Phytochemistry, Vol 28, No 10, pp 2711 2716, 1989
Printed in Great Britain

0031 9422/89 $3 00 + 0 00
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ISOLATION OF DAUCANE ESTERS FROM *FERULA COMMUNIS* VAR. *BREVIFOLIA*

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(*Received* 22 *November* 1988)

Key Word Index—*Ferula communis* var *brevifolia*, Umbelliferae, sesquiterpenoids, daucane esters

Abstract—Three new daucane sesquiterpenes related to jaeschkeanadiol have been isolated from the leaves and the seeds of *Ferula communis* var *brevifolia*. The structures were elucidated by spectroscopic studies and correlated with known compounds.

INTRODUCTION

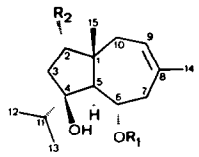
In the course of our studies on the constituents of *Ferula communis* L. indigenous to Morocco [1], we investigated *Ferula communis* var. *brevifolia* a widely distributed weed along the Moroccan western coast. *Ferula communis* is well-known as a medicinal plant since ancient times [2] and it was also reported to be highly toxic to animals [3–5] and humans [3]. A number of sesquiterpenes esters and lactones from the daucane class have been isolated from *Ferula* species [6–13]. Recently we have isolated two 4-hydroxy coumarin derivatives from the root sap of *F. communis* var. *genuina* collected in Morocco [1],

The present work was undertaken to examine the compounds of the leaves and seeds of *F. communis* var. *brevifolia*. We describe the isolation of two new daucane esters from the seeds and of a new daucane aromatic ester along with the known ferulenol and 10-angeloyloxy-6-*p*-hydroxybenzoyl-jaeschkeanadiol from the leaves.

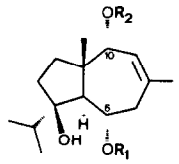
RESULTS AND DISCUSSION

The dried and ground leaves were extracted successively with petrol and CH_2Cl_2. Purification of the CH_2Cl_2 extract by repetitive column chromatography gave the two sesquiterpenes FB4 (**1**) and FB5 (**4**). Ferulenol was characterized in the first fractions from the column. The finely ground seeds were extracted with petrol and the crude extract chromatographed over silica gel. The sesquiterpenic fraction thus obtained, was further purified by column chromatography to give sesquiterpenes FB3 (**2**) and FB2 (**3**) as pure compounds. All these compounds were obtained as gums or as amorphous solids.

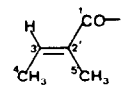
The CIMS of **1** showed the pseudomolecular ions $[M+NH_4]^+$ and $[M+H]^+$ at *m/z* 434 and 417, respectively, in agreement with the molecular formula $C_{24}H_{32}O_6$ Important fragmentations observed in the EIMS were due to the loss of a molecule of water (*m/z* 398) and of an isopropyl radical (*m/z* 373) and the base peak was that of the *p*-hydroxybenzoyl ion ($HO-C_6H_4-C\equiv O^+$, *m/z* 121).



1 R_1= *p*-hydroxybenzoyl R_2 = -O-CO-CH_3
2 R_1=3',4'-dimethoxybenzoyl R_2 = -H
7 R_1= *p*-anisoyl R_2 = -O-CO-CH_3



3 R_1= angeloyl R_2 = -H
4 R_1= *p*-hydroxybenzoyl R_2 = angeloyl
5 R_1= *p*-methoxybenzoyl R_2 = angeloyl
6 R_1= angeloyl R_2 = *p*-methoxybenzoyl

Angeloyl. 

The IR spectrum exhibited absorptions of a conjugated ester (1713 cm^{-1}) and an alcohol (3402 cm^{-1}). The ^{13}C NMR spectrum (Table 1) contained signals of two carbonyls (δ167.10 and 170.93), six sp_2 carbon atoms from an aromatic ring *para* disubstituted, two sp_2 carbon atoms from a trisubstituted double bond (δ133.80 *s* and 124.40 *d*), five methyls (including that of an acetoxyl

†Author to whom correspondence should be addressed.

