CH_2O), 5.31 (bs; 1H, C = CH).

$C_{12}H_{22}O$ (182.3) Calc. C 79.06 H 12.16 Found C 79.10 H 12.31

3,5-Dinitrobenzoate of **18**: m. p. 144 – 146 °C (methanol).

3-Methyl-4-(2-pinen-10-yl)butanol (**19**): It was prepared from 26.2 g (0.10 mol) of **17** as described for the alcohol **18**. Thus 16.1 g (72%) of **19** was isolated, b. p. 132 – 134 °C/1 Torr, n_D^{20} = 1.4882, $[\alpha]_D^{25}$ = +20.3° (*c* = 1.612 in methanol). – GC: One peak. – IR (film): 1650 (C = C), 3340 cm^{-1} (OH). – ^{1}H NMR (CCl_4): δ = 0.75 (s; 3H, CH_3-C-CH_3), 0.81 (d, *J* = 6 Hz; 3H, CH_3), 1.20 (s; 3H, CH_3-C-CH_3), 3.48 (t, *J* = 6.5 Hz; 2H, CH_2O), 5.08 (m; 1H, C = CH).

$C_{15}H_{26}O$ (222.4) Calc. C 81.02 H 11.79 Found C 80.88 H 11.65

3,5-Dinitrobenzoate of **19**: m. p. 152 – 153 °C (methanol).

1-Acetoxy-5-(1-cyclohexenyl)-3-methylpentane (**20**): To the solution of 5.28 g (0.029 mol) of **18** in 15 ml of pyridine 5.92 g (0.058 mol) of acetic anhydride was added. The solution was allowed to stand for ca. 12 h at room temperature. The reaction mixture was poured into water and extracted with ether. The extract was washed with water, sulfuric acid (1 : 10), water, saturated $NaHCO_3$ solution, brine, and dried with $MgSO_4$. After removing of the solvent the residue was distilled under reduced pressure giving 4.7 g (72%) of **20**, b. p. 80 – 82 °C/0.05 Torr, n_D^{20} = 1.4669. – GC: One peak. – TLC: R_F = 0.74 (*n*-hexane/acetone 15 : 1). – IR (film): 1670 (C = C), 1745 cm^{-1} (C = O). – ^{1}H NMR ($CDCl_3$): δ = 0.84 (d, *J* = 6 Hz; 3H, CH_3), 1.0 – 1.9 (m; 15H), 1.96 (s; 3H, OCH_3), 4.02 (t, *J* = 7 Hz; 2H, CH_2O), 5.32 (bs; 1H, C = CH).

$C_{14}H_{24}O_2$ (224.3) Calc. C 74.95 H 10.78 Found C 74.82 H 10.67

5-(1-Methoxycyclohexyl)-3-methylpentanol (**21**): To a vigorously stirred suspension of 5.42 g (0.017 mol) of mercury(II) acetate in 17 ml of dry methanol, 3.81 g (0.017 mol) of ester **20** was

added. The resulting mixture was stirred for 2 h at room temperature. Subsequently 17 ml of 3 M NaOH solution was added and stirred for 12 further hours. The coagulated mercury was filtered off and the solution extracted with ether. The extract was washed with water, brine, and dried with $MgSO_4$. After removing of the solvent the residue was distilled under reduced pressure giving 3.34 g (92%) of **21**, b. p. 101 – 103 °C/0.05 Torr, n_D^{20} = 1.4750. – GC: One peak. – TLC: R_F = 0.30 (*n*-hexane/acetone 4:1). – IR (film): 1060, 1070 (C – O), 3340 cm^{-1} (OH). – ^1H NMR ($CDCl_3$): δ = 0.82 (d, *J* = 6 Hz; 3H, CH_3), 0.94 – 1.96 (m; 17H), 3.0 (s; 1H, OH), 3.0 (s; 3H, OCH_3), 3.56 (t, *J* = 6.5 Hz; 2H, CH_2O).

$C_{13}H_{26}O_2$ (214.3) Calc. C 72.84 H 12.23 Found C 72.75 H 12.25

3,5-Dinitrobenzoate of **21**: m. p. 148 – 150 °C (methanol).

