

α -, β -, AND γ -PINACENES - NEW DITERPENOIDS

FROM THE OLEORESINS OF *Pinus koraiensis*

AND *P. sibirica*

V. A. Raldugin, N. K. Kashtanova,
and V. A. Pentegova

UDC 547.914

The cembrane diterpenoids isolated from the oleoresins of species of *Pinus* (Pinaceae) consist of cembrene [1], isocembrene, isocembrol [2, 3], and neocembrene [4]. In continuing a study of the components of the oleoresin of *Pinus koraiensis* Sieb. et Zucc, we have isolated from it three new cembrane diterpenoid hydrocarbons, which we have called α -, β -, and γ -pinacenes.

On the basis of analytical and mass-spectrometric results, these compounds have the formula $C_{20}H_{32}$. The IR spectra of the pinacenes show the absence from them of exomethylene and trans-disubstituted double bonds. The exhaustive hydrogenation of α - and β -pinacenes gave octahydro derivatives identical (GLC and mass spectrometry) with an authentic sample of cembrane (octahydrocembrene).

In the NMR spectrum of β -pinacene (Fig. 1, curve b), a doublet at 1.00 ppm is due to the methyls of an isopropyl group. (The spectrum was recorded on an instrument with a working frequency of 100 MHz.) The methine proton of the isopropyl group resonates at 3.00 ppm. (Only five lines of the septet are clearly visible, $J=7.0$ Hz.) Thus, the isopropyl group in this compound is present on a double bond. Two protons of a conjugated diene system, whose presence is confirmed by the UV spectrum [λ_{\max} 253 nm ($\log \epsilon$ 4.32)] form an AB system with δ_A 5.66; δ_B 6.07 ppm, ($J_{AB}=12$ Hz). The signals of the B part of the AB system are somewhat broadened, possibly because of the spin-spin coupling of the proton responsible for these signals with a neighboring vinyl methyl group resonating at 1.77 ppm. The chemical shifts of the coincident signals of two other methyl groups (1.56 ppm) show that these groups are present on nonconjugated double bonds. The conjugated diene system of β -pinacene is therefore present in the cembrane skeleton between the methyl and isopropyl groups.

The protons of the two isopropyl double bonds of β -pinacene give a broad multiplet at 4.94 ppm. The absence of any signals whatever in the 2.35-4.00 ppm region, apart from the signal of the methine proton of the isopropyl group shows the absence of the $=C-CH_2-C=$ fragment from the β -pinacene molecule [5, 6]. These results permit structure 1 (with undetermined configurations of the double bonds) to be put forward for β -pinacene.

The UV spectra of α - and γ -pinacenes [λ_{\max} 254, 252 nm ($\log \epsilon$ 3.75, 4.11), respectively] are similar to that of β -pinacene. The NMR spectra of α - and γ -pinacenes (Fig. 1, curves a and c) differ from that of β -pinacene by the chemical shifts of the signals of the protons in the groups common to all three pinacenes. The most substantial difference of the NMR spectra of α - and γ -pinacenes from that of β -pinacene is the appearance of an AB system of the protons of a conjugated diene system and the displacement of the signal of the methine proton of the isopropyl group to a somewhat stronger field.

The spectral and chemical information obtained shows that α - and γ -pinacenes possess the same structure as β -pinacene (1). Their difference is therefore due to different geometrical configurations of the double bonds. The absence of optical activity from all three pinacenes agrees with the structure of cembra-1,3,7,11-tetraene (1) established for them. It is interesting to observe that, unlike their sesqui-

Novosibirsk Institute of Organic Chemistry, Siberian Branch, Academy of Sciences of the USSR.
Translated from *Khimiya Prirodnykh Soedinenii*, No. 5, pp. 604-608, September-October, 1971. Original article submitted June 7, 1971.

© 1974 Consultants Bureau, a division of Plenum Publishing Corporation, 227 West 17th Street, New York, N. Y. 10011. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission of the publisher. A copy of this article is available from the publisher for \$15.00.

