LITERATURE CITED

1. V. V. Vandyshev, Yu. E. Sklyar, M. E. Perel'son, M. D. Moroz, and M. G. Pimenov, Khim. Prirodn. Soedin., 669 (1972).
2. V. V. Vandyshev, Yu. E. Sklyar, M. E. Perel'son, M. D. Moroz, and M. G. Pimenov, Khim. Prirodn. Soedin., 670 (1972).
3. M. E. Perel'son, A. A. Kir'yanov, Yu. E. Sklyar, and V. V. Vandyshev, Khim. Prirodn. Soedin., 726 (1973).
4. V. V. Vandyshev, Yu. E. Sklyar, M. E. Perel'son, and M. D. Moroz, Khim. Prirodn. Soedin., 658 (1974).
5. V. V. Vandyshev, M. E. Perel'son, Yu. E. Sklyar, and M. D. Moroz, Khim. Prirodn. Soedin., 660 (1974).
6. M. E. Perel'son, V. V. Vandyshev, and Yu. E. Sklyar, Khim. Prirodn. Soedin. 248 (1975).
7. P. I. Zakharov, V. S. Kabanov, M. E. Perel'son, A. I. Ban'kovskii, and N. E. Ermatov, Khim. Prirodn. Soedin., 296 (1970).
8. P. B. Terent'ev, P. I. Zakharov, G. K. Nikonov, T. Kh. Khasanov, and A. I. Saidhodzhaev, Khim. Prirodn. Soedin., 207 (1977).
9. L. Caglioti, H. Naef, D. Arigoni, and O. Jeger, Helv. Chim. Acta, 41, 2278 (1958).
10. N. E. Ermatov, A. I. Ban'kovskii, M. E. Perel'son, G. P. Syrova, and Yu. N. Sheinker, Khim. Prirodn. Soedin., 79 (1969).
11. T. Kh. Khasanov, A. I. Saidkhodzhaev, and G. K. Nikonov, Khim. Prirodn. Soedin., 10 (1974).
12. T. Kh. Khasanov, A. I. Saidkhodzhaev, and G. K. Nikonov, Khim. Prirodn. Soedin., 25 (1974).
13. Yu. E. Sklyar, M. E. Perel'son, and M. G. Pimenov, Khim. Priodn. Soedin., 428 (1973).
14. T. Kh. Khasanov, A. I. Saidkhodzhaev, and G. K. Nikonov, Khim. Prirodn. Soedin., 91 (1976).
15. T. Kh. Khasanov, A. I. Saidkhodzhaev, and G. K. Nikonov, Khim. Prirodn. Soedin., 95 (1976).

STRUCTURES OF CAUFERIN AND CAUFERIDIN

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Continuing a study of the coumarins of the roots of *Ferula conocaula* Korov. [1], we have isolated two new terpenoid coumarins which we have called cauferin (I) and cauferidin (II).

Cauferin (I) has the composition $C_{24}H_{30}O_5$, M^+ 398, mp 104-106°C, $[\alpha]_D^{23}$ −50° (c 1.0; $CHCl_3$). The UV spectrum of (I) is characteristic for a 7-hydroxycoumarin chromophore. The IR spectrum shows absorption bands due to the presence of an aromatic nucleus, the carbonyl of an α-pyrone, and a hydroxy group. The terpenoid moiety of cauferin has the composition $C_{15}H_{25}O_2$, both oxygen atoms in it being in the form of secondary hydroxy group. This is confirmed by the PMR spectrum of the diacetyl derivative of cauferin (III), $C_{28}H_{34}O_7$, M^+ 482.

The mass spectrum of (I) shows the peaks of ions with m/e 398 (M^+), 380 $(M - H_2O)^+$, 237 $(M - ArO)^+$, 219 $(M - ArO - H_2O)^+$, 201 $(M - ArO - 2H_2O)^+$, 162 $(ArOH)^+$ which are characteristic for terpenoid coumarins of the iresane series [2-4]. With the given composition and the characteristics of the IR, PMR, and mass spectra, the sesquiterpene fragment of cauferin must have a bicyclic structure. This is also shown by the formation of umbelliferone (IV) and of a tetramethylnaphthalene (V) on the dehydrogenation of (I) with selenium. The formation of the latter compound enables us to consider that the sesquiterpene moiety is represented by an iresane structure and that one of the hydroxy groups is present in position 6' [5-7].