Table 1 ^{13}C NMR data of compounds 1–4 (62.8 MHz, $CDCl_3$)

C	1 δ_C	2 δ_C	3 δ_C	4 δ_C
1	47.19 *s*	44.06 *s*	48.13 *s*	46.83 *s*
2	82.91 *d*	31.88 *t*	31.56 *t*	31.04 *t*
3	40.70 *t*	[a]41.20 *t*	40.83 *t*	40.57 *t*
4	85.43 *s*	86.38 *s*	86.80 *s*	86.42 *s*
5	55.91 *d*	60.07 *d*	49.84 *d*	51.58 *d*
6	70.46 *d*	71.26 *d*	[a]71.30 *d*	71.16 *d*
7	39.53 *t*	[a]41.44 *d*	36.64 *t*	36.37 *t*
8	133.80 *s*	133.68 *s*	136.78 *s*	137.36 *s*
9	124.40 *d*	123.70 *d*	127.62 *d*	124.43 *d*
10	34.79 *t*	[a]41.49 *t*	[a]73.57 *d*	74.68 *d*
11	36.82 *d*	37.33 *d*	37.72 *d*	37.34 *d*
12	[a]17.53 *q*	[b]17.53 *q*	[b]17.93 *q*	[a]17.47 *q*
13	[a]18.12 *q*	[b]18.59 *q*	[b]18.95 *q*	[a]18.49 *q*
14	25.81 *q*	26.35 *q*	27.99 *q*	27.30 *q*
15	[b]19.76 *q*	20.33 *q*	20.97 *q*	[b]20.74 *q*
1′	170.93 *s*		168.67 *s*	166.60 *s*
2′	[b]21.12 *q*		128.34 *s*	128.05 *s*
3′			139.21 *d*	138.41 *d*
4′			21.28 *q*	[b]20.92 *q*
5′			16.24 *q*	15.82 *q*
1″	167.10 *s*	166.26 *s*		167.40 *s*
2″	121.98 *s*	123.29 *s*		122.69 *s*
3″	131.96 *d*	112.47 *d*		132.05 *d*
4″	115.48 *d*	148.99 *s*		115.51 *d*
5″	161.09 *s*	153.43 *s*		160.66 *s*
6″	115.48 *d*	110.72 *d*		115.51 *d*
7″	131.96 *d*	125.19 *d*		132.05 *d*
OMe		56.03 *q*		
OMe		56.03 *q*		

[a, b] May be exchanged within the same column

group), three methylenes, four methines two of which bearing an oxygen atom (δ 82.91 and 70.46) and two quaternary carbon atoms, one of which was linked to an oxygen atom (δ 85.43)

The ^1H NMR spectrum was analysed by using the 2D COSY techniques (Table 2) It exhibited one methyl linked to a quaternary carbon atom, an acetoxyl (δ 2.075), a *p*-hydroxy benzoyl (δ 7.930 and 6.901) and an isopropyl Couplings showed that methine at δ 4.889, bearing the acetoxyl group, was linked to the methylene giving signals at δ 1.888 and 2.092, leading to the substructure **a**: Me–CO–O–CH–CH_2– The methine at δ 5.327 linked to the benzoate group was coupled to the methine at δ 2.517 and also to the methylene fixed on the double bond, giving thus the substructure **b** >CH–CH(O–Bz)–CH_2 –C(Me)=CH–CH_2– These results suggested **2** to be an ester of jaeschkeanadiol [13] Substructures **a** and **b** were respectively located on the 5- and 7-membered cycles of such a daucane sesquiterpene

The high value of the coupling constant $^3J_{H5,H6}$ (10,7 Hz) indicated that H-5 and H-6 were in a *trans*-diaxial disposition An intense NOE effect was observed between Me-15 and the protons H-6 (6.5%), H-10β (8%) and H-2β (6.5%) and not with the methine proton H-5 This result agreed with their location on the daucane nucleus and indicated that H-6, H-10β and H-2β were on the same side of the molecule as Me-15 (β), and that H-5 was located on the opposite face (α). The 6-*p*-hydroxybenzoyl group was thus equatorial All these data agreed with structure **1** for this compound, which is thus 2-acetoxy-6-*p*-hydroxybenzoyl-jaeschkeanadiol Confirmation of structure **1** was obtained by its methylation by diazomethane that gave the derivative **7**, the spectral data of which were identical to that recently described for 2-acetoxy-6-*p*-anisoyl-jaeschkeanadiol [9]