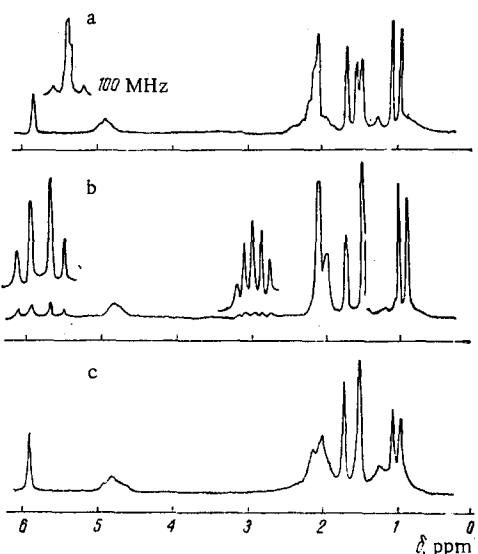


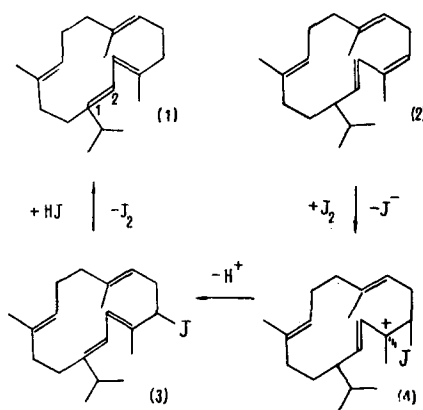
Fig. 1. NMR spectrum (60 MHz) of α -pinacene (a), β -pinacene (b), and γ -pinacene (c).

terpene analog, germacrene C [7], the pinacenes are stable with respect to the adsorbents used. The presence of α -, β -, and γ -pinacenes in the initial mixture of neutral diterpenoids of *Pinus koraiensis* Sieb. et Zucc was confirmed by GLC.

On attempting to obtain geometrical isomers of cembrene at the C_2 and C_4 double bonds, we first studied the iodine-catalyzed isomerization of cembrene (2). However, instead of the expected geometrical isomers a mixture of four hydrocarbons was formed, one of which was unchanged cembrene while the other three were identical, according to their NMR spectra and TLC and GLC behavior, with natural α -, β -, and γ -pinacenes. According to the NMR spectrum, the total reaction products consisted of cembrene and α -, β -, and γ -pinacenes in a ratio of 3:1:5:1. When each of the three pinacenes was kept with iodine under the same conditions, no interconversion was observed. Consequently, the ratio of the isomerization products is determined not by their relative thermodynamic stabilities, as has been reported for cis- and trans-alloocimenes [8] and for substituted vinyl ethers [9] but by kinetic control in the formation of the pinacenes from an intermediate compound.

3-trans, 7-trans, 11-trans-2,5-Dihydrocembrene, which we obtained [10] from cembrene, does not change on treatment with iodine under the conditions for the isomerization of cembrene. Thus, the nonconjugated trisubstituted trans double bonds in the cembrene hydrocarbon skeleton undergo neither migration in the ring nor cis-trans isomerization under the action of iodine in these conditions. Since we have shown that the nonconjugated double bonds of cembrene have the trans configuration [10], the nonconjugated double bonds of all three pinacenes also have the trans configuration. In addition to this, this experiment is an independent proof of the positions of the nonconjugated double bonds in the α -, β -, and γ -pinacenes.

The mechanism of this isomerization is apparently related to the mechanism of the migration of the double bonds in substituted vinyl ethers and can be expressed by the following scheme (taking into account the fact that the isomerization conditions used are favorable for the nonradical attack of iodine [11, 12]).



The formation of the three geometrical isomers of (1) is explained within the framework of this scheme by the presence of an unsymmetrical bridge iodonium ion (4) as a kinetically independent particle with an existence long enough for the occurrence in it of intramolecular rotations of the C_1-C_2 and C_3-C_4 bonds. The reduction of (3) to (1) possibly takes place without the ionization of (3), in a similar manner to what has been proposed for the nonradical reductions of iodophenols and alkyl iodides [13, 14] with hydriodic acid. However, it is impossible to exclude the possibility of the ionization of (3) with the formation of a substituted pentadienyl cation, although the use of a comparatively nonpolar solvent does not favor this.

