Pergamon

Phytochemistry, Vol. 46, No. 8, pp. 1403–1415, 1997

Printed in Great Britain
0031-9422/97 $17.00+0.00

PII: S0031-9422(97)00510-4

PSEUDOFUHALOLS FROM THE BROWN ALGA *SARGASSUM SPINULIGERUM**

MICHAEL KEUSGEN and KARL-WERNER GLOMBITZA†

Institut für Pharmazeutische Biologie, Nußallee 6, 53115 Bonn, Germany

(*Received in revised form* 21 *April* 1997)

Key Word Index—*Sargassum spinuligerum*; Phaeophyceae; phlorotannins; pseudofuhalols; structural elucidation; desacetylation.

Abstract—In addition to a large number of fuhalols and phlorethols previously identified in an ethanolic extract of *Sargassum spinuligerum*, a new class of fuhalols was isolated in form of their peracetyl derivatives and identified by means of spectral analysis. Fuhalols typically consist of phloroglucinol units linked by ether bridges. The pseudofuhalols described are isomers of known fuhalols with a different substitution pattern. The peracetyl derivatives from pseudotrifuhalol-A, pseudotetrafuhalol-A, pseudopentafuhalols-A–D, pseudohexafuhols-A–C, pseudoheptafuhalols-A–D and psuedooctafuhalols-B–D were isolated. Also an efficient method for conversion of peracetylated polyphenols into free phenols *via* reductive ester cleavage is described.

INTRODUCTION

Sargassum spinuligerum contains a great variety of phlorotannins. All main compounds belong to the class of fuhalols [1, 2]. The term "fuhalol" refers to compounds comprising ether-linked phloroglucinol units which contain an extra hydroxyl group on one unit, making that unit vicinal trihydroxylated. The ether bonds are oriented *para* and *ortho*, and in most cases, the vicinally trihydroxylated ring bears *ortho*-phenyl ethers (Fig. 1) [3]. Because of their unusual substitution pattern, the phlorotannins described in this paper are named 'pseudofuhalols'. They contain at least one 1,3-diphenoxy-4,5-diacetoxybenzene moiety, instead of a 1,4-diphenoxy-3,5-diacetoxybenzene unit. All of them were obtained from an ethanolic extract and peracetylated before isolation in order to prevent oxidation. But for bioactivity testing the desacetylated phenol is needed. The investigated species was collected at Wangaparoa Island, New Zealand.

RESULTS AND DISCUSSION

The acetylated crude mixture of phlorotannins was separated by flash chromatography and HPLC [1]. In comparison with fuhalols of the A-series [1], the R_fs

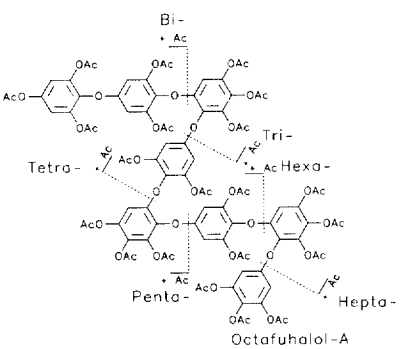


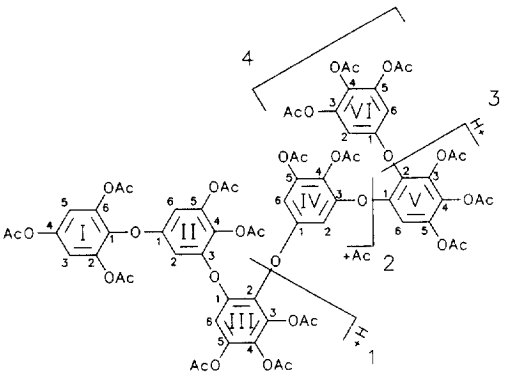
Fig. 1. Structure of some peracetylated fuhalols of the A-series [1, 3].

of the pseudofuhalols are slightly longer than those of regular fuhalols with the same number of phloroglucinol units. The substances after multiple step HPLC separation were examined by mass and NMR spectroscopy (Tables 1–10).