5-(1-Cyclohexenyl)-3-methylpentanal (**22**): To the solution of 6.55 g (0.036 mol) of **18** in 70 ml of dichloromethane, 27.07 g (0.072 mol) of finely powdered pyridinium dichromate was added portionwise. The reaction mixture was stirred for 12 h at room temperature, then diluted with ether and filtered. The solution was filtered through a short column filled with silica gel (100 – 200 mesh) and dried with $MgSO_4$. After removing of the solvent, the crude product was purified by column chromatography (elution with *n*-hexane/acetone 4:1). Distillation under reduced pressure gave 4.13 g (64%) of **22**, b. p. 61 – 62 °C/0.05 Torr, n_D^{20} = 1.4773. – GC: One peak. – TLC: R_F = 0.81 (*n*-hexane/acetone 4:1). – IR (film): 1650 (C=C), 1730 cm^{-1} (C=O). – ^1H NMR ($CDCl_3$): δ = 0.88 (d, *J* = 6 Hz; 3H, CH_3), 1.0 – 2.57 (m; 15H), 5.32 (bs; 1H, C=CH), 9.70 (t, *J* = 2 Hz; 1H, CHO).

$C_{12}H_{20}O$ (180.3) Calc. C 79.94 H 11.18 Found C 79.78 H 11.40

2,4-Dinitrophenylhydrazone of **22**: m. p. 81 – 83 °C (ethanol).

3-Methyl-4-(2-pinen-10-yl)butanal (**23**): It was prepared from 7.0 g (0.031 mol) of **19** as described for the aldehyde **22**. Thus 3.6 g (52%) of **23** was isolated, b. p. 98 – 100 °C/1 Torr, n_D^{20} = 1.4852, $[\alpha]_D^{23}$ = +23.3° (*c* = 1.025 in methanol). – GC: One peak. – IR (film): 1660 (C=C), 1730 cm^{-1} (C=O). – ^1H NMR (CCl_4): δ = 0.77 (s; 3H, CH_3-C-CH_3), 0.90 (d, *J* = 6 Hz; 3H, CH_3), 1.22 (s; 3H, CH_3-C-CH_3), 5.11 (m; 1H, C=CH), 9.62 (t, *J* = 2 Hz; 1H, CHO).

$C_{15}H_{24}O$ (220.3) Calc. C 81.76 H 10.98 Found C 81.59 H 10.81

2,4-Dinitrophenylhydrazone of **23**: m. p. 85 – 86 °C (ethanol).

5-(1-Methoxycyclohexyl)-3-methylpentanal (**24**): It was prepared from 3.12 g (0.015 mol) of **21** as described for the aldehyde **22**. Thus 2.55 g (82%) of **24** was isolated, b. p. 77 – 78 °C/0.05 Torr, n_D^{20} = 1.4666. – GC: One peak. – TLC: R_F = 0.68 (*n*-hexane/acetone 4:1). – IR (film): 1080 (C – O), 1735 cm^{-1} (C=O). – ^1H NMR ($CDCl_3$): δ = 0.90 (d, *J* = 6 Hz; 3H, CH_3), 1.0 – 2.37 (m; 17H), 3.03 (s; 3H, OCH_3), 9.70 (t, *J* = 2 Hz; 1H, CHO).

$C_{13}H_{24}O$ (212.3) Calc. C 73.53 H 11.39 Found C 73.80 H 11.51

2,4-Dinitrophenylhydrazone of **24**: m. p. 84 – 86 °C (methanol).