The CIMS of **2** showed the pseudomolecular ion $[M+H]^+$ at *m/z* 403 and an ion at *m/z* 385 arising from the loss of a molecule of water, in agreement with the molecular formula $C_{24}H_{34}O_5$ that involved eight degrees of unsaturation. The ^{13}C NMR spectrum displayed the 24 carbon atoms of the molecule (Table 1), among which one carbonyl (δ 166.26), two sp_2 carbons from one double bond (δ 133.68 and 123.70) and six sp_2 carbon atoms from a trisubstituted benzene ring In addition we observed two methoxyl groups (δ 56.03), two carbon atoms bearing an oxygen atom (δ 86.38 *s* and 71.26 *d*), four methyls, four methylenes, two methines and one quaternary carbon atom The main distinctions between the ^{13}C NMR spectra of **2** and **1** were relative to the chemical shift of C-2 (δ 82.91 *d*, >CH– in **1** and 31.88 *t*, CH_2– in **2**), the absence of signals from the acetoxyl group and the nature of the aromatic ring substituents

The ^1H NMR spectrum of **2** (Table 2) showed signals of a 3′,4′-dimethoxybenzoate ring, an isopropyl side chain and a methyl group linked to a quaternary carbon atom Couplings, analysed by using 2D COSY, allowed the detection of the two substructures **a**, $-CH_2$ CH_2– and **b** >CH–CH(O–R)–CH_2 C(Me)=CH–CH_2– All the results indicated **2** also to be a daucane ester derivative where the daucane part would be jaeschkeanadiol and the aromatic acid ester moiety (R) 3′,4′-dimethoxybenzoate A small coupling was detected from the ^1H COSY between Me-15 and H-2α and a NOE between Me-15 and H-2β allowing the assignment of substructure **a** Compound **2** is thus the *O*-methyl ester of teferin [6]

The diastereotopic Me-12 and Me-13 of compounds **1** and **2** are non-equivalent their chemical shifts in the ^1H NMR spectrum differed from 0.11 ppm This non-equivalence is due to the presence in the *peri* (-6) position of an aromatic substituent, either *p*-hydroxybenzoyl or 3′,4′-dimethoxybenzoyl [9] Methanolysis of **2** yielded the methyl ester of 3,4-dimethoxybenzoic acid and jaeschkeanadiol that were identified by mass spectrometry As the $[\alpha]_D$ measured for the obtained jaeschkeanadiol (+32.5°) was similar to that described for jaeschkeanadiol (+38.3) [14], they must have the same absolute configuration The absolute stereochemistry of jaeschkeanadiol has been established previously by a direct chemical correlation with laserol [14]

The CIMS of compound **3** showed the pseudomolecular ion $[M+H]^+$ at *m/z* 337, in agreement with the molecular formula $C_{20}H_{32}O_4$, and an abundant ion at *m/z* 319 arising from the loss of a molecule of water An important fragment ion was observed in the EIMS at *m/z* 236 arising from the elimination of an angelic acid molecule The IR spectrum showed absorptions of alcohol (3481 cm^{-1}) and α,β unsaturated ester (1697 cm^{-1})

In the ^{13}C NMR spectrum the angeloyl moiety carbon atoms were observed at δ 168.67 (C=O), 128.34 (*s*) and 139.21 (*d*) (>C=CH–) and 21.28 and 16.24 (two Me) Among the sesquiterpenic carbon atoms were noticed three carbon atoms bearing an oxygen atom (a quaternary one at δ 86.80 and two methines at 71.30 and 73.57), as

well as a trisubstituted double bond giving signals at 136.78 (*s*) and 127.62 (*d*).