On the basis of what has been said, and taking into account the fact that the PMR spectrum of (I) (Table 1) has signals on the protons of three methyl groups (attached to quaternary carbon atoms) and of $-CH_2-OAr$ and $>C=CH_2$ groups, and also the signal of a hemihydroxylic proton, the sesquiterpene residue can be assigned the following partial structure:

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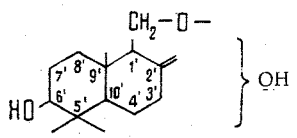
TABLE 1. Parameters of the PMR Spectra of (I) and (III) (δ, ppm; multiplicity, J, Hz)

Assignment	Compound	
	I	III
$3CH_3-\overset{\vert}{\underset{\vert}{C}}-$	0,83;s 0,97;s 1,30;s	0,90;s, 6H 0,98;s
$C_{4'}-OCOCH_3$ $C_{6'}-OCOCH_3$	—	2,00;s 6H
$C_{3'}-H^e$	2,65;q, 13,0; 5,0	2.72;q, 13,0; 5.0
$C_{6'}-H$	3.20;q, 8.5; 6.0	4,48;m, $\Sigma\frac{1}{2}=17.0$
$C_{4'}-H$	3,95;sex, 12,0; 11,0; 5,0	5.10;sex, 12,0; 11,0; 5,0
$C_{1'}-CH_2-O-$	4,11; m, 2H	4,13;m, 2H
$C_{2'}=CH_2$	4,56;ur, 1H; 4,89;ur, 1H	4,63;ur, 1H; 4,96;ur, 1 H
C_3-H	6,17;d, 9,5	6,17;d; 9.5
C_8-H C_6-H	6,73;d, 2,5 6,82;d, 9,0; 2.5	6,75;m, 2H
C_5-H	7,33;d, 9.0	7,30;d, 9,0
C_4-H	7,60;d, 9,5	7.57; d, 9,5

Note. s) singlet; d) doublet; q) quartet; sex) sextet; m) multiplet; ur) unresolved signal.



The position of the second hydroxy group was established on the basis of the following considerations. In the PMR spectrum of (I) the signal from the hemihydroxylic proton appears at 3.95 ppm (sex, 1 H, J_1 = 12.0 Hz; J_2 = 11.0 Hz; J_3 = 5.0 Hz). The multiplicity and value of the splitting constants of this signal show that this proton interacts with three others. Such a pattern can be observed where the second hydroxy group is present in position 4' or 7'. The 7' position is excluded by the multiplicity of the signal from the proton geminal to the hydroxy group at C_6' (3.20 ppm, q, 1 H, J_1 = 8.5 Hz, J_2 = 6.0 Hz). This shows that the 7' position is occupied by a methylene group. Consequently, only the position at C_4' remains for the second hydroxy group. It must be mentioned that under the electron-accepting influence of the double bond (C_2'=CH_2) and of the hydroxy group (C_4'—OH), the signal from the equatorial proton at C_3' appears in a weaker field — 2.67 ppm (q, 1 H, J_{vic} = 5.0 Hz). The identical values of the spin—spin coupling constants of the latter (J_{vic} = 5.0 Hz) and of the signal of the hemihydroxylic proton at C_4 (J_3 = 5.0 Hz) show that they interact with one another and this confirms the position of the hydroxy group at C_4'.

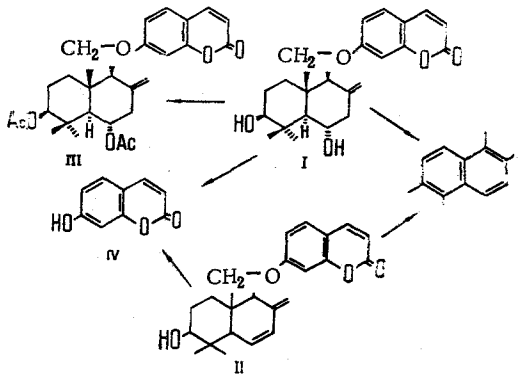
The stereochemistry of the asymmetric centers (C_1', C_4', C_6', C_9' and C_{10}) follows from the PMR spectrum of (I). The nature of the splitting and of the SSCC values of the hemihydroxylic protons (at C_4' and C_6') show that they are oriented axially and, therefore, both hydroxy groups are oriented equatorially. The value of the coupling constant of the proton at C_4' (J_1 = 12.0 Hz) shows the axial orientation of the methine proton at C_{10}', i.e., the decalin nucleus has a trans linkage. On the basis of biogenetic considerations and taking into account the configuration at C_1', the equatorial orientation is proposed for the C_1'—CH_2 group of all the coumarins isolated from the species of *Ferula* [8-10].

