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FUNCTIONALIZED CYCLOPENTANE DERIVATIVES FROM THE PHOTOADDUCTS OF METHYL 2,4-DIOXOPENTANOATE-OLEFINS: ALTERNATIVE SYNTHESES OF dl-DEHYDROIRIDODIAL AND dl-CHRYSOMELIDIAL

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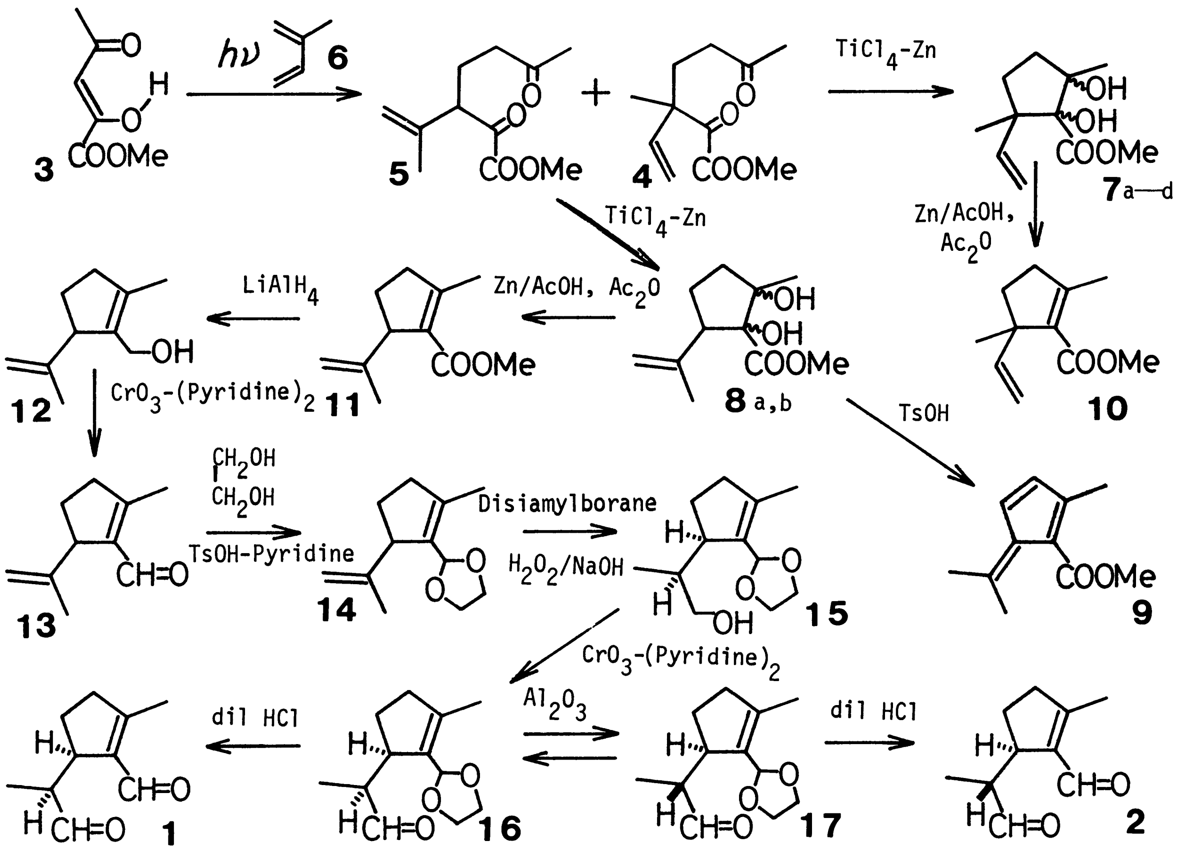
Functionalized cyclopentane derivatives were prepared by the *retro*-ozonolysis of methyl 2,6-dioxoheptanoates, which are readily accessible from the photocycloaddition of methyl 2,4-dioxopentanoate with olefins. By this method, 3-isopropenyl-2-methoxycarbonyl-1-methylcyclopentene, a versatile intermediate to iridoid terpenoids, and 1-methoxycarbonyl-2,6,6-trimethylfulvene were synthesized from isoprene. Alternative syntheses of *dl*-dehydroiridodial and *dl*-chrysomelidial were accomplished.