A M_r of 726 ($C_{34}H_{30}O_{18}$) could be deduced from the EI-mass spectrum of pseudotrifuhalol-A octa-acetate (**1**). The ^{1}H NMR spectrum (chloroform-*d*) gave singlets for two aromatic protons at δ 6.94 and δ 6.78. Also, an AB System at δ 6.56/δ 6.65 with a coupling constant of J = 3.2 Hz was identified, which is typical for *meta*-positionated aromatic protons. In conclusion, **1** consists of three tetrasubstituted benzene units which are linked by ether bonds. In addition, the ^{1}H NMR showed signals for a total of eight acetoxyl groups (Table 1).

The resonances at δ 6.94 (2H), δ 2.11 (6H) and δ

* From the dissertation of M. Keusgen (1993), Bonn D5.
† Author to whom correspondence should be addressed.



The numbering of the carbons in the formulae is not in accordance with IUPAC-rules.

2.27 (3H) are typical for an 1-phenoxylated 2,4,6-triacetoxybenzene unit, which is common for phlorotannins [1]. In contrast, a chemical shift of δ 6.78 has never been observed for fuhalols. To explain this signal, the chemical shifts of the synthetic compounds 3,4,5,3′,4′,5′-hexa-acetoxydiphenylether (homologous to partial structure **A**) [4] and 2,3,4,3′,4,3′,4′,5′-hexa-acetoxydiphenylether (homologous to partial structure **B**) [5, 6] were compared with a 4-phenoxylated 2,6,3′,4′,5′-hexa-acetoxydiphenylether unit (homologous to partial structure **C**), which is also characteristic for fuhalols [1–3] (Fig. 2, **A**, **B** and **C**, and Table 2). The influence of the substitution pattern at C-2 and C-6 of ring I on the chemical shifts of ring II was also of interest. The signals for the aromatic protons at C-2′ and C-6′ of ring II are shifted upfield

Table 1. ^{1}H NMR spectral data of compounds **1–4**

	1		**2**		**3**		**4**	
H	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO
Ring I								
3,5	6.94	7.03	6.94	7.02	6.94	7.02	6.94	7.01(5)
Ac-2, Ac-6	2.11	2.10	2.09	2.08	2.08	2.07	2.07	2.07
Ac-4	2.27	2.26	2.27	2.27(5)	2.27	2.27	2.27	2.27
Ring II								
2	6.65[a]	6.67[a]	6.59[b]	6.66[a]	6.60[c]	6.64[c]	6.59[d]	6.64[d]
6	6.56[a]	6.65[a]	6.44[b]	6.57[a]	6.44[c]	6.55[c]	6.44[d]	6.56[d]
Ac-4	2.15	2.14	2.05	2.07	2.05	2.06(5)	2.02[k]	2.04(3)[q]
Ac-5	2.24(7)	2.24(8)	2.24(5)[e]	2.24(5)[f]	2.23(7)[g]	2.23[i]	2.21[l]	2.21(5)[r]
Ring III								
2	6.78	6.83						
6	6.78	6.83	6.94(5)	6.99	6.89	6.97	6.90	6.98
Ac-3	2.25	2.24(2)	2.14	2.13	2.13[h]	2.12[j]	2.13(3)[m]	2.13[s]
Ac-4	2.26	2.25(2)	2.25[e]	2.25(3)[f]	2.24(3)[g]	2.25[i]	2.23(5)[l,o]	2.24[r,t]
Ac-5	2.25	2.24(2)	2.21	2.22(5)	2.20	2.21(7)	2.20[p]	2.21[u]
Ring IV								
2			6.65	6.74	6.62[a]	6.68[a]	6.61[a]	6.70[d]
6			6.65	6.74	6.49[a]	6.62[a]	6.41[a]	6.55[d]
Ac-3			2.24(5)	2.22(7)				
Ac-4			2.26(5)[e]	2.25(5)[f]	2.16[h]	2.15[j]	2.02(5)[k]	2.04(5)[q]
Ac-5			2.24(5)	2.22(7)	2.26[g]	2.25(7)[i]	2.24[l,o]	2.24(5)[r,t]
Ring V								
2					6.81	6.85		
6					6.81	6.85	7.01	7.01
Ac-3					2.23	2.22(7)	2.13(5)[m]	2.13(3)[s]
Ac-4					2.26(5)[g]	2.26[i]	2.25(5)[o]	2.26[t]
Ac-5					2.23	2.22(7)	2.21[p]	2.21(5)[u]
Ring VI								
2,6							6.67	6.75
Ac-3, Ac-5							2.24[o]	2.24(5)[t]
Ac-4							2.26	2.27

[a]: AB System, J = 3.2 Hz.
[b]: AB System, J = 3.1 Hz.
[c]: AB System, J = 2.9 Hz.
[d]: AB System, J = 3.0 Hz.
[e–u] Assignments with same letter may be interchanged.

