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A FURANODITERPENOID FROM THE LIVERWORT *JAMESONIELLA AUTUMNALIS**

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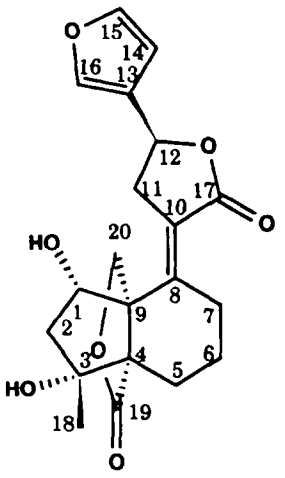
Key Word Index—*Jamesoniella autumnalis*; Hepaticae; furanoditerpenoid; jamesoniellide C; X-ray analysis.

Abstract—A new furanoditerpenoid, jamesoniellide C, has been isolated from the liverwort *Jamesoniella autumnalis*. The structure of jamesoniellide C was established by spectroscopic methods, including X-ray analysis which also established its relative stereochemistry.

INTRODUCTION

Liverworts are known to be a rich source of sesquiterpenoids and diterpenoids, some of which are new structural types [1–3]. In the course of our investigation of these compounds [4–7], we have examined *Jamesoniella autumnalis* (DC) Steph. This species is distributed over the northern hemisphere in Europe, Asia, and America [8]. We have previously reported the isolation and structure elucidation of six *ent*-labdanes, and three furanoditerpenoids related to the clerodane type, i.e. jamesoniellides A and B and 17-acetoxy-1β,12-dihydroxy-15,16-epoxy-*cis*-*ent*-cleroda-3,13(16),14-triene-22,18-olide, from *J. autumnalis* [9]. In this paper, we describe the structure of the newly isolated diterpenoid jamesoniellide C (**1**) with a novel carbon skeleton.



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RESULTS AND DISCUSSION

The extraction and fractionation of the liverwort *J. autumnalis* (1100 g, fr. wt) were described in a previous report [9]. Fraction 8 from the crude extract was further separated by several chromatographic steps to afford jamesoniellide C (**1**, 15 mg). Jamesoniellide C (**1**), crystals (mp 199–201°), showed a molecular ion peak in the HR-CI mass spectrum at *m/z* 375.1431, corresponding to the molecular composition of $C_{20}H_{22}O_7$. Further peaks at *m/z* 357 $[M+1-18]^+$ and 339 $[M+1-18-18]^+$, revealed the presence of two hydroxy groups. This was confirmed by the IR spectrum (3470 cm^{-1}). The ^{13}C NMR spectrum showed the signals of one methyl, six methylenes, five methine and eight quaternary carbons, suggesting the presence of three double bonds. The IR (875, 1020, 1505 cm^{-1}) and ^1H NMR (δ6.39, 7.40 and 7.47) spectra suggested the presence of a β-substituted furan ring. The ester signal at 1740 cm^{-1} was overlapped by a carbonyl absorption at 1760 cm^{-1} which, in combination with the signals at δ170.0 and 178.3 in the ^{13}C NMR spectrum, indicated two lactones. The low field shift of the olefinic carbon at δ160.8 and the IR (band at 1635 cm^{-1}) suggested one of the double bonds was conjugated with a carbonyl function. Therefore, the oxygens in the molecule corresponded to those in one furan ring, two hydroxy groups and two lactone rings. These facts mean jamesoniellide C (**1**) is a pentacyclic diterpenoid.

^1H–^1H COSY and ^{13}C–^1H COSY experiments established the partial structures A–E except for the presence of two quaternary carbons (Fig. 1). The signals at δ2.94

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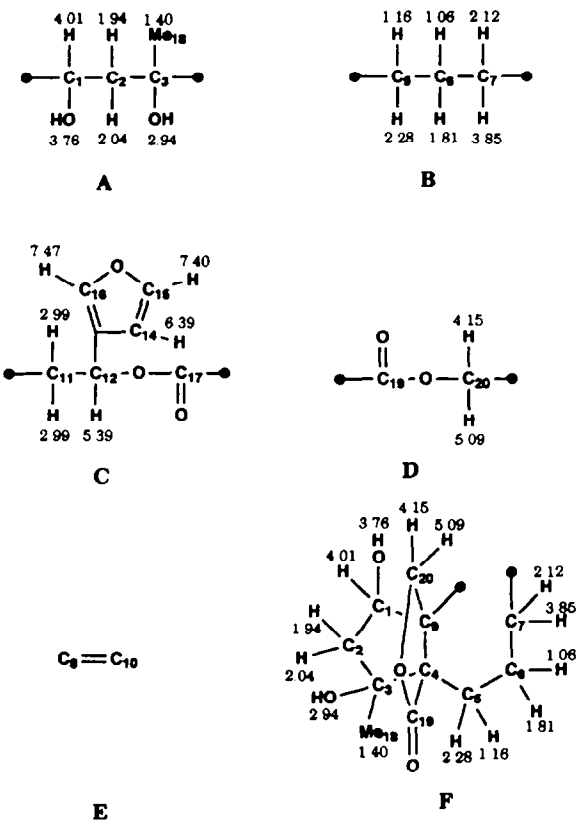

Fig. 1. Partial structures of jamesoniellide C (1).

and 3.76 in structure A were identified as hydroxy groups by exchange with D_2O. The long range coupling between H-16 (δ7.47) and H-12 (δ5.39) led to the structure C.