Ethyl 9-(1-cyclohexenyl)-3,7-dimethyl-2,4-nonadienoate (**6**): To a suspension of 0.33 g (0.011 mol) of 80% sodium hydride in 10 ml of dry dimethoxyethane, 2.904 g (0.011 mol) of **30** in 5 ml of dimethoxyethane was added at room temperature under argon. After stirring for 0.5 h at 20 – 30 °C 1.8 g (0.010 mol) of **22** in 5 ml of dimethoxyethane was added, and the reaction mixture was kept at 50 – 60 °C for 12 h. Subsequently it was poured into water, extracted with ether, and dried with $MgSO_4$. After removing of the solvent, the residue was distilled under reduced pressure giving 1.9 g (66%) of **6**, b.p. 128 – 136 °C/0.05 Torr, n_D^{20} = 1.5047. – GC: Two peaks, (2*E*,4*E*) and (2*Z*,4*E*) isomers, 1.3:1, respectively. – TLC: R_F = 0.84 (*n*-hexane/acetone 4:1). – IR

(film): 1055, 1160, 1245 (C–O), 1620, 1645, 1680 (C=C), 1720 cm^{-1} (C=O). – ^1H NMR ($CDCl_3$): δ = 0.82 (d, J = 6 Hz; 3H, 7-CH_3), 1.20 (t, J = 7 Hz; 3H, CH_2-CH_3), 1.90 (d, J = 1 Hz; 3-CH_3, 2*Z*), 2.20 (d, J = 1 Hz; 3-CH_3, 2*E*), 4.06 (q, J = 7 Hz; 2H, OCH_2), 5.31 (bs; 1H, C=CH), 5.52 (bs; H-2, 2*Z*), 5.62 (bs; H-2, 2*E*), 6.01 (bm; H-4, 2*E* and H-5, 2*E* and 2*Z*), 7.52 (d, J = 16 Hz; H-4, 2*Z*).

$C_{19}H_{30}O_2$ (290.4) Calc. C 78.57 H 10.41 Found C 78.49 H 10.35

Ethyl 3,7-dimethyl-8-(2-pinen-10-yl)-2,4-octadienoate (**7**): It was prepared from 3.3 g (0.015 mol) of **23** as described for **6**. Thus 3.1 g (63%) of **7** was isolated, b. p. 142–150°C/1 Torr, n_D^{20} = 1.5092, $[\alpha]_D^{19}$ = +15.1° (c = 0.532 in methanol). – GC: Two peaks, (2*E*,4*E*) and (2*Z*,4*E*) isomers, 1.3:1, respectively. – IR (film): 1050, 1160, 1240 (C–O), 1610, 1635, 1680 (C=C), 1710 cm^{-1} (C=O). – ^1H NMR (CCl_4): δ = 0.76 (s; 3H, CH_3-C-CH_3), 0.80 (d, J = 6 Hz; 3H, 7-CH_3), 1.17 (t, J = 7 Hz, 3H, CH_2-CH_3), 1.20 (s; 3H, CH_3-C-CH_3), 1.89 (d, J = 1 Hz; 3-CH_3, 2*Z*), 2.17 (d, J = 1 Hz; 3-CH_3, 2*E*), 4.03 (q, J = 7 Hz; 2H, OCH_2), 5.01 (m; 1H, C=CH), 5.47 (bs; H-2, 2*Z*), 5.56 (bs; H-2, 2*E*), 5.98 (bm; H-4, 2*E* and H-5, 2*E* and 2*Z*), 7.51 (d, J = 16 Hz; H-4, 2*E*).

$C_{22}H_{34}O_2$ (330.5) Calc. C 79.95 H 10.37 Found C 80.11 H 10.25

Ethyl 9-(1-methoxycyclohexyl)-3,7-dimethyl-2,4-nonadienoate (**8**): It was prepared from 1.06 g (0.005 mol) of **24** as described for **6**. Thus 1.103 g (69%) of **8** was isolated, b. p. 136–144°C/0.05 Torr, n_D^{20} = 1.5033. – GC: Two peaks, (2*E*,4*E*) and (2*Z*,4*E*) isomers, 1.3:1, respectively. – TLC: R_F = 0.80 (*n*-hexane/acetone 4:1). – IR (film): 1060, 1090, 1160, 1245 (C–O), 1615, 1645 (C=C), 1720 cm^{-1} (C=O). – ^1H NMR ($CDCl_3$): δ = 0.83 (d, J = 6 Hz; 3H, 7-CH_3), 1.20 (t, J = 7 Hz; 3H, CH_2-CH_3), 1.90 (d, J = 1 Hz; 3-CH_3, 2*Z*), 2.20 (d, J = 1 Hz; 3-CH_3, 2*E*), 3.04 (s, 3H, OCH_3), 4.06 (q, J = 7 Hz; 2H, OCH_2), 5.51 (bs; H-2, 2*Z*), 5.60 (bs; H-2, 2*E*), 6.02 (bm; H-4, 2*E* and H-5 2*E* and 2*Z*), 7.52 (d, J = 16 Hz; H-4, 2*Z*).