The ^{1}H NMR spectrum presented signals of the angeloyl group (an ethylenic proton at δ6.105 and two methyls linked to a double bond at δ 1.882 and 2.005) and those of a quaternary methyl and an isopropyl (Table 2). Analysis of the spectrum by 2D COSY revealed two substructures: the first one $-CH_2-CH_2-$ was located on the five-membered cycle of the daucane backbone. The proton at δ5.270, assigned to the methine attached to the angeloyl group, was coupled with a methine (δ2 727) and a methylene (δ2.175 and 2.724) itself linked to a >C=C< double bond This double bond was in addition substituted by a methyl (δ1.815), a proton (5.728) and a methine group bearing an alcoholic function (3.822). These results indicated the second substructure of the chain to be >CH–CH(O-angeloyl)–CH_2–C(Me) = CH–CH(OH)– which was located on the seven-membered ring and indicated that **3** was also a jaeschkeanadiol derivative.

A clear NOE effect was observed between the angular Me-15β and the proton geminal to the secondary alcohol function (4%) which was thus in -10β from the jaeschkeanadiol backbone. Important NOE effects were also observed with protons H-2β and H-6β (6.0%), but not with proton H-5, which was thus located on the α-side, H-5 showed, in addition a strong coupling with proton H-6β (11.0 Hz), characteristic of a *trans*-diaxial disposition. Thus the 6-angeloyl group was equatorial. In this case the methyls C-12 and C-13 from the isopropyl group were very slightly non-equivalent ($\Delta\delta$0.03). The results revealed structure **3** for this compound.

The IR spectrum of compound **4** suggested it was also an ester derived of jaeschkeanadiol. It reacted with diazomethane to form a monomethyl ether **5**. The EIMS of **4** showed the ion of highest mass at *m/z* 438. The pseudomolecular ion $[M+H]^+$ appeared at *m/z* 471 in the CIMS of the ether derivative **5** for which the proposed molecular formula was $C_{28}H_{38}O_6$. The molecular mass of **4** was thus 456 and the ion *m/z* 438 observed in its EI mass spectrum arose from the elimination of a molecule of water as already observed for the other daucane esters studied. The molecular formula proposed for **4** is thus $C_{27}H_{36}O_6$. The EIMS of **4** showed abundant fragment ions at *m/z* 438, 338, 313, 275 and 218 corresponding to the successive loss of molecules of water, *p*-hydroxybenzoic acid, angelic acid and of an isopropyl group.

The ^{13}C NMR spectrum displayed signals from angeloyl and *p*-hydroxybenzoyl moieties in addition to signals belonging to the sesquiterpenic part. This part was characterized by four methyls (δ17.47, 18.49, 20.74 and 27.30), three methylenes (40.57, 36.37 and 31.04), five methines two of which bearing an oxygen atom (74.68 and 71.16) and three quaternary carbon atoms one bearing an oxygen atom (δ86.42)

The ^{1}H NMR 2D COSY allowed the construction of the two substructures **a** ($-CH_2-CH_2-$) and **b** [>CH–CH(O–R^1)–CH_2–C(Me)=CH–CH(O–R^2)–] in addition to the angeloyl (R^2), *p*-hydroxybenzoyl (R^1) and isopropyl groups. These substructures were located respectively on the five- and the seven-membered cycles.

Irradiation of Me-15 gave NOE's with protons H-6 (8%) and H-10 (6%) which were thus on the same face of the molecule. No NOE was observed with H-5 which was thus located on the opposite face. This result agreed with the coupling constant value between H-5 and H-6 (11.0 Hz) which was characteristic of a *trans*-diaxial disposition. The two ester groups R^1 and R^2 were placed on the face β-opposed to the Me-15 of the daucane nucleus. Their reciprocal locations on the positions C-6 and C-10 were assigned on the basis of the strong non-equivalence observed for the Me-12 and Me-13 from the 4-isopropyl group ($\Delta\delta$0.11): thus the *p*-hydroxylbenzoic ester (R^1) was located on C-6 and the angelic ester (R^2) on C-10 to lead to structure **4** as 10-angeloyloxy-6-*p*-hydroxybenzoyl-jaeschkeanadiol. Miski and Mabry [13] have isolated this compound from *F. tingitana* and its methyl ether, 10-angeloyloxy-6-*p*-anisoyl-jaeschkeanadiol from *F. communis* subsp *communis* [9]. Methylation of **4** by diazomethane gave the ester **5**, the spectral characteristics of which were identical to those published by these authors. To have a complementary proof of the structure of **5**, we have synthesized its isomer (6-angeloyl-10-*p*-anisoyloxy-jaeschkeanadiol, **6**) by the action of *p*-anisoyl chloride on the sesquiterpenic alcohol **3**. The compound **6** thus obtained had the same molecular weight as **5** and similar fragmentations in mass spectrometry, but its ^{1}H NMR spectrum was different (Table 2). In particular a small non-equivalence was observed in this spectrum, between Me-12 and Me-13 ($\Delta\delta$0.06), which was in agreement with the lack of an aromatic substituent at C-6. Compound **4** was thus 10-angeloyloxy-6-*p*-hydroxybenzoyl-jaeschkeanadiol.