Photocycloaddition is a versatile technique to construct certain alicyclic systems under mild conditions,[1)] but, the ring sizes feasible in this strategy are usually limited to four- and six-membered rings.[2,3)] To date, no versatile photochemical formation of the cyclopentanes is known,[4)] and it is desirable to develop a practical route for the cyclopentanes. This paper will describe an achievement of the point, *i.e.*, alternative syntheses of dehydroiridodial (**1**), a constituent of *Actinidia polygama*,[5)] and chrysomelidial (**2**), a component of the defensive secretion of the insect, *Plagiodera versicolora*.[6)]

2,6-Heptanediones prepared by the photocycloaddition of acetylacetone (**A**) with olefins are readily dehydrated with acid or base to cyclohexenones under very mild conditions,[2)] and our several efforts to convert them to the functionalized cyclopentene derivatives by reductive cyclizations have been unsuccessful. On the other hand, the 2,6-dioxoheptanoates, analogous photocycloadducts of methyl 2,4-dioxopentanoate (**3**) with olefins, needed more severe conditions to form the cyclohexenones,[3)] and the titanium(II)-chloride-catalyzed reductive coupling[7)] of these photoadducts may become competent.

By the titanium(II)-chloride-induced reductive cyclization under the Mukaiyama's conditions, the photoadducts, methyl 3-methyl-3-vinyl-2,6-dioxoheptanoate (**4**) and methyl 3-isopropenyl-2,6-dioxoheptanoate (**5**) obtained from isoprene (**6**) and **3**,[8)] respectively yielded 1,2,3-trisubstituted cyclopentanediols; **4** gave four isomeric glycols, **7a** (colorless granules, mp 59.5-60.5°C, 16%), **7b** (colorless prisms, mp 66-66.5°C, 1.2%), **7c** (colorless needles, mp 105.5-106°C 4%), and **7d** (colorless plates, mp 25°C, 14%), while **5** gave two oily glycol isomers, **8a** (49%) and **8b** (23%). The Cyclopentane frameworks in **7** and **8** were proven by a ready dehydration of 8a with *p*-toluenesulfonic acid (TsOH) in benzene to 1-methoxycarbonyl-2,6,6-trimethylfulvene (9, a yellow oil, 85%) [ν: 1715, 1240, 945, 880 cm^{-1}. λ_{max}^{MeOH}: 282.5 nm (ε=3800), 230(2000), 360(500)].



By the zinc-in acid reduction with acetic acid and acetic anhydride, 7 and 8 respectively yielded 2-methoxycarbonyl-1,3-dimethyl-3-vinylcyclopentene (10, a colorless oil, 95% from 7a), and 3-isopropenyl-2-methoxycarbonyl-1-methylcyclopentene (11, a colorless oil, 74% from a 1:1-mixture of 8a and 8b)[9,10) [ν: 1720, 1220, 890 cm^{-1}]. From 11, an oily allylalcohol (12, 71%),[10) and an α,β-unsaturated aldehyde (13, 97%),[10) were consecutively prepared.

From this versatile 13, we have completed a four-step synthesis of recently-identified iridoid dials, 1 and 2. Treatment of 13 with 1,2-ethanediol, TsOH, and pyridine in benzene gave a colorless-oily acetal (14, 77%). This was then consecutively treated with disiamylborane in diglyme and basic hydrogen peroxide to diastereospecifically form a hydroxy acetal (15, a colorless oil, 81%). Collins oxidation of 15 in dichloromethane gave an acetal aldehyde (16, a colorless oil, 65%), which, upon hydrolysis with 0.2 M hydrochloric acid in aqueous ether, gave a dialdehyde (95%), whose NMR have confirmed the identity with 1. The previous syntheses of 1, similar in principle to the present method, was less stereoselective than this; the work-up involved a tedious fractionation.

Subsequent conversion of 16 to 2[12) was rather straightforward: By contact with alumina at room temperature for 24 h, 16 caused a partial epimerization to form another acetal aldehyde (17, a colorless oil), in 1:1. From this mixture, 17 was isolated by means of the high-pressure liquid chromatography (microporasil: hexane-ethyl acetate), and then hydrolyzed similarly to give the other dialdehyde (95%) whose identity with 2 has been confirmed by the NMR analysis.[6b,11,13]

As described, the photocycloadducts obtained from 3 with 6, *e.g.*, 4 and 5, are useful common precursors for various cyclopentane monoterpenoids. And, since 3, in sharp contrast to a simple β-diketone, is reactive toward various conjugated olefins,[14] it suggests that the photoaddition of isoprene oligomers, *e.g.*, myrcene or farnesene, with 3 should provide versatile precursors for the higher terpenoids of one more isoprene unit having a proper head-to-tail linkage. Further works on this line are in progress, and the results will be reported in future.

The NMR Data of Some Compounds (δ units from the internal Me$_4$Si in CDCl$_3$)

^{1}H-NMR Spectra.