Furthermore, the CSs and multiplicities of the C_1'—CH_2— and C_2'=CH_2 groups correspond to the rule for the stereochemistry of terpenoic coumarins of the iresane series established previously [11].

On the basis of what has been said above, the structure and configuration (I) are proposed for cauferin.

Cauferidin (II), $C_{24}H_{28}O_4$, M^+ 380, mp 184-185.5°C, $[\alpha]_D^{23}$ —60° (c 1.0; $CHCl_3$). The UV spectrum of (II) is also characteristic for 7-hydroxycoumarin derivatives. In the IR spec-

trum there are absorption bands due to the presence of a hydroxy group, the carbonyl of an α-pyrone, a double bond, and an aromatic nucleus. On acid hydrolysis, (II) formed umbelliferone (IV).



The mass spectrum of cauferidin contains the peaks of ions with m/e 380 (M^+), 219 $(M - ArO)^+$, 201 $(M - ArO - H_2O)^+$, and 162 $(ArOH)^+$, showing that the substance belongs to the coumarins of the iresane series.

On dehydrogenation with selenium, as was to be expected (II) formed 1,2,5,6-tetramethylnaphthalene (V), which confirms the bicyclic structure of the sesquiterpene moiety and unambiguously shows the position of the hydroxy group at C_6'.

The PMR spectrum of cauferidin contains the signals of three methyl groups on quaternary carbon atoms — singlets at 0.79 ppm (6 H) and 1.02 ppm (3 H) — and a quartet at 3.27 ppm (1 H, J_1 = 9.0 Hz, J_2 = 6.0 Hz) due to a hemihydroxylic proton and showing that the hydroxy group is secondary and has the equatorial orientation. A multiplet in the 4.14 ppm region (2 H) is due to the methylene protons in the $-CH_2-OAr$ grouping. Two broadened singlets at 4.86 ppm (1 H) and 4.93 ppm (1 H) are due to exocyclic methylene protons, and two doublets in the neighborhood of 5.68 ppm (1 H, J = 10.0 Hz) and 6.17 ppm (1 H, J = 10.0 Hz) are due to olefinic protons. The equal SSCCs of the latter show that these olefinic protons are present on adjacent carbon atoms. Furthermore, in the weak-field region there are doublets at 7.62 and 6.19 ppm (1 H, J = 9.5 Hz) belonging to the H_4 and H_3 protons, a quartet at 6.76 ppm (1 H, J_1 = 9.0 Hz, J_2 = 2.5 Hz), and doublets at 7.34 ppm (1 H, J_1 = 9.0 Hz) and 6.81 ppm (1 H, J = 2.5 Hz) due, respectively, to the H_6, H_5, and H_8 protons of the coumarin nucleus.

The PMR spectrum shows the presence in the terpenoid residue of (II) of tow double bonds, one of which has the form of an exocyclic methylene group and is located at C_2. Judging from the CSs and the nature of the splittings of the signals of the olefinic protons, and also the characteristics of the UV spectrum of (II) [λ_{max} 236 nm (log ε 4.30)], which is characteristic for conjugated dienes, the second double bond is present at $C_3'-C_4'$.

Thus, cauferidin may be assigned structure (II). The study of the stereochemistry of cauferidin is continuing.

EXPERIMENTAL

The conditions for recording the spectra have been described in the preceding paper [1]. For chromatography we used type KSK silica gel. The homogeneity of the substances was checked and the course of the reactions was followed by TLC on Silufol plates.

Isolation of the Coumarins. A mixture of 30 g of the methanolic extract and silica gel was placed in a chromatographic column (3 × 125 cm) and elution was carried out with mixture of hexane and chloroform with a rising gradient of the latter, 200-ml fractions being collected.

Cauferidin. When fractions 42-49 [eluent: hexane—chloroform (2:1)] were evaporated, 210 mg (0.029% of the weight of the dry plant) of small crystals was obtained with the composition $C_{24}H_{28}O_4$, M^+ 380, mp 184-185.5°C, $[\alpha]_D^{23}$ −60° (c 1.0; $CHCl_3$), R_f 0.17. UV spectrum: λ_{max} 222, 236, 291, 325 nm (log ε 4.33, 4.30, 3.94, 4.15, respectively). IR spectrum: ν_{max} 1510, 1622, 1720, 3630 cm^{-1}.

