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ACORAFURAN, A NEW SESQUITERPENOID FROM *Acorus calamus* ESSENTIAL OIL

A. V. Tkachev,[1] A. M. Gur′ev,[2] and M. S. Yusubov[2]

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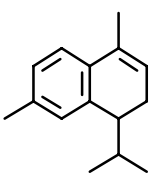
*The structure of acorafuran (6-isopropyl-4-methyl-7,8-dihydro-6*H*-naphtho[1,8-*bc*]furan), a new cadalin-type sesquiterpenoid from* Acorus calamus *essential oil, was established using spectral data (NMR, mass spectrometry).*

Key words: *Acorus calamus*, Araceae, acorafuran, 6-isopropyl-4-methyl-7,8-dihydro-6*H*-naphtho[1,8-*bc*]furan.

Rhizomes of *Acorus calamus* L. (Araceae) are used in traditional and conventional medicine, veterinary medicine, and the food and fragrance industries. Sweet flag is considered native to southeastern Asia and at present is widely distributed throughout the whole temperate zone of the northern hemisphere. Essential oil from roots of sweet flag has been extensively studied [1]. However, the essential oil components of *A. calamus* roots from northern Asia have not been reported.

In studying the composition of various samples of essential oil from sweet flag rhizomes collected both under laboratory conditions and from industrial facilities, we observed that oil samples obtained from rhizomes collected in northern Kazakhstan and southern West Siberia contained an unusual component with a content of 0.1-0.5% of the whole oil. This component, which we called acorafuran, is slightly polar. It was eluted by column chromatography over silica gel immediately after cadalin-type aromatic hydrocarbons (calocorene **1** and cadalin **2**) and gives a TLC spot on spraying with alcoholic vanillin with a characteristic red color.



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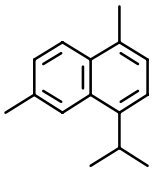

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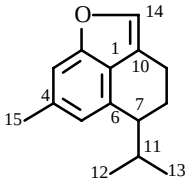

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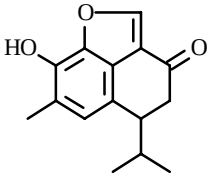

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The IR spectrum of acorafuran (**3**) had not absorption bands for carbonyl and hydroxyl groups. The high-resolution mass spectrum of **3** exhibited a rather strong peak for the molecular ion (33%) that corresponded to the empirical formula $C_{15}H_{18}O$. According to PMR and ^{13}C NMR spectra (Table 1), **3** contained the following structural fragments: 1) a 1,2,3,5-tetrasubstituted benzene ring with a methyl (δ_C 22.67 ppm and δ_H 2.36 ppm) as one of the substituents and H atoms in the positions *ortho* to it. One of the benzene substituents was an O atom according to the magnitudes of the chemical shifts of the H and C atoms in the aromatic ring. 2) a $-{}^aCH_2-{}^bCH_2-{}^cCH-CH-(CH_3)_2$ spin system where the $^aCH_2$ and ^cCH positions are allylic (benzylic) according to $^{2,3}J$(C–H) spin—spin coupling constants between the $^aCH_2$ and ^cCH protons and sp^2-hybridized C atoms. The nonequivalence of the methylene protons $^aCH_2$ and $^bCH_2$ and the nonequivalence of the isopropyl methyls indicated that **3** contained at least one chiral center. 3) a 2,3,4-trisubstituted furan ring according to a signal for a C atom at δ_C 136.80 ppm, a H atom bonded to this C atom (δ_H 7.04 ppm), and the SSCC between these atoms $^1J_{CH}$ = 199.4 Hz).

1) N. N. Vorozhtsov Novosibirsk Institute of Organic Chemistry, 630090, Novosibirsk, fax (383) 330 97 52, e-mail: atkachev@nioch.nsc.ru; 2) Tomsk State Medical University, Tomsk, 634050, Russian Federation. Translated from Khimiya Prirodnykh Soedinenii, No. 6, pp. 566-568, November-December, 2006. Original article submitted May 19, 2006.

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TABLE 1. PMR and ^{13}C NMR of Acorafuran (**3**)

i	δC^i, ppm	$^1J(C^i\text{-}H^i)$, Hz*	$^{2,3}J(C^i\text{-}H^j)$, Hz*	δH^j, ppm***	δH^i, ppm (J/Hz)
1	125.63	-	?***	2.57, 2.70, 6.69, 7.04	-
2	154.09	-	6.7, 2.4	6.92, 7.04	-
3	109.19	160.8	4×5.8	2.36, 6.69	6.92
4	134.16	-	3×6.2	2.36	-
5	120.91	154.2	5.0, 4×4.8	2.36, 6.92, 2.55	6.69
6	135.17	-	?***	1.75, 1.89, 2.02, 2.55, 6.69	-
7	43.57	126.7	8×4.3	0.87, 0.96, 6.69, 2.70	2.55 (6.8, 6.4, 4.0)
8	25.87	2×127.4	4×4.1	2.02, 2.55, 2.57, 2.70	1.75 (13.4, 8.8, 4.7, 4.0)
	18.65				1.89 (13.4, 6.9, 6.4, 4.5)
9		2×129.3	3×4.1	1.75, 1.89, 7.04	2.57 (15.8,. 6.9, 4.7, 1.5)
	116.86				2.70 (15.8, 8.8, 4.5, 1.5)
10	29.76	-	?***	1.75, 1.89, 2.57, 2.70, 7.04	-
11	22.01	127.2	?***	0.87, 0.96, 2.55	2.02 (7×6.8)
12	19.59	3×124.8	6.5, 3×5.0, 4.3	0.87, 2.02, 2.55	0.96 (6.8)
13	136.80	3×124.8	5×4.8	0.96, 2.02, 2.55	0.87 (6.8)
14	22.67	199.4	2×3.4	2.57, 2.70	7.04 (2×1.5)
15		3×126.2	2×4.8	6.69, 6.92	2.36

*From single-resonance ^{13}C NMR spectra; **from double-resonance ^{13}C-^1H heteronuclear correlation spectra for through-space SSCC; ***several small constants, signal multiplicity, and the size of constants could not be characterized.