Four isomers are theoretically possible for (1) which differ by the configurations of the double bonds of the conjugated diene system. Apparently, the fourth, unknown isomer possesses a high steric strain in the ring and is not formed under the experimental conditions used.

We obtained the α - and β -pinacenes by the chromatographic separation of the diterpene hydrocarbons of the oleoresin of Pinus sibirica R. Mayr. The hydrocarbon B isolated previously with λ_{\max} 253 nm ($\log \epsilon$ 4.08) [15] is not identical with any of the pinacenes.

EXPERIMENTAL

The NMR spectra were obtained on Varian A-56-60A and Varian HA-100 instruments [with HMDS as internal standard, its signal being taken as 0.05 ppm (δ scale), and CCl_4 as the solvent]; the UV spectra were taken of solutions in heptane on a Unicam SP 700 C; the IR spectra were recorded on a UR-20 in CCl_4 ; the angles of rotation were determined in CHCl_3 on a Zeiss polarimeter; and the molecular weights were determined on an MKh-1303 instrument. The apparatus and the recording conditions for GLC were the same as in previous work [4]. The analyses of all the compounds corresponded to the calculated figures.

Isolation of the Pinacenes. From 3 g of the total diterpene hydrocarbons of the oleoresin of Pinus koraiensis Sieb. et Zucc we obtained a fraction (1.1 g) of hydrocarbons issuing from a column containing $\text{SiO}_2 + 5\%$ of AgNO_3 after cembrene. This fraction was separated additionally on $\text{SiO}_2 + 5\%$ of AgNO_3 (1:60). Elution with petroleum ether containing 2.5% of diethyl ether gave successively 0.06 g of neocembrene, 0.04 g of α -pinacene, 0.07 g of β -pinacene, and 0.005 g of γ -pinacene. Then elution with a mixture of petroleum ether and 10% of diethyl ether gave 0.9 g of hydrocarbons whose main component was isocembrene. The pinacenes were finally purified by chromatography on air-dry SiO_2 . The α - and β -pinacenes obtained similarly from the oleoresin of Pinus sibirica R. Mayr. were identical with the α - and β -pinacenes from Pinus koraiensis Sieb. et Zucc.

α -Pinacene, $\text{C}_{20}\text{H}_{32}$: n_D^{22} 1.5218, $[\alpha]_D^{22}$ 0° (c 2.69), IR spectrum, cm^{-1} : 3060, 1680, 1620, 1390, 1370, 860; NMR spectrum (Fig. 1, curve a); 1.03 (6H, doublet, $J=7$ Hz, methyls of an isopropyl group), 1.49 and 1.56 (3H each, singlets, methyl groups at C_8 and C_{12}), 1.70 (3H, singlet, methyl group at C_4), 4.94 (2H, multiplet, C_7 -H and C_{11} -H), 5.88 ppm (2H, singlet, C_2 -H and C_3 -H). In the spectrum obtained from the instrument with a working frequency of 100 MHz, these protons formed a strongly bound AB system with $J_{AB}=11$ Hz). Mol. wt. 272 (mass spectrometry).

β -Pinacene, $\text{C}_{20}\text{H}_{32}$: n_D^{22} 1.5210, $[\alpha]_D^{22}$ 0° (c 2.50). The IR spectrum differed insignificantly from that of α -pinacene in the 800-1400 cm^{-1} region. Mol. wt. 272 (mass spectrometry).

γ -Pinacene, $\text{C}_{20}\text{H}_{32}$: n_D^{22} 1.5200, $[\alpha]_D^{22}$ 0° (c 1.69). The IR spectrum differed insignificantly from those of α - and β -pinacenes in the 800-1400 cm^{-1} region. NMR spectrum (Fig. 1, curve c) 1.03 (6H, doublet, $J=7$ Hz, methyls of an isopropyl group), 1.52 (6H, singlet, methyl groups at C_8 and C_{12}), 1.73 (3H, singlet, methyl group at C_4), 4.83 (2H, C_7 -H and C_{11} -H), 5.95 ppm (2H, singlet, C_2 -H and C_3 -H). Mol. wt. 272 (mass spectrometry).