$C_{20}H_{34}O_3$ (322.5) Calc. C 74.49 H 10.63 Found C 74.42 H 10.68

Isopropyl 9-(1-cyclohexenyl)-3,7-dimethyl-2,4-nonadienoate (**9**): It was prepared from 1.116 g (0.006 mol) of **22** and 1.896 g (0.0068 mol) of **31** as described for **6**. Thus 1.202 g (64%) of ester **9** was isolated, b. p. 122–134°C/0.05 Torr, n_D^{20} = 1.5080. – GC: Two peaks, (2*E*,4*E*) and (2*Z*,4*E*) isomers, 1:1, respectively. – TLC: R_F = 0.86 (*n*-hexane/acetone 4:1). – IR (film): 1055, 1160, 1245 (C–O), 1620, 1645, 1680 (C=C), 1720 cm^{-1} (C=O). – ^1H NMR ($CDCl_3$): δ = 0.82 (d, J = 6 Hz; 3H, 7-CH_3), 1.19 (d, J = 7 Hz; 6H, isopropyl CH_3). 1.90 (d, J = 1 Hz; 3-CH_3, 2*Z*), 2.19 (d, J = 1 Hz; 3-CH_3, 2*E*), 4.97 (h, J = 7 Hz; 1H, OCH=), 5.31 (bs; 1H, C=CH), 5.52 (bs; H-2, 2*Z*), 5.61 (bs; H-2, 2*E*), 6.03 (bm; H-4, 2*E* and H-5, 2*E* and 2*Z*), 7.52 (d, J = 16 Hz; H-4, 2*Z*).

$C_{20}H_{32}O_2$ (304.7) Calc. C 78.89 H 10.59 Found C 79.02 H 10.52

Isopropyl 3,7-dimethyl-8-(2-pinen-10-yl)-2,4-octadienoate (**10**): It was prepared from 2.2 g (0.01 mol) of **23** and 3.06 g (0.11 mol) of **31** as described for **6**. Thus 2.2 g (64%) of **10** was isolated, b.p. 150–160°C/1 Torr, n_D^{20} = 1.5005, $[\alpha]_D^{21}$ = +13.7° (c = 0.508 in methanol). – GC: Two peaks, (2*E*,4*E*) and (2*Z*,4*E*) isomers, 1:1, respectively. – IR (film): 1050, 1160, 1250 (C–O), 1610, 1650, 1690 (C=C), 1710 cm^{-1} (C=O). – ^1H NMR (CCl_4): δ = 0.75 (s; 3H, CH_3-C-CH_3), 0.82 (d, J = 1 Hz; 3H, 7-CH_3), 1.16 (d, J = 7 Hz; 6H, isopropyl CH_3), 1.20 (s; 3H, CH_3-C-CH_3), 1.90 (d, J = 1 Hz; 3-CH_3, 2*E*), 2.16 (d, J = 1 Hz; 3-CH_3, 2*E*), 4.96 (h, J = 7 Hz; 1H, OCH=), 5.09 (m, 1H, C=CH), 5.45 (bs; H-2, 2*Z*), 5.53 (bs; H-2, 2*E*), 5.97 (bm; H-4, 2*E* and H-5, 2*E* and 2*Z*), 7.51 (d, J = 16 Hz; H-4, 2*Z*).