	R_1	R_2
A	H	H
B	H	OAc
C	OAc	OAc

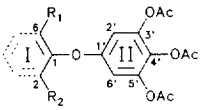


Fig. 2. Partial structures **A**, **B** and **C** derived from model compounds.

in accordance with the number of acetoxyl groups at C-2 and C-6 of ring I (Table 2). For the aromatic protons of ring II, substance (**B**) showed a resonance at δ 6.79 (chloroform-*d*). In the spectrum of **1**, a singlet for two protons at δ 6.78 was obtained. Consequently, this signal belongs to the triacetoxylated ring III of **1**, and ring II carries only one acetoxyl group in an *ortho*-position to the ether bond between ring II and III. Taking into account the total number of acetoxyl groups and the coupling constant for the AB system in the ^{1}H NMR spectrum, ring II of **1** is a 1,3-diphenoxy-4,5-diacetoxybenzene unit, which is new for phlorotannins and characteristic for all pseudofuhalols; the substitution pattern of ring II is not in accordance with the 'phloroglucinol rule' (all ring elements are derivable from phloroglucinol) [3]. In conclusion, **1** is built up by the ring types A, E and D (Fig. 3).

A comparison between the chemical shifts in the ^{13}C NMR spectrum (chloroform-*d*) of (**A**), (**B**) and (**C**) showed a correlation between the resonances of C-1′, C-2′ and C-6′ of ring II and the number of acetoxyl groups in positions 2 and 6 of ring I (Table 2). Remarkable are the slightly upfield-shifted signals for C-1′, of **B** (δ 153.8) in comparison with the element **C** and the downfield-shifted signal for C-2′, 6′ of **B** (δ 111.0). Assignments of chemical shifts were made by comparison with known fuhalols [3] and by calculation, according to Wegner-Hambloch and Glombitza [7]. In concordance with the ^{1}H NMR data, the ^{13}C NMR chemical shifts of ring III of 1 are nearly identical with the shifts of ring II in **B** (Table 3). The corresponding values of C-1, ring III of **1**, are δ 153.6 and, for C-2,6 of the same ring, are δ 110.8. The largest differences between the carbon shifts of ring III of **1** and ring II of model compound **B** are δ 0.2 ppm. In conclusion, both rings are identical and the substitution pattern of the neighbouring rings are similar.

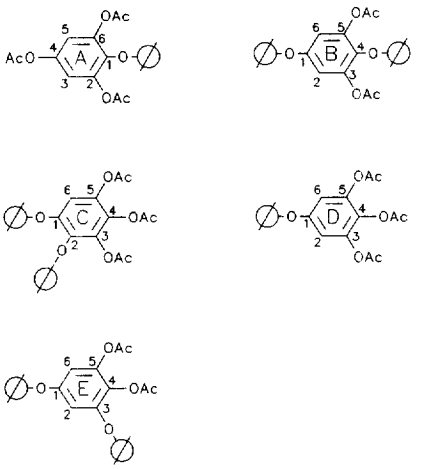


Fig. 3. Ring-types A, B, C, D and E of the peracetylated pseudofuhalols. ∅: aryl.

Pseudotetrafuhalol-A undeca-acetate (**2**) has a M_r of 992 ($C_{46}H_{40}O_{25}$) and has been obtained from a few brown algae but only in small amounts, and was assumed formerly to be 'tetrafuhalol-C undeca-acetate' [8–12]. The published structure (Fig. 4) was based upon the assumption that it has to follow the 'phloroglucinol rule'. All ketene elimination series in the EI-mass spectrum of tetrafuhalol-C undeca-acetate [8,