EXPERIMENTAL

Plant material Leaves and seeds of *Ferula communis* var *brevifolia* were collected at Mamora Forest near Rabat in March and July 1985, respectively. Voucher specimens were deposited in the Department of Pharmacy-Toxicology at the Institut of Agriculture and Veterinary Medecine, Rabat, Morocco.

Extraction and isolation. Dried and ground leaves (300 g) were extracted in a Soxhlet apparatus with successively petrol and CH_2Cl_2 for 8 hr each Concentrating these extracts gave, respectively, 9 9 g and 11 3 g of residue. A portion (2 g) of the CH_2Cl_2 extract was chromatographed on a silica gel column with CH_2Cl_2. Ferulenol was obtained from the first fractions and then a mixture (500 mg) of sesquiterpenes FB4 (**1**) and FB5 (**4**) which were further separated by CC over silica gel eluted with CH_2Cl_2 to give pure FB5 (67 mg) and FB4 (220 mg) and a mixture of FB4 and FB5 (193 mg).

Dried and finely ground seeds (100 g) were extracted in a Soxhlet apparatus with petrol for 8 hr and the solvent evapd to give a gummy residue (8.2 g) that was chromatographed on a silica gel column with CH_2Cl_2 to give a terpene containing fraction (2.5 g). This fraction was chromatographed in the same conditions and five fractions I to V were collected Fraction IV gave FB2 (**3**) (72 mg) Further purification of fraction III (2.2 g) on a silica gel column eluted with *n*-hexane–EtOAc (9:1) gave pure FB3 (**2**) (15 mg).

General ^{1}H NMR spectra were taken at 250 MHz and ^{13}C NMR spectra at 20 MHz. EI mass spectra were obtained using a direct inlet system.

2-Acetoxy-6-p-hydroxybenzoyl-jaeschkeanadiol, (FB4, **1**) $C_{24}H_{32}O_6$: 416; $[\alpha]_D^{19}$ +5.9° ($CHCl_3$, *c* 0.5); IR ν_{max}^{KBr} cm^{-1}: 3402, 2967, 2931, 1740 sh, 1713, 1611, 1516, 1445, 1379, 1273, 1166, 1097, 1027, 945, 850, 772, 733. EIMS (200°, 70 eV) *m/z* (rel int.): 398 (1), 373 (0 5), 313 (1), 295 (0.5), 235 (0.5), 218 (2.5), 203 (1 4), 202 (0.5), 200 (2), 185 (3), 175 (30), 157 (7), 147 (10), 139 (3), 132 (22), 121 (100), 105 (14), 93 (15) CIMS (NH_3) *m/z* 434 $[M+NH_4]^+$, 417 $[M+H]^+$, 399 $[M-H_2O+H]^+$

6-(3',4'-dimethoxybenzoyl)-Jaeschkeanadiol, (FB3, **2**).