$C_{23}H_{36}O_2$ (344.5) Calc. C 80.18 H 10.53 Found C 80.31 H 10.36

Isopropyl 9-(methoxycyclohexyl)-3,7-dimethyl-2,4-nonadienoate (**11**): It was prepared from 1.06 g (0.005 mol) of **24** and 1.53 g (0.0055 mol) of **31** as described for **6**. Thus 1.11 g (66%) of **11** was isolated, b. p. 136–146 °C/0.05 Torr, n_D^{20} = 1.5013. – GC: Two peaks, (2*E*,4*E*) and (2*Z*,4*E*) isomers, 1:1, respectively. – TLC: R_f = 0.84 (*n*-hexane/acetone 4:1). – IR (film): 1060, 1160, 1245 (C=O), 1615, 1645 (C=C), 1720 cm^{-1} (C=O). – ^1H NMR ($CDCl_3$): δ = 0.83 (d, *J* = 6 Hz; 3H, 7-CH_3), 1.18 (d, *J* = 7 Hz; 6H, isopropyl CH_3), 1.90 (d, *J* = 1 Hz; 3-CH_3, 2*Z*), 2.19 (d, *J* = 1 Hz; 3-CH_3, 2*E*), 3.04 (s; 3H, OCH_3), 4.97 (h, *J* = 7 Hz; 1H, OCH=), 5.51 (bs; H-2, 2*Z*), 5.60 (bs; H-2, 2*E*), 6.03 (bm; H-4, 2*E* and H-5, 2*E* and 2*Z*), 7.52 (d, *J* = 16 Hz; H-4, 2*Z*).

$C_{21}H_{36}O_3$ (336.5) Calc. C 74.95 H 10.78 Found C 74.86 H 11.00

---

1) Part I: *L. Borowiecki* und *A. Kazubski*, Pol. J. Chem. **52**, 1447 (1978).
2) *C. A. Henrick, G. B. Staal,* and *J. B. Siddall,* J. Agric. Food Chem. **21**, 354 (1973).
3) *C. A. Henrick, W. E. Willy, B. A. Garcia,* and *G. B. Staal,* J. Agric. Food. Chem. **23**, 396 (1975).
4) *Ceskoslovenska Akademie Ved* (Erf. *L. Streinz, M. Romanuk, F. Šorm,* and *F. Sehnal*), Ger. Offen. 2244837 (03. April 1975) [Chem. Abstr. **83**, 38821 v (1975)].
5) *F. Sehnal, M. Romanuk,* and *L. Streinz,* Acta Entomol Bohemoslov. **73**, 1 (1976).
6) *M. Kozłowska* and *W. Sobótka,* Pol. J. Chem. **53**, 1805 (1979).
7) *M. Ohki, K. Mori,* and *M. Matsui,* Agric. Biol. Chem. **36**, 979 (1972).
8) *K. H. Dahm, B. M. Trost,* and *H. Röller,* J. Am. Chem. Soc. **89**, 5292 (1967).
9) *L. M. Jackman,* Zastosowanie spektroskopii magnetycznego rezonansu jądrowego w chemii organicznej, p. 198, PWN, Warszawa 1962.
10) *D. Caine,* Organic Reactions, Vol. 23, p. 1, John Wiley and Sons Inc., New York 1976.
11) *H. C. Brown* and *M. H. Rei,* J. Am. Chem. Soc. **91**, 5646 (1969).
12) *E. J. Corey* und *G. Schmidt,* Tetrahedron Lett. **1979**, 399.
13) *L. Ahmad, R. N. Gedye,* and *A. Nechvatel,* J. Chem. Soc. C **1968**, 185.
14) *J. B. Davis, L. M. Jackman, P. T. Siddons,* and *B. C. L. Weedon,* J. Chem. Soc. C **1966**, 2154.
15) *G. Pattenden* and *B. C. L. Weedon,* J. Chem. Soc. C **1968**, 1984.
16) *B. A. Arbuzow,* Pure Appl. Chem. **9**, 307 (1964).
17) *P. C. Crofts,* Q. Rev., Chem. Soc. **12**, 341 (1958).
18) *W. S. Wadworth, Jr.* and *W. D. Emmons,* J. Am. Chem. Soc. **83**, 1733 (1961).
19) *G. Pattenden* and *B. C. L. Weedon,* J. Chem. Soc. C **1968**, 977.
20) *G. Pattenden,* J. Chem. Soc. C **1970**, 1404.
21) *G. Ohloff, H. Farnow,* and *G. Schade,* Chem. Ber. **89**, 1549 (1956).

[58/82]