Table 2. NMR chemical shifts of structures **A**–**C**

	^{1}H NMR		^{13}C NMR		
	Ring II			Ring II	
H	$CDCl_3$	d_6-Me_2CO	C	Measured	Calculated*
			Structure **A**		
			1′	153.3	155.2
2′,6′	6.83	6.93	2′,6′	111.5	111.9
Ac-3′, Ac-5′	2.25	2.24	3′,5′	143.9	144.3
Ac-4′	2.26	2.27	4′	131.0	130.2
			Structure **B**		
			1′	153.8	155.2
2′,6′	6.79	6.84	2′,6′	111.0	111.9
Ac-3′, Ac-5′	2.25	2.24	3′,5′	143.8	144.3
Ac-4′	2.26	2.26	4′	130.9	130.2
			Structure **C**†		
			1′	154.6	155.2
2′,6′	6.71	6.79	2′,6′	108.8	111.9
Ac-3′, Ac-5′	2.22	2.21	3′,5′	143.5	144.3
Ac-4′	2.25	2.23	4′	130.9	130.2

* Calculated according to ref. [7], but without steric factors caused by ring I.

† Average of measured values obtained from fuhalols [1–3].

Table 3. ^{13}C NMR spectral data of compounds **1**, **2** and **4** in comparison with tetrafuhalol-A undeca-acetate (in $CDCl_3$)

C	**1** [ppm]	[ppm]	**2** System	*J* [Hz]	**4** [ppm]	tetrafuhalol-A undeca-acetate* [ppm]	System	*J* [Hz]
Ring type A								
	Ring I	Ring I			Ring I			
1	136.3	136.2	*dd*	7.2	136.4	136.3	*dd*	7.0
2,6	143.5	143.5	*d*	3.0	143.6	143.7	*d*	‡
3,5	115.0	114.9	*Dd*	164.2/5.5	114.9	114.8	*Dd*	168.4/5.4
4	146.7	146.5	*dd*	5.0	146.6	146.5	*dd*	5.1
Ring type E								
	Ring II	Ring II			Ring II, IV			
1	155.0	154.7	*dd*	5.1	154.4/154.7	†		
2	107.2	106.5	*Dd*	167.1/5.1	105.9/106.5			
3	148.9	149.0	*d*	5.0	148.8/148.9			
4	129.9	129.1	*dd*	7.0	129.3(1)/129.2(7)			
5	144.3	144.1	*d*	5.2	144.1/144.2			
6	106.7	105.3	*Dd*	165.2/5.5	105.3/105.5			
Ring type C								
		Ring III			Ring III, IV			
1		146.1	*d*	5.0	146.2/146.4	147.5	*d*	4.7
2		136.0	*d*	8.5	135.8/135.9	134.3	*d*	8.0
3		138.1	*s*	—	138.1/138.2	137.7	*s*	
4		132.6	*d*	8.8	132.5(8)/132.6(3)	131.2	*d*	8.5
5		140.2	*d*	5.9	140.3(1)/140.3(3)	140.0	*d*	6.0
6		112.3	*D*	168.2	111.9/112.1	108.8	*D*	167.0
Ring type D								
	Ring III	Ring IV			Ring VI			
1	153.6	154.3	*dd*	4.9	154.8	154.3	*dd*	4.7
2,6	110.8	108.6	*Dd*	166.8/5.0	108.6	108.6	*Dd*	167.0/4.7
3,5	143.8	143.6	*d*	3.0	143.7	143.7	*d*	5.5
4	130.9	130.3	*dd*	7.5	130.3	130.2	*dd*	‡

* Described in refs [3, 13].
† Data not comparable with **1**, **2** and **4**.
‡ could not be determined.

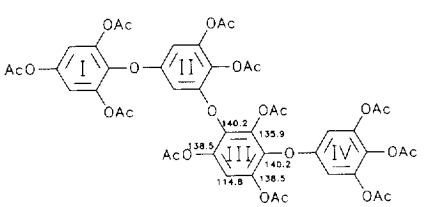


Fig. 4. Published structure of tetrafuhalol-C undeca-acetate and calculated ^{13}C NMR chemical shifts for the aromatic protons of ring III [7].

12] are similar to those of tetrafuhalol-A undeca-acetate [13], indicating that the substitution pattern of both fuhalols also must be similar (Fig. 1).

The ^1H NMR spectrum (chloroform-*d*) of **2** showed an AB system at δ 6.44/δ 6.59, with a coupling constant of $J = 3.1$ Hz. Analogously to ring II of **1**, these aromatic protons are arranged in a *meta*-position. But both signals for the AB system of **2** are shifted upfield relative to **1**. This indicated that ring III of **2** is more highly substituted (acetoxyl and/or phenoxyl groups) than ring III of **1**. In addition, the spectrum showed a singlet for one proton at δ 6.94(5), which indicates a diphenoxylated triacetoxylated unit (Table 1).