Thus, **3** had the 4-isopropyl-6-methyl-1-methylene-1,2,3,4-tetrahydronaphthalene skeleton and was a cadalin-type sesquiterpene. Therefore, the isolated compound was 6-isopropyl-4-methyl-7,8-dihydro-6*H*-naphtho[1,8-*bc*]furan (**3**). The atomic numbering of **3** was the same as that for cadalin-type sesquiterpenes [2]. The electron-impact mass spectrum of **3** gave a parent peak with *m*/*z* 171 that corresponded to loss of a $C_3H_7^{\cdot}$ radical, which is characteristic of sesquiterpenes that contain an isopropyl group. Capillary gas chromatography gave a retention index (RI = 1735) for **3** that fell in the region for slightly oxygenated sesquiterpenes [3].

Several cadalin-type sesquiterpenes with an additional fused furan ring are known [2]. However, they all have the furan ring in a different position. The exception is hibiscone D (**4**), which was isolated from hibiscus extract (*Hibiscus tiliaceua* L., Malvaceae) [4]. The absolute configuration of **3** was not established, like the hibiscones described earlier.

EXPERIMENTAL

General Comments. All solvents were freshly distilled. TLC was performed on Silufol plates with a fixed layer of SiO_2. Compounds were developed by spraying with alcoholic vanillin (2 g vanillin + 5 mL conc. H_2SO_4 in 150 mL EtOH) and heating. Preparative column chromatography used Merck silica gel (0.063-0.100 mm). IR spectra of $CHCl_3$ solutions (*c* 1%) were recorded on a Bruker Vector-22 instrument. Mass spectra were obtained using GC—MS [Hewlett—Packard 5890/II with HP 5972A mass-selective detector, 30-m HP-5 MS quartz capillary column, 30 m × 0.25 mm, 0.25 μm stationary phase (diphenyl—dimethylsiloxane copolymer, 5:95), He carrier gas (1 mL/min), vaporizer temperature 280°C, column 50°C (2 min)-4°C/min-280°C, ion source 173°C, interface between GC and MS detector 280°C, ionizing-electron energy 70 eV, data collection 1.2 scans/s for mass range 30-650 amu]. High-resolution mass spectra were obtained in a Finnigan MAT-8200 mass spectrometer (electron-impact ionization, 70 eV).

PMR and ^{13}C NMR spectra were recorded on a Bruker DRX-500 spectrometer (500.13 MHz for ^1H; 125.75 MHz for ^{13}C) using CCl_4 and benzene-d_6 solutions (4:1 by volume) at 25°C and benzene-d_6 signals as standards (δ_C 128.00 ppm, δ_H 7.19 ppm). Signals were assigned using ^{13}C NMR spectra recorded with J-modulation (decoupling from protons, opposite phases for signals of atoms with an even and uneven number of bonded protons with tuning at J = 135 Hz) and 2D homonuclear ^1H—^1H and heteronuclear ^{13}C—^1H correlation spectra for direct SSCC (J = 135 Hz) and heteronuclear ^{13}C—^1H correlations for through-space SSCC (J = 8 Hz). Optical rotation angles were measured on a Polamat A polarimeter.

Isolation of Acorafuran (3). Ground (5-10 mm) and air-dried rhizomes of *A. calamus* (21 kg, collected in northern Kazakhstan in July-August 2001) were steam distilled at atmospheric pressure in September 2001 in a stainless-steel apparatus for 6 h to afford essential oil (150 mL, d_4^{25} 0.89 g/cm^3, 0.64% yield) as a light-brown oily liquid with a characteristic pleasant fragrance. The oil and all fractions prepared from it were stored under air-free conditions in dark vials at -12 to -18°C.

Highly volatile components (monoterpene hydrocarbons, oxygenated monoterpenes, bp ≤ 105°C at 5 mm Hg) were first distilled from the essential oil sample (10.0 g). The solid (8.8 g, brownish oil) was separated by column chromatography with elution by hexane to afford sesquiterpene hydrocarbons (3.5 g); by hexane:diethylether (20:1 v/v), slightly polar oxygenated sesquiterpenes (3.0 g); diethylether, polar sesquiterpenes (2.3 g). Repeated column chromatography of the slightly polar fraction using a hexane:diethylether gradient isolated **3** (0.020 g, 0.2% yield calculated for total essential oil) as a colorless viscous oil. TLC (hexane), R_f 0.25, gave a spot that turned red on spraying with alcoholic vanillin and subsequent heating. GC: RI 1735, $[\alpha]_{578}^{22}$ -161 (*c* 0.67, $CHCl_3$). High-resolution mass spectrum: found *m/z* 214.13520; cald. for $C_{15}H_{18}O$ $[M]^+$ 214.13577. Mass spectrum (*m/z*, I_{rel}, %): 215 (5) $[M + 1]^+$, 214 (33) $[M]^+$, 172 (14), 171 (100), 170 (3), 169 (6), 156 (10), 155 (6), 143 (15), 142 (3), 141 (11), 139 (2), 129 (3), 128 (28), 127 (6), 115 (10). Table 1 gives the NMR spectrum.

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