7a: 1.10(3H, s), 1.28(3H, s), 1.6-2.3(4H, m), 2.90(1H, br. s, OH), 3.71(3H, s), 3.84(1H, s, OH), 4.92(1H, dd, J=10.5, 1.5 Hz), 4.99(1H, dd, J=17.5, 1.5 Hz), and 5.79(1H, dd, J=17.5, 10.5 Hz).

7d: 1.03(3H, s), 1.13(3H, s), 1.7-2.2(4H, m), 2.64(1H, br.s, OH), 3.64(1H, s, OH), 3.80(3H, s), 5.03(1H, dd, J=10.5, 1.5 Hz), 5.05(1H, dd, J=18, 1.5 Hz), and 6.34(1H, dd, J=18, 10.5 Hz).

8a: 1.26(3H, s), 1.4-2.1(5H, m), 1.72(3H, s), 3.79(3H, s), 4.80(1H, m), and 4.88(1H, m).

8b: 1.29(3H, s), 1.4-2.1(5H, m), 1.72(3H, s), 3.81(3H, s), 4.98(1H, m), and 5.08(1H, m).

9: 2.04(3H, s), 2.08(3H, s), 2.11(3H, s), 3.69(3H, s), 6.07(1H, d, J=5 Hz), and 6.48(1H, d, J=5 Hz).

10: 1.03(3H, s), 1.6-2.0(2H, m), 2.05(3H, br. s), 2.39(2H, tm, J=7 Hz), 3.67(3H, s), 4.90(1H, dd, J=10.5, 1.5 Hz), 4.91(1H, dd, J=17.5, 1.5 Hz), and 5.96(1H, dd, J=17.5, 10.5 Hz).

11: 1.68(3H, br. s), 1.4-2.2(4H, m), 2.12(3H, br. s), 3.50(1H, m), 3.66(3H, s), and 4.64(2H, m).

12: 1.64(3H, br. s), 1.3-2.3(6H, m), 1.72(3H, br. s), 3.97(1H, d, J=12 Hz), 4.20(1H, d, J=12 Hz), and 4.75(2H, m).

14: 1.64(3H, br. s), 1.4-2.6(4H, m), 1.81(3H, br. s), 3.50(1H, br. m), 3.7-4.1(4H, m), 4.58(1H, br. s), 4.67(1H, br. s), and 5.49(1H, s).

15: 0.88(3H, d, J=7 Hz), 1.5-2.4(5H, m), 1.76(3H, br. s), 2.63(1H, br. t, OH), 3.01(1H, br. m), 2.7-3.2(2H, m, changed to 3.31(1H, dd, J=11, 6 Hz) and 3.54(1H, dd, J=18, 8 Hz) by addition of D$_2$O), and 3.54(1H, dd, J=11, 8 Hz).

16: 1.01(3H, d, J=7 Hz), 1.58(1H, m), 1.77(3H, br. s), 1.9-2.2(3H, m), 2.70(1H, qd, J=7, 3.5 Hz), 3.33(1H, br. m), 3.7-4.1(4H, m), 5.51(1H, s), and 9.65(1H, s).

1: 0.99(3H, d, J=7 Hz), 1.63(1H, m), 2.08(1H, m), 2.16(3H, br. s), 2.54(2H, m), 2.80(1H, qdd, J=7, 4, 1 Hz), 3.40(1H, br. m), 9.62(1H, d, J=1 Hz), and 9.97(1H, s).

17: 0.96(3H, d, J=7 Hz), 1.44(1H, m), 1.78(3H, br. s), 1.7-2.4(3H, m), 2.86(1H, qd, J=7, 3.5 Hz), 3.55(1H, br. m), 3.7-4.1(4H, m), 5.51(1H, s), and 9.64(1H, s).

2: 0.89(3H, d, J=7 Hz), 2.17(3H, br. s), 1.3-2.2(2H, m), 2.54(2H, m), 3.10(1H, qdd, J=7, 4, 1 Hz), 3.65(1H, br. m), 9.67(1H, d, J=1 Hz), and 9.96(1H, s).

^{13}C-NMR Spectra.

11: 14.3, 20.4, 28.7, 39.2, 50.8, 53.2, 109.1, 128.8, 147.0, 156.7, and 166.5.

1: 10.7, 14.6, 25.6, 39.5, 45.4, 48.3, 137.6, 165.5, 188.2, and 204.6.

2: 7.8, 14.5, 23.1, 40.1, 42.9, 48.1, 137.4, 165.3, 188.0, and 204.3.

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