Table 2 ^{1}H NMR data of compounds

H	1		2		3	
2α	—	1 272 *m*		1 773 *ddd*	−11 9, 10 6, 9.6	1 587 *ddd*
2β	4 889 *dd*	5 9, 0 2	1 525* *m*	1 356 *ddd*	−11 9, 8 6, 2 0	1 457 *ddd*
3α	2 092 *dd*	−16 4, 0 2	1.920* *m*	1 916 *ddd*	−13.8, 9 6, 2 0	1 931 *ddd*
3β	1.888 *dd*	−16.4, 5 9	1 620* *m*	1 575 *ddd*	−13 8, 10 6, 8 6	1.639 *ddd*
5	2.517 *d*	10 7	2.010 *d*	10 4	2 727 *d*	11 0	2 792 *d*
6β	5 327 *ddd*	10.7, 9.9, 2.6	5 265 *ddd*	10 5, 10 4, 2 9	5 270 *ddd*	11 0, 10 7, 3 3	5 439 *ddd*
7α	2.607 *dd*	−13 9, 9 9	2 529 *dd*	−13 4, 10 5	2 724 *dd*	−14 5, 10 7	2 784 *dddd*
7β	2 276 *dd*	−13 9, 2 6	2 310 *dd*	−13 4, 2 9	2 175 *dd*	−14 5, 3 3	2 235 *ddd*
9	5 533 *dd*	8 5, 5 0	5 555 *br t*	7 8	5 728 *br d*	7 1	5 791 *ddd*
10α	2 210 *dd*	−14 6, 5.0	1 963 *d*	−13 2	—		—
10β	1.933 *dd*	−14 6, 8 5	2 063 *dd*	−13 2, 7 8	3 822 *d*	7 1	4.936 *d*
11	1 812 *qq*	6 8, 6 7	1 971 *qq*	6 8, 6 7	2 215 *m*		1 938 *m*
12	0.819 *d*	6 7	0.863 *d*	6.7	0 910 *d*	6 8	0 856 *d*
13	0 934 *d*	6 8	0 973 *d*	6 8	0 937 *d*	6 8	0 969 *d*
14	1 831 *s*		1.834 *br s*		1 815 *br s*		1 817 *br s*
15	1 128 *s*		1 103 *s*		1 098 *s*		1 222 *s*
2′	2 075 *s*		—				—
3′	—		—		6 105 *qq*	7 2, 1 4	6 117 *qq*
4′	—		—		2 005 *dq*	7 2, 1.5	2.053 *dq*
5′	—		—		1 882 *qd*	1 5, 1 4	1 969 *dq*
3″	7 930 *m*		7 543 *d*	2 0	—		7 942 *m*
4″	6 901 *m*		—		—		6 891 *m*
6″	6 901 *m*		6 910 *d*	8 4	—		6 801 *m*
7″	7 930 *m*		7 663 *dd*	8 4, 2 0	—		7 942 *m*
OMe	—		3 951 *s*		—		—
OMe$^-$	—		3 931 *s*		—		—

$C_{24}H_{34}O_5$· 402, $[\alpha]_D^{20}$ +29.6° ($CHCl_3$, *c* 1 0), IR ν_{max}^{KBr} cm^{-1}. 3516, 2961, 2876, 1709, 1693, 1604, 1515, 1467, 1384, 1349, 1274, 1223, 1178, 1137, 1106, 954, 764. EIMS (200°, 70 eV) *m/z* (rel int). 359 (2), 234 (1), 220 (4), 202 (1), 182 (65), 177 (28), 165 (100), 159 (17), 149 (2), 134 (18), 132 (13), 122 (17), 121 (15), 119 (14), 93 (18), 83 (32), 77 (27), 71 (25) CIMS (NH_3) *m/z* 403 $[M+H]^+$, 385 $[M-H_2O+H]^+$.

Methanolysis of **2**. Compound **2** (14 mg) was treated with 2% KOH in MeOH at room temp for 2 hr Water was then added, the mixture acidified to pH 4 with aq HCl (5%) and extracted with CH_2Cl_2 The extract was concd and the residue (7 mg) chromatographed on a silica gel column with CH_2Cl_2 to yield the methyl ester of 3,4-dimethoxybenzoic acid (1.6 mg; EIMS (200°, 70 eV) *m/z* 196 $[M^+]$) and jaeschkeanadiol (2 0 mg; $[\alpha]_D^{22}$ +32.6° ($CHCl_3$, *c* 0 09); EIMS (200°, 70 eV) *m/z* (rel int). 238 $[M]^+$ (1), 220 $[M-H_2O]^+$ (17), 205 (14), 195 (55), 177 (100), 159 (69), 151 (55), 133 (34), 123 (48), 93 (49), 91 (50)