The ^{13}C NMR spectrum (chloroform-*d*) of **2** showed signals which are typical for an 1,2-diphenoxylated 3,4,5-triacetoxybenzene ring (Table 3 and Fig. 3, ring-type C). Assignment of carbon shifts was made by comparison with known data [3, 7], comparison with model structures **A**–**C** and deduced from the carbon–proton coupling constants. In comparison with the data obtained for tetrafuhalol-A undeca-acetate [8], the signal for C-1 (ring III) was upfield-shifted (δ 146.1; $J = 5.0$ Hz indicating a proton in an *ortho*-position) and the signals for C-2 and C-6 were significantly downfield-shifted (δ 136.0; $J = 8.5$ Hz indicating a proton in a *meta*-position, and δ 112.3; $J = 168.2$ Hz indicating a protonated carbon). Analogously to structure **B** (Table 2) and ring III of **1**, these shifts reveal information about the substitution pattern of ring II of **2**. This means that ring II has only one acetoxyl group in an *ortho*-position to the ether bond between ring II and ring III. Consequently, C-1 of ring III is substituted with the ring type 'E'

(ring II) and the signal at δ 6.94(5) in the ^{1}H NMR spectrum belongs to the proton attached to C-6 of ring III (type C, Fig. 3).

The protonated carbons C-2 and C-6 of **2**, ring II, gave resonances at δ 106.5 (J = 167.1–5.1 Hz) and δ 105.3 (J = 165.2–5.5 Hz), respectively. In comparison with **1** (C-2: δ 107.2; C-6: δ 106.7) these values are slightly upfield-shifted as an effect of the additional ring unit. The small difference between the resonances of each pair of signals (*ca* 1 ppm) leads to the conclusion, that the oxygen substitution of this ring II is nearly symmetrical relating to the axis through C-1 and C-4 (the structure-related influence of acetyl- or benzene-substitution is fairly small [7]). The two acetoxylated C-4 and C-5 of ring II in substance **2** gave signals at δ 129.1 and 144.1, respectively. The resonance of C-4 is strongly affected by the phenoxyl substituent at C-3 and, therefore, significantly upfield-shifted. All other ^{13}C NMR chemical shifts for rings I and IV of **2** are nearly identical with those published for tetrafuhalol-C undeca-acetate (Fig. 4) and were supported by the proton–carbon coupling constants of both substances.

In previous investigations, the suggested structure of tetrafuhalol-C undeca-acetate was not confirmed by ^{13}C NMR; Fig. 4 shows the calculated ^{13}C NMR chemical shifts for ring III of the formerly proposed structure. The corresponding signals were not obtained in the spectrum of **2** so that the structure of tetrafuhalol-C undeca-acetate must be revised.

Furthermore, the ^{1}H NMR spectrum of **2** gave singlets for aromatic protons at δ 6.94 (2H) and δ 6.65 (2H). They belong to the aromatic protons of ring I and IV, respectively, and are also characteristic for fuhalols [1]. The spectrum showed seven singlets for one acetoxyl group each and two signals for two equivalent acetoxyl groups each. The signal at δ 2.05 (chloroform-*d*) and one of the signals at *ca* δ 2.25 could be assigned to the acetoxyl groups at C-4 and C-5 of ring II, respectively. All other chemical shifts for these groups of ring I, III and IV are similar to those for fuhalol structural elements described recently [1, 2].

To confirm that **2** does not follow the 'phloroglucinol rule', a NOESY spectrum and a set of 1D NOE experiments were recorded. The obtained effects are indicated in Fig. 5 by arrows. A NOE between the proton at C-6 of ring III and the aromatic protons at C-2, as well as C-6 of ring II, indicates a linkage of

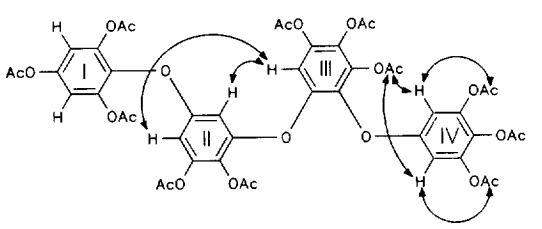


Fig. 5. Proton NOE's of **2**. Observed effects marked by arrows.