^{13}C-^1H long range COSY and NOE experiments revealed some connections of each partial structure. The quaternary carbon C-4 (δ63.7) showed correlations with Me at C-3 (δ1.40), H-1 (δ4.01) and H-6 (δ1.06 and 1.81), and C-9 (δ59.2) showed correlations with H-1, H-20 (δ4.15 and 5.09), and H-5 (δ1.16 and 2.28) which correlated with the signal at δ170.0. These results and the NOE observed from H-18 to H-5 led to structure F which combined the structures A, B and D with two quaternary carbons.

Furthermore, C-8 (δ160.8) showed correlations with H-1, H-6, H-11 (δ2.99), and H-20 (δ4.15 and 5.09), and C-10 (δ122.2) showed correlations with H-11, H-12 and H-7α (δ2.12). These results suggested two alternative structures of 1 combining the structures C, E and F (Fig. 2). However, even though the IR spectrum (1740, 1760 cm^{-1}) and low-field shift of C-8 in the ^{13}C NMR spectrum suggested the presence of an α_1,β-unsaturated γ-lactone group, the structure of 1 could not be finally resolved by additional NOE experiments (Tables 1 and 2).

The structure elucidation of 1 was completed by X-ray crystallographic analysis, which established the relative arrangement of the various partial structures and the stereochemistry (Fig. 3).

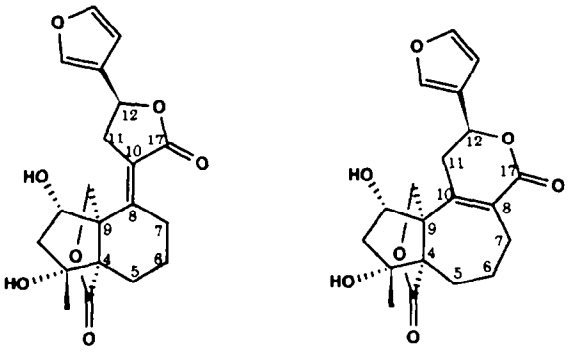

Fig. 2. Two alternative structures of jamesoniellide C (1).

Table 1. ^1H and ^{13}C NMR spectral data of 1 (400 MHz, $CDCl_3$)*

C		H	
1	81.7	1	4.01 *dd*, J = 5.8, 11.5
2	47.2	2α	1.94 *d*, J = 14.1
		2β	2.04[a] *dd*, J = 1.9, 6.1
3	85.7		
4	63.7		
5	28.8	5α	1.16[b] *m*
		5β	2.28 *m*
6	19.7	6α	1.06[b] *m*
		6β	1.81 *m*
7	27.7	7α	2.12[a] *m*
		7β	3.85 *br dd*, J = 1.5, 19.1
8	160.8		
9	59.2		
10	122.2		
11	35.7	11α	2.99[c] *m*
		11β	2.99[c] *m*
12	71.1	12	5.39 *t*, J = 6.8
13	124.7		
14	108.3	14	6.39 *m*
15	144.1	15	7.40 *m*
16	139.8	16	7.47 *m*
17	170.0		
18	21.2	18	1.40 *s*
19	178.3		
20	73.6	20, 20′	4.15 *d*, 5.09 *d*, J = 9.4
		1-, 3-OH	3.76, 2.94

*All assignments were accomplished by ^1H-^1H COSY, NOE, ^{13}C-^1H COSY and long range ^{13}C-^1H COSY experiments.
[a]-[c]Signals partly overlapping.

Recently, Nagashima *et al.* [10] have reported that the terpenoids from *J. autumnalis* collected in Japan are based on four *ent*-kaurane type diterpenoid structures. From a chemotaxonomic point of view, there must be at least two different chemical races of *J. autumnalis*, one producing 1, labdane and clerodane type diterpenoids, the other producing *ent*-kaurane type diterpenoids.

