87. The Natural Occurrence of the Campholenyl Skeleton, Another «Non-isoprenoid» Monoterpene System

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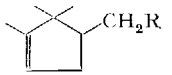
Summary. In the essential oil of *Juniperus communis L.* (fruit), campholenic aldehyde and its epoxide have been identified, together with the corresponding alcohol and its acetate. This is the first time the natural occurence of 2-(2, 2, 3-trimethylcyclopent-3-en-1-yl)-ethyl system is reported.

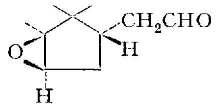
Although campholenic aldehyde (**1**) has been known for more than 60 years as a product of the photolysis of camphor [1], its natural occurrence has not so far been reported. This publication concerns the discovery of several campholenyl derivatives in the oil from the fruit of *Juniperus communis*, L.

Although the fruit from this species has been examined previously [2][1], we do not agree with *von Rudloff* [3] that the examinations have been very thorough, as they have been mostly restricted to those of hydrocarbons present, which constitute the bulk of the oil – indeed, *von Rudloff*'s own examination of the leaf oil[2] is considerably better than most of the earlier analyses of the fruits.

The details of the isolation of campholenic aldehyde (**1**) and its *trans*-epoxide (**2**), as well as the alcohol **3** and its acetate **4**, are given in the experimental section. It is very probably that the 'unknown aldehyde' that *von Rudloff* found in the leaf oil of Canadian *J. communis* is campholenic aldehyde, judged by the spectral data he reported [3]. The finding of campholenic aldehyde in an oil that contains a high proportion of α-pinene[3] would not be surprising: indeed, it has been reported [7] that the action of carbon dioxide on pinene epoxide gives a mixture of sobrerol (**5**) and campholenic aldehyde (**1**), so that the aldehyde could arise as an autoxidation product



1 $R = CHO$
3 $R = CH_2OH$
4 $R = CH_2OCOCH_3$



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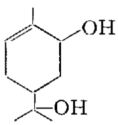

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[1] For list of earlier analyses see [2a and 2b] and later references.

[2] For leaf oil analyses see [2c] and [3].

[3] Generally, authors have been reticent about the rotation of the α-pinene they identified in juniper oil. An early report [4a] (refers to Norwegian oil, see also [4b]) states that (–)-α-pinene was present, while oil from a different geographical source (Indian oil) was quoted as (+) [5]. *von Rudloff* found $[\alpha]_D$ –20.2° for the α-pinene from his leaf oil [3]. Our juniper oil yielded an α-pinene having $[\alpha]_D^{20}$ –27.2° (neat). The amounts of pinene reported in the different oils also vary considerably; that for our oil was approximately the same as that given by *Klein & Farnow* (26.5%) [6].

of pinene. One might postulate further autoxidation for the formation of the aldehyde epoxide (**2**), but such an explanation cannot apply to campholenic alcohol or its acetate, and there is thus no doubt that the skeleton is present in nature. Its formation might well be from a pinane or bornane precursor.

The substances used for comparison with natural materials were all made by common techniques, the epoxidation of campholenic aldehyde (**1**) yielding only a single epoxide, which we presumed from the examination of models to be *trans*, by peracid attack from the least hindered side of the molecule.

On account of the very low optical rotations of campholenic derivatives in general, we do not think that discussion of the chirality of the natural products is justified at this time.

Experimental Part

NMR. spectra were recorded on a *Hitachi Perkin-Elmer* R-20B instrument, and chemical shifts are given in ppm with tetramethylsilane as 0.00 ppm. IR. spectra were measured with a *Perkin-Elmer* type 125 spectrophotometer. Mass spectra were measured on an *Atlas* CH4 mass spectrometer, using an inlet temperature of about 150° and electrons of 70 eV energy. Gas chromatography (GLPC.) was carried out on a *Carlo Erba* Fractovap type P (preparative) or a *Carlo Erba* type GT instrument, using Carbowax 20M, 15% on Chromosorb W60–80 mesh, acid-washed. All products isolated by GLPC. on the Carbowax columns were checked for purity on silicone oil columns.

Isolation of the campholenyl derivatives from J. communis *oil.* Repeated distillation of the commercial oil yielded a small fraction (0.1%), b.p. 82–88°/10 Torr[4]), chromatography of which on silica gel allowed a fraction to be eluted that had Rf 0.67 in benzene/chloroform (1:1) on thin-layer chromatography (TLC.); this polarity lies between that of the hydrocarbons (Rf ca. 0.95) and that of menth-1-en-4-ol (Rf 0.34) in this solvent system. GLPC. on Carbowax allowed the main component of this fraction to be collected and identified spectrally as *oct-1-en-3-yl acetate.* A compound having a retention time of nearly $1^1/_2$ times that of the octenyl acetate was isolated by preparative gas chromatography; it was identical in all respects (NMR., IR. and mass spectra, and retention times on silicone oil and Carbowax GLPC.) with *campholenic aldehyde.* The Rf value (TLC.) of the spot observed before GLPC. was the same as that of campholenic aldehyde, so the latter was not an artefact formed on GLPC.