6-Angeloyl-10-hydroxy-jaeschkeanadiol, (FB2, **3**). $C_{20}H_{32}O_4$ 336, $[\alpha]_D^{19}$ −57 8° ($CHCl_3$, *c* 0 5); IR ν_{max}^{KBr} cm^{-1}· 3481, 2965, 2876, 1697, 1646, 1570, 1548, 1456, 1381, 1239, 1165, 1101, 1022, 986, 955, 923, 849, 738 EIMS (200°, 70 eV) *m/z* (rel int) 275 (2), 257 (3), 236 (5), 221 (3), 219 (2), 218 (5), 203 (4), 200 (2), 193 (11), 175 (75), 165 (8), 157 (18), 147 (31), 135 (27), 133 (32), 132 (48), 123 (15), 121 (24), 119 (52), 109 (27), 107 (20), 105 (40), 95 (27), 93 (18), 91 (26), 83 (100), 71 (79) CIMS (NH_3) *m/z* 337 $[M+H]^+$, 319 $[M-H_2O+H]^+$

10-Angeloyloxy-6-p-hydroxybenzoyl-jaeschkeanadiol, (FB5, **4**) $C_{27}H_{36}O_6$· 456, $[\alpha]_D^{20}$ −139 8° ($CHCl_3$, *c* 0 9), IR ν_{max}^{KBr} cm^{-1} 3499, 3220, 2969, 1716, 1703, 1696, 1611, 1457, 1440, 1384, 1308, 1282, 1270, 1234, 1162, 1150, 1090, 955, 833, 772 EIMS (200°, 70 eV) *m/z* (rel int)· 438 (2), 356 (1), 338 (8), 313 (12), 275 (19), 257 (3), 237 (9), 235 (14), 219 (8), 218 (20), 217 (12), 203 (14), 201 (13), 200 (13), 193 (4), 189 (5), 185 (13), 177 (7), 175 (100), 159 (10), 157 (35), 147 (18), 138 (15), 132 (69), 121 (90), 119 (22), 93 (13), 83 (30). CIMS (NH_3) *m/z* 457 $[M+H]^+$, 439 $[M-H_2O+H]^+$

10-Angeloyloxy-6-p-methoxybenzoyl-jaeschkeanadiol, (FB7, **5**) A mixture (193 mg) of **1** and **4** was dissolved in Et_2O and methylated by CH_2N_2 The product of the reaction was chromatographed on a silica gel column (CH_2Cl_2–EtOAc, 19 1) 10 mg of **4** methyl ether (**5**) and 52 mg of FB4 methyl ether (**7**) were successively obtained as colourless oils FB7, $C_{28}H_{38}O_6$ 470, $[\alpha]_D^{19}$ −147 6° ($CHCl_3$, *c* 0 2), IR ν_{max}^{KBr} cm^{-1} 3497, 2829,

1–7 (250 1 MHz, $CDCl_3$)

4		5		6		7
−14.5, 9.9, 9.7				—		
−14.5, 10.9, 2 0					4 876 *d*	5.8
	1.30–2 00	*massif*	1.30–2.00	*massif*		
−13.4, 9.9, 2.0					2 094 *d*	−15.8
−13 4, 10 9, 9.7					2.058 *dd*	−15.8, 5.8
11.0	2 785 *d*	11.0	2 852 *d*	10.9	2.506 *d*	10.8
11 0, 10.8, 3.1	5.438 *ddd*	11.0, 10 7, 3 2	5.339 *ddd*	10.9, 10.0, 3.1	5.324 *ddd*	10 8, 9.8, 2.8
−14.3, 10.8, 2.1, 0.7	2 763 *dd*	−13.3, 10.7	2 765 *dd*	−14 4, 10.0	2.584 *dd*	−13.9, 9 8
−14.3, 3 1, 0.6	2 238 *dd*	−13.3, 3 2	2.207 *dd*	−14.4, 3 1	2 266 *dd*	−13.9, 2.8
7.5, 2.1, 1.0	5.790 *dq*	7 5, 0 7	5 810 *br d*	7 3	5.528 *dd*	8.4, 4.5
	—		—		2.265 *dd*	−14.5, 4.5
7.5	4.938 *d*	7 5	5.066 *d*	7 3	1.923 *dd*	−14.6, 8.4
	≈1.9 *m*		≈1 9 *m*		1 811 *qq*	6 7, 6.8
6.7	0.852 *d*	6 7	0.934 *d*	6.8	0.809 *d*	6.7
6.8	0.973 *d*	6.8	0.996 *d*	6 8	0 935 *d*	6.8
	1.822 *br s*		1.812 *br s*		1.831 *s*	
	1 225 *s*		1 235 *s*		1.127 *s*	
	—		—		2 059 *s*	
7.2, 1.5	6 104 *qq*	7 2, 1.4	6 122 *qq*	7.3, 1.4	—	
7.2, 1.5	2.052 *dq*	7.2, 1 5	2 024 *dq*	7 3, 1.5	—	
1 5, 1.5	1.968 *qd*	1.5, 1 4	1 917 *qd*	1 5, 1.4	—	
	7.987 *m*		7 993 *m*		7.979 *m*	
	6 945 *m*		6.932 *m*		6 942 *m*	
	6.945 *m*		6 932 *m*		6 942 *m*	
	7 987 *m*		7.993 *m*		7 942 *m*	
	3.879 *s*		3 863 *s*		3.876 *s*	
	—		—		—	