Cauferin. From the last fractions, 103-111 [eluent: hexane–chloroform (1:1)], 260 mg (0.034%) of a crystalline compound was obtained with the composition $C_{24}H_{30}O_5$, M^+ 398, mp 104-106°C, $[\alpha]_D^{23}$ −50° (c 1.0; $CHCl_3$), R_f 0.02. UV spectrum: λ_{max} 217, 241, 296, 325 nm (log ε 3.96, 3.50, 3.80, 3.95, respectively). IR spectrum: ν_{max} 1518, 1617, 1730, 3200-3600 cm^{-1}.

Acetylation of Cauferin. A mixture of 90 mg of the substance, 1.2 ml of pyridine, and 1 ml of acetic anhydride was left at room temperature for three days. After the usual working up, 80 mg of a substance $C_{28}H_{34}O_7$, M^+ 482, was obtained.

Dehydrogenation of Cauferin. A mixture of 120 mg of the coumarin with 100 mg of selenium was ground to a fine powder and was then heated at 270-290°C for 30 min. The reaction mixture was treated with petroleum ether and chromatographed on alumina (10 g, activity grade II). This gave 35 mg of 1,2,5,6-tetramethylnaphthalene with mp 110-112°C.

After the dehydrogenation product had been freed from hydrocarbons, the residue was treated with ether, and the extract was shaken with 2% caustic potash solution. The alkaline solution was acidified with 5% sulfuric acid and extracted with ether, the extract was washed with water and dried, and the solvent was distilled off. The residue contained 25 mg of umbelliferone with mp 228-230°C (from water).

Acid Hydrolysis of Cauferidin. A solution of 70 mg of (II) in 3 ml of acetic acid was gradually treated with 2 ml of concentrated sulfuric acid. After 40 min, 15 ml of water was added to the mixture and it was heated to the boil and filtered. The crystals that deposited from the filtrate were recrystallized from water: mp 227-229°C.

Dehydrogenation of Cauferidin. The process was performed under conditions similar to those described for cauferin at 250-280°C. A compound with mp 111-112°C was obtained, which was identical with 1,2,5,6-tetramethylnaphthalene.

SUMMARY

Two new terpenoid coumarins have been obtained from the roots of *Ferula conocaula* Korov. and have been called cauferin and cauferidin.

On the basis of chemical and spectral characteristics, the structure and relative configuration of cauferin represented by formula (I) and the structure of cauferidin represented by formula (II) have been suggested.

LITERATURE CITED

1. Z. A. Kuliev and T. Kh. Khasanov, Khim. Prirodn. Soedin., No. 3, 322 (1978) [preceding paper].
2. P. I. Zakharov, V. S. Kabanov, M. E. Perel'son, A. I. Ban'kovskii, and N. E. Ermatov, Khim. Prirodn. Soedin., 296 (1970).
3. P. I. Zakharov, N. P. Terent'ev, G. K. Nikonov, and A. I. Ban'kovskii, Khim. Prirodn. Soedin., 18 (1974).
4. P. B. Terent'ev, P. I. Zakharov, G. K. Nikonov, T. Kh. Khasanov, and A. I. Saidkhodzhaev, Khim. Prirodn. Soedin., 207 (1977).
5. L. Caglioti, H. Naef, D. Arigoni, and O. Jeger, Helv. Chim. Acta, 41, 2278 (1958).
6. N. E. Ermatov, A. I. Ban'kovskii, M. E. Perel'son, G. P. Syrova, and Yu. N. Sheinker, Khim. Prirodn. Soedin., 79 (1969).
7. N. P. Kir'yalov and S. D. Movchan, Khim. Prirodn. Soedin., 73 (1968).
8. M. E. Perel'son, A. A. Kir'yanov, Yu. E. Sklyar, and V. V. Vandyshev, Khim. Prirodn. Soedin., 726 (1973).
9. V. V. Vandyshev, Yu. E. Sklyar, M. E. Perel'son, and M. D. Moroz, Khim. Prirodn. Soedin., 658 (1974).
10. M. E. Perel'son, V. V. Vandyshev, and Yu. E. Sklyar, Khim. Prirodn. Soedin, 248 (1975).
11. M. E. Perel'son, A. A. Kir'yanov, A. I. Ban'kovskii, N. P. Kir'yalov, and T. V. Bukreeva, Khim. Prirodn. Soedin., 442 (1976).