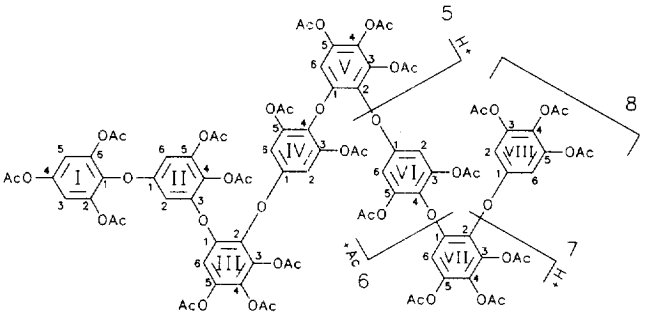
these two rings against the 'phloroglucinol rule'. The mutual effect between the aromatic proton at δ 6.59 (assigned to C-2 of II) and δ 6.94(5) (at C-6 of III) is significantly stronger than that between the protons at δ 6.44 (assigned to C-6 of II) and δ 6.94(5) (0.5 and 0.1% enhancement, respectively). The weak mutual effect between the protons at C-6 of rings II and III may be explained by a limited rotation about the ether bridge between both rings. These NMR assignments were different from the proton shifts which were reported for fuhalols with a similar substitution pattern like that of ring II, e.g. ring-type C′ (identical with *c* of Fig. 3, but without OAc at C-4) [1–3].

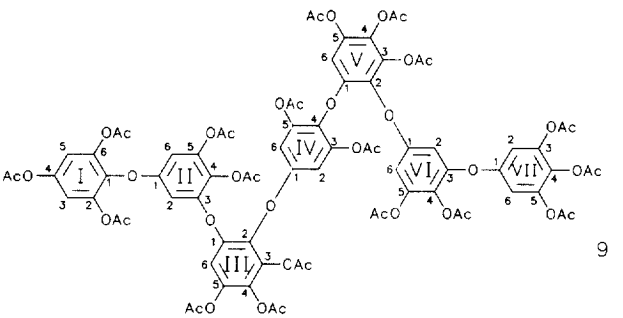
As a control, the same set of NOE experiments was recorded for octafuhalol-A heneicosa-acetate (Fig. 1), which strictly follows the 'phloroglucinol rule' and also contains 1,2-diphenoxylated 3,4,5-triacetoxybenzene units like ring III of **2**. But in contrast to **2**, there are no aromatic protons of two neighbouring rings arranged in *ortho*-position to the common ether bridge. No NOE between aromatic protons was obtained.

Pseudopentafuhalol-A trideca-acetate (**3**) is homologous to **1** and **2**. The ^{1}H NMR spectrum of **3** showed two AB-systems for aromatic protons at δ 6.44/6.60 and δ 6.49/6.62, respectively (Table 1). Also, a singlet for one proton at δ 6.89 and one for two protons at δ 6.81 are observable. Both AB systems belong to aromatic protons of the ring type E; one of them is connected with a ring-type C (proton at C-6: δ 6.89), the other is connected with a unit of the D-type (protons at C-2 and C-6: δ 6.81). A signal at δ 6.94 for two protons indicates ring-type A. In conclusion the different benzene units are arranged in the following sequence: A (ring I)–E–C–E–D (ring V). The M_r of 1200 ($C_{56}H_{48}O_{30}$) was confirmed by a FAB-mass spectrum.

Pseudohexafuhalol-B hexadeca-acetate (**4**) contains two structural elements consisting of the pattern [E+C]. In the ^{1}H NMR spectrum (chloroform-*d*), the corresponding signals for the aromatic protons of the ring types E (II, IV) were observed at δ 6.44/6.59 and δ 6.41/6.61, forming AB systems with coupling constants of J = 3.2 Hz and 3.0 Hz, respectively (Table 1). The protons at C-6 of ring-type C (III, V) gave singlets at δ 6.90 and δ 7.01. Also the ^{13}C NMR of **4** showed double sets for the signals belonging to the ring-types C and E (Table 3). Characteristic were the shifts of protonated C-2 and C-6 of rings II and IV (δ 105.9/106.5 and δ 105.3/105.5, respectively), as well as the shifts of the protonated C-6 of rings III and V (δ 111.9/112.1). All values of ring-types C and E did show an excellent correlation with those obtained for **2**. The chemical shifts for the aromatic carbons of ring I and VI are nearly identical to those of ring I and IV of **2** and of tetrafuhalol-A undeca-acetate.