EXPERIMENTAL

HPLC was carried out as previously reported [9]. Optical rotations: $CHCl_3$; NMR: ^1H at 400 MHz, ^{13}C at

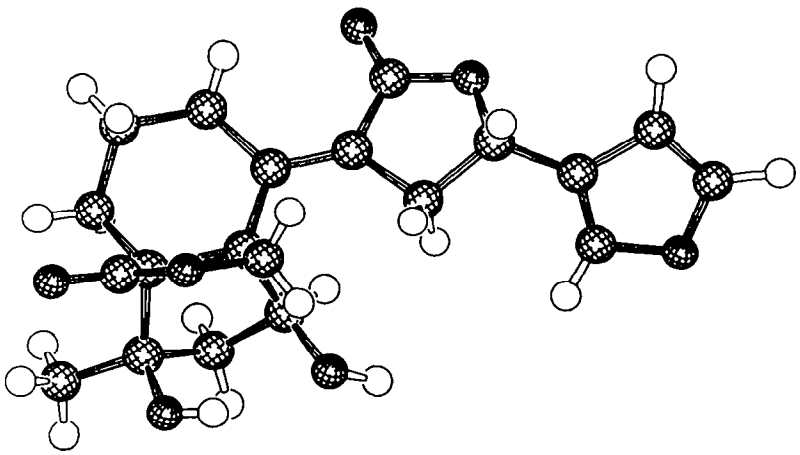

Fig. 3. SCHAKAL drawing of the molecule of jamesoniellide C (1) with the atomic numbering.

Table 2. NOE experiment on 1

Irradiation H	Observed NOE (signal enhancements per cent)
1	H-11 (5.7), H-14 (1.2), H-16 (1.9)
2β	H-18 (1.4)
18	H-5α (2.3), H-5β (2.1)
20	H-11 (4.9)
20′	OH-1 (8.6), H-11 (3.9)

100.5 MHz, $CDCl_3$, relative to $CHCl_3$ at δ_H7.25 and $CDCl_3$ at δ_{CH}77.0, respectively. ^{13}C multiplicities were determined using the DEPT pulse sequence.

Jamesoniella autumnalis (DC) Steph. was collected in December 1988 near Orscholz Saar and identified by Prof. Mues. Voucher specimens were deposited at the Institute of Pharmakognosie und Analytische Phytochemie der Universität des Saarlandes, Saarbrücken.

Extraction and isolation of 1. Previously, 8 frs were obtained from the crude extract (10.24 g) of the ground

Table 3. Crystallographic data and data collection characteristics for the X-ray analysis of 1

Crystal data	
Molecular formula	$C_{20}H_{22}O_7$
M_r (g mol^{-1})	374.4
Crystal system	Monoclinic
Space group	$P2_1$
Cell dimensions (Å) *a*	7.135(7)
b	12.566 (10)
c	10.357 (9)
β	104.79 (7)
Volume (Å^{-3})	897.9 (14)
Z	2
Density (g cm^{-3})	1.385
Absorption coefficient (cm^{-1})	1.05
F (000)	396
Data collection: Siemens Stoe AED2	
Graphite monochromated MoKα; ω/θ scans; scan width 1.20° + Kα-separation; scan speed 4.0 to 1.1° min^{-1}; 2θ range 3 to 50°;	
Reflections collected	3340
Independent reflections	3166 (R_{int} = 0.88%)
Observed reflections	2679($F > 2.0\sigma(F)$)
R-value	0.062
Computer and programs used: Siemens SHELXTL PLUS (VMS [11])	

material (1100 g, fr. wt) by vacuum liquid chromatography on silica gel (*n*-hexane–EtOAc, gradient) [9]. Chromatography [Sephadex LH-20 with CH_2Cl_2–MeOH (1:1) as an eluant, silica gel with *n*-hexane–EtOAc (3:2) as an eluant, and HPLC with a Diol column and *n*-hexane–EtOAc (3:2) as an eluant] of fr. 8 (100% EtOAc) afforded **1** (15 mg, crystallization from EtOAc and MeOH). Mp 199–201°. $[\alpha]_D$ −54.1° (*c* 0.015). HRMS $C_{20}H_{23}O_7$ Found: *m/z* 375.1431 $[M+1]^+$, requires 375.1444. IR ν^{KBr} cm^{-1}: 3470, 1760, 1740, 1635, 1505, 1170, 1020, 875; ^1H and ^{13}C NMR: Table 1; CIMS *m/z* (rel. int.): 375 $[M+1]^+$, (12), 357 (42), 338 (26), 295 (6), 289 (100), 271 (22), 243 (17), 201 (8), 167 (5), 149 (15), 87 (100).

X-Ray structure determination of **1**. Experimental details of the X-ray diffraction analysis of **1** are listed in Table 3. The data were corrected for Lorentz and polarization effects, but not for absorption. The structure was refined first isotropically, then anisotropically. The hydrogen atoms were located in difference maps and they were included in the last cycles of the refinement and refined. The highest peak in the final difference Fourier had a density less than 0.25 $eÅ^{-3}$.

The relative configuration of **1** was determined by a micro-Vax with the following programs: SHELX [11], SCHAKAL [12].

Lists of atomic coordinates, thermal parameters, structure factors, bond lengths, bond angles and torsion angles of **1** are deposited at the Cambridge Crystallographic Data Centre.

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