In the same fraction from the silica gel column, the Carbowax GLPC. revealed a component with just over twice the retention time of campholenic aldehyde. After purification by preparative gas chromatography, this had NMR. and mass spectra and GLPC. retention identical with those of authentic *campholenic aldehyde epoxide* (see below); $[\alpha]_D^{20}$ – 0.83° (c = 10% in CCl_4).

The fraction of the juniper oil that distilled just after the previously described fraction, and which had b.p. 89–96°/10 Torr, constituted about 4% of the oil, and consisted mainly of *menth-1-en-4-ol.* Chromatography on silica gel of 140 g of this material in benzene resulted in the elution of, first, 2.2 g of *hydrocarbons*, followed by 1.7 g of a fraction containing mostly oxygenated compounds. The latter were separated by GLPC. into the following components (in order of elution): 1. *Fenchyl acetate* (7% of the fraction); 2. *Campholenyl acetate* (22% of the fraction), identical in all respects with an authentic sample, $[\alpha]_D^{20}$ – 0.95° (c = 10% in CCl_4); 3. *Methyl citronellate* (29%); 4. *Bornyl acetate* (36%); 5. *Cuminaldehyde* (5%).

A fraction of the crude oil distilling after the menth-1-en-4-ol, with b.p. 49–50°/0.3 Torr constituted about 0.4% of the total, and was further purified by chromatography in benzene on silica gel. After elution of the acetates (mostly terpenyl acetates together with a trace of camphol-

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[4]) This fraction is traditionally the fraction of juniper oil that has the most interesting organoleptic properties, and was originally reported to be a mixture of alcohols and '4-terpineol' (cf. [8]).

enyl acetate), a fraction consisting of 95% ***undecan-2-one*** was obtained, followed finally by a fraction containing alcohols. This was a very complex mixture, but the following compounds were isolated by preparative GLPC. on Carbowax: 1. α-Terpineol; 2. Citronellol; 3. ***Campholenyl alcohol***, identical in all respects with the authentic sample. These three alcohols constituted more than half the fraction.

2,2,3-Trimethylcyclopent-3-en-1-yl-acetaldehyde (*campholenic aldehyde*, **1**)[6]. This was made from (+)-pinene epoxide with zinc bromide [9], and had b.p. 77°/10 Torr, $[\alpha]_D^{20}$ $-3.1°$ ($c = 10\%$ in CCl_4).

2,2,3-Trimethyl-3,4-epoxy-cyclopentyl-acetaldehyde (**2**). A mixture of 10 g of campholenic aldehyde and 5 g of sodium acetate was stirred at 0° in 500 ml of methylene chloride while 1.1 equivalents of peracetic acid were added. After 18 h the reaction was complete, and the mixture was washed with water to neutrality, dried, concentrated, and distilled. The title product had b.p. 101–102°/10 Torr, and was purified by GLPC. NMR. spectrum: 0.76, 0.99, 1.27 (*s*, 3H each, $CH_3-\overset{|}{\underset{|}{C}}-$), 1.8–2.4 (mult., 4H), 3.13 (*s*, 1H, $-\overset{O}{\overbrace{CH-C}}\!<$, note the lack of coupling with the adjacent CH_2 group), 9.66 (*d*, $J = 1.5$ Hz, 1H, —C*H*O). Mass spectrum, *m/e* (% relative abundance): 41 (100), 43 (97), 83 (93), 55 (85), 69 (44), 109 (41), 125 and 153 (6). $[\alpha]_D^{20}$ $-1.1°$ ($c = 10\%$ in CCl_4).

2-(2,2,3-Trimethylcyclopent-3-en-1-yl)-ethanol (*campholenic alcohol*, **3**). This was made by reduction of the aldehyde with lithium aluminium hydride in ether. $[\alpha]_D^{20}$ $-1.5°$ ($c = 8\%$ in CCl_4). – *Acetate of* **3**. Made by acetylation of the alcohol with acetic anhydride in pyridine; $[\alpha]_D^{20}$ $-0.98°$ ($c = 8\%$ in CCl_4).

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[6] We are very grateful to Dr. *E. Sundt* and Mr. *B. Egger* for a generous sample of this substance.