The spectra measured in acetone-d_6 are also of interest for the structural elucidation of these pseudofuhalols. Analogously to the NMR analysis of fuhal-

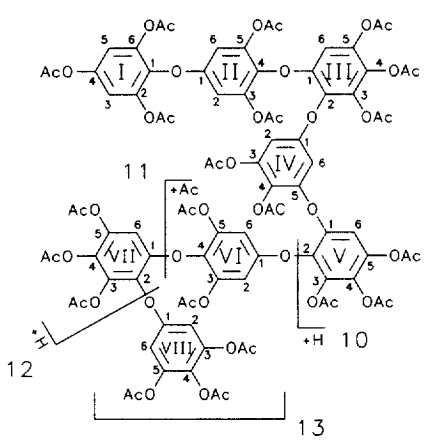


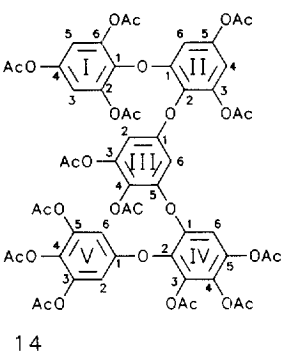


ols [1, 3], acetone-d_6 spectra gave useful information about the different ring-types. The aromatic proton of the ring-type C, which is substituted with the ring-type E at C-1, always showed a signal at *ca* δ 6.98 and was clearly distinguished from typical fucophlorethol signals [3].

The FAB-mass spectrum of **4** showed a $[M+H]^+$ at *m/z* 1467 corresponding with the molecular formula of $C_{68}H_{58}O_{37}$. A ketene elimination series starting from *m/z* 682 was observed in the EI-mass spectrum. This series is based on a dioxin fragment formed by the rings III and II substituted by I (after loss of IV, V and VI). Analogous fragmentations are described for fuhalols [3]. This proves the position of one of the 1,2-diphenoxylated 3,4,5-triacetoxybenzene rings (III).

Substances **5** to **16** contain typical fuhalol structural elements combined with the pseudo-fuhalol element (ring-types E and C or E and D). For these substances, the sequence of rings was determined by spectral comparison with pseudofuhalols **1**–**4** and with typical fuhalols [1, 2].





Pseudopentafuhalol-B trideca-acetate (**5**) has the same M_r (1200) and the same molecular formula ($C_{58}H_{48}O_{30}$) as **3**. Similar to **4**, the EI-mass spectrum of **5** showed a dioxin fragment ion at *m/z* 682, indicating the position of a ring of type C as the third ring