1708, 1607, 1521, 1456, 1377, 1266, 1163, 1104, 1036, 962, 849, 767 EIMS (200°, 70 eV) *m/z* (rel. int.): 352 (1), 327 (1), 319 (0 5), 301 (0.2), 275 (2), 257 (0.8), 235 (4), 218 (8), 203 (5), 201 (22), 175 (71), 157 (13), 152 (14), 147 (13), 135 (100), 133 (19), 132 (74), 126 (24), 119 (19), 107 (13), 105 (17), 83 (40) CIMS (NH_3) *m/z* 471 [M + H]$^+$, 453 [M − H_2O + H]$^+$

6-*Angeloyloxy*-10-p-*methoxybenzoyl-jaeschkeanadiol*, (FB6, **6**). 40 mg of **3** were added to a soln of *p*-anisoyl chloride (100 mg) and dry pyridine (1 ml) in CH_2Cl_2 (10 ml) and the mixture heated to reflux for 1 hr, then cooled and the solvent evapd The residue was chromatographed on a silica gel column with CH_2Cl_2 to give 35 mg of the *p*-anisoyl derivative **6**. $C_{28}H_{38}O_6$: 470, $[\alpha]_D^{19}$ −99 9° ($CHCl_3$, *c* 0.7), IR ν_{max}^{KBr} cm^{-1}: 3515, 2967, 2875, 1709, 1647, 1607, 1512, 1460, 1382, 1323, 1258, 1167, 1100, 1034, 976, 848, 767. EIMS (200°, 70 eV) *m/z* (rel. int.): 327 (0.5), 275 (1), 235 (1.5), 218 (2.5), 202 (1), 175 (31), 157 (5), 152 (6), 147 (4), 135 (100), 132 (32), 126 (9), 119 (7), 107 (8), 105 (9), 92 (6), 91 (6), 83 (34). CIMS (NH_3) *m/z*: 453 [M − H_2O + H]$^+$

2-*Acetoxy*-6-p-*methoxybenzoyl-jaeschkeanadiol*, (FB8, **7**). $C_{25}H_{34}O_6$ 430; $[\alpha]_D^{19}$ + 9 6° ($CHCl_3$; *c* 0.5), IR ν_{max}^{KBr} cm^{-1}: 3482, 2964, 2879, 1730, 1696, 1608, 1548, 1512, 1464, 1376, 1256, 1169, 1098, 1029, 945, 846, 768. EIMS (200°, 70 eV) *m/z* (rel. int.): 387 (0 5), 327 (0.5), 275 (0 3), 235 (1), 218 (4), 203 (1.2), 201 (1.2), 200 (0 8), 175 (40), 157 (5), 153 (4), 152 (6), 147 (10), 136 (12), 135 (100), 132 (42), 126 (10), 121 (6), 119 (9), 107 (10), 105 (14), 83 (55). CIMS (NH_3) *m/z*: 431 [M + H]$^+$, 413 [M − H_2O + H]$^+$

Acknowledgement—We thank Dr J. P. Brouard for mass spectral measurements.

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