Hydrogenation of α - and β -Pinacenes. β -Pinacene (30 mg) was hydrogenated in glacial acetic acid over 4 mg of PtO_2 . The amount of hydrogen absorbed was 10.6 ml (0°C , 760 mm Hg), which corresponds to four double bonds (theoretical consumption for four double bonds 9.96 ml). After the usual working up and chromatography on SiO_2 , the resulting cembrene had n_D^{22} 1.4720, mol. wt. 280. Cembrene was obtained from α -pinacene similarly.

Isomerization of Cembrene. To 0.39 mmole of cembrene in 4 ml of CCl_4 was added 0.25 ml of a saturated solution of iodine (0.03-0.04 mmole) in CCl_4 (4 ml). After the reaction mixture had been kept in the dark at room temperature for 4 hours, it was treated with aqueous $\text{Na}_2\text{S}_2\text{O}_4$ solution and extracted with petroleum ether (3×30 ml). The organic extracts were washed with water and dried with Na_2SO_4 . The solvent was evaporated at room temperature and filtered through silica gel. (According to GLC, the components of the mixture of hydrocarbons before and after passage through the silica gel were identical.) By chromatographing the product on $\text{SiO}_2 + 5\%$ of AgNO_3 , α -, β -, and γ -pinacenes were isolated (yields 7%, 45%, and 8%, respectively). The formation of the α -, β -, and γ -pinacenes was accelerated by increasing the concentration of iodine and also by passing to a more polar solvent - chloroform.

Among the isomerization products there was about 5% of unidentified hydrocarbons containing no conjugated diene system (according to the UV spectrum). Their amount rose when the amount of iodine, the temperature, and the time of standing were increased.

SUMMARY

1. From the oleoresin of Pinus koraiensis Sieb. et Zucc we have isolated new diterpenoids - α -, β -, and γ -pinacenes - for which the structure of 7-trans, 11-trans-cembra-1,3,7,11-tetraene has been shown. They differ by the configurations of the double bonds of the conjugated diene system. α - and β -Pinacenes have also been isolated from the oleoresin of Pinus sibirica R. Mayr.
2. The isomerization of cembrene with iodine under conditions favoring an ionic reaction has led to α -, β -, and γ -pinacenes.

LITERATURE CITED

1. Y. Sebe, J. Chem. Soc. Japan, 56, 1118 (1935).
2. N. K. Kashtanova, A. I. Lisina, and V. A. Pentegova, Khim. Prirodn. Soedin., 4, 52 (1968).
3. V. A. Raldugin, N. K. Kashtanova, and V. A. Pentegova, Khim. Prirodn. Soedin., 6, 481 (1970).
4. É. N. Shmidt, N. K. Kashtanova, and V. A. Pentegova, Khim. Prirodn. Soedin., 6, 694 (1970).
5. L. M. Jackman, Applications of NMR Spectroscopy in Organic Chemistry, Pergamon Press, London (1959), p. 60.
6. N. P. Damodaran and Sukh Dev, Tetrahedron Lett., 1965, 1977.
7. K. Morikawa and Y. Hirose, Tetrahedron Lett., 1969, 1799.
8. E. K. Gustorf and J. Lettich, Tetrahedron Lett., 1968, 4689.
9. S. J. Rhoads, J. K. Chattopadhyay, and E. E. Waali, J. Org. Chem., 35, 3352 (1970).
10. V. A. Raldugin, A. I. Rezvukhin, and V. A. Pentegova, Khim. Prirodn. Soedin., 7, 598 (1971).
11. W. J. Muizebelt and R. J. F. Nivard, J. Chem. Soc., B, 1968, 921.
12. V. L. Heasley and P. H. Chamberlain, J. Org. Chem., 35, 539 (1970).
13. V. Gold and M. Whittaker, J. Chem. Soc., 1951, 1184.
14. R. A. Ogg, J. Amer. Chem. Soc., 56, 526 (1934).
15. V. A. Pentegova and N. K. Kashtanova, Khim. Prirodn. Soedin., 1, 223 (1965).