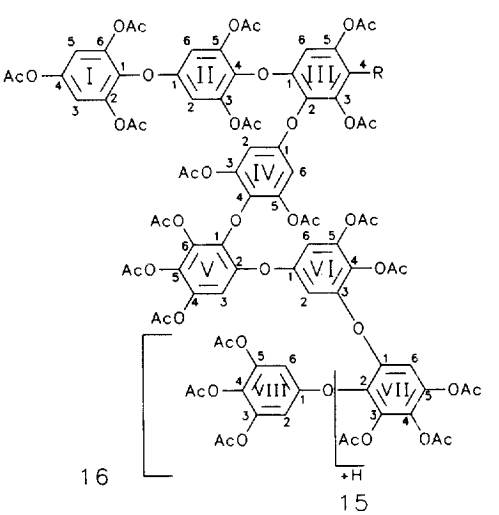


Table 4. ^{1}H NMR spectral data of compounds **5–8**

H	**5**		**6**		**7**		**8**	
	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO
Ring I								
3,5	6.94	7.03	6.94	7.03	6.94	7.02	6.94	7.03
Ac-2, Ac-6	2.09	2.08	2.08	2.08	2.08[k]	2.07(7)[n]	2.08	2.08
Ac-4	2.27(5)	2.28	2.27	2.28	2.27	2.28	2.27	2.28
Ring II								
2	6.60[a]	6.67[b]	6.58[b]	6.66[b]	6.58[a]	6.66[a]	6.58[b]	6.65[a]
6	6.46[a]	6.59[b]	6.44[b]	6.57[b]	6.44[a]	6.57[a]	6.44[b]	6.57[a]
Ac-4	2.08	2.05	2.02	*	2.03	*	2.01(7)	*
Ac-5	2.25[c]	2.25[d]	2.24[e]	2.24(8)[h]	2.24[l]	2.24(8)[o]	2.24(5)[q]	2.22(7)[u]
Ring III								
6	6.89	6.97	6.89(5)	6.97	6.89	6.97	6.89	6.97
Ac-3	2.18	2.16	2.18[f]	2.16(1)[i]	2.18[m]	2.16[p]	2.17(3)[r]	2.16[w]
Ac-4	2.25(5)[c]	2.26[d]	2.24(7)[e]	2.25(5)[h]	2.25[l]	2.25(1)[o]	2.25[q]	2.25[u]
Ac-5	2.22	2.22(3)	2.21[g]	2.23[i]	2.21	2.21	2.20(3)[s]	2.22(3)[w]
Ring IV								
2,6	6.65	6.73	6.62	6.76	6.62	6.73	6.61	6.76
Ac-3, Ac-5	2.07(5)	2.05	2.03	2.07	2.05	2.06(5)	2.02(5)[t]	*
Ring V								
2	6.70	6.78						
6	6.70	6.78	6.69	6.68	6.67	6.68	6.66	6.68
Ac-3	2.23	2.22(5)	2.17[f]	2.15(7)[i]	2.20[m]	2.20[p]	2.17(7)[r]	2.18(3)[v]
Ac-4	2.27(3)[c]	2.26[d]	2.24(5)[e]	2.25[h]	2.26[l]	2.25(1)[o]	2.26[q]	2.26[u]
Ac-5	2.23	2.22(5)	2.21[g]	2.23[i]	2.21	2.21	2.20(3)[s]	2.21[w]
Ring VI								
2,6			6.71	6.76	6.70	6.77	6.68	6.76
Ac-3, Ac-5			2.23(5)[e]	2.23(5)[i]	2.07[k]	2.07(5)[n]	2.02[t]	*
Ac-4			2.27	2.26				
Ring VII								
2					6.71	6.80		
6					6.71	6.80	6.69	6.70
Ac-3					2.22	2.21	2.19[r]	2.18(8)[v]
Ac-4					2.27[l]	2.27[o]	2.26[q]	2.25(5)[u]
Ac-5					2.22	2.21	2.17(3)[s]	2.15(8)
Ring VIII								
2,6							6.72	6.78
Ac-3, Ac-5							2.24[q]	2.23(2)[u]
Ac-4							2.27	2.26(3)

[a]: AB System, $J = 2.8$ Hz.
[b]: AB System, $J = 3.0$ Hz.
[c–w]: Assignments with same letter may be interchanged.
*: Hidden by solvent.

in a chain. The chemical shifts for rings I and II of **5** (Table 4) are very similar to those of the corresponding rings of **3** (Table 1). But in contrast to the ^{1}H NMR spectrum (chloroform-*d*) of **3**, the spectrum of **5** showed a singlet for two aromatic protons at δ 6.65, which is characteristic for a 1,4-diphenoxylated 3,5-diacetoxybenzene ring (type B), and a singlet for two protons at δ 6.70, which is characteristic for an 1-phenoxylated 3,4,5-triacetoxybenzene ring (type D). The typical signals for the carbons C-1 of ring IV and V were present in the ^{13}C NMR spectrum (δ 153.5 and 154.4, Table 5). From these results the following sequence of ring types could be deduced: A–E–C–B–D.

The FAB-mass spectrum of pseudohexafuhalol-B hexadeca-acetate (**6**) gave a $[M+H]^+$ at *m/z* 1467 ($C_{68}H_{58}O_{37}$), the spectrum of pseudoheptafuhalol-B octadeca-acetate (**7**) showed a $[M+H]^+$ at *m/z* 1675 ($C_{78}H_{66}O_{42}$) and the $[M+H]^+$ of pseudooctafuhalol-B henicosa-acetate (**8**) was observed at *m/z* 1941 ($C_{90}H_{76}O_{49}$). Consequently, **6–8** are homologous to **5**. In comparison with **5**, the ^{1}H NMR spectrum (chloroform-*d*) of **6–8** showed additional signals for protons belonging to the ring-types B and C (Fig. 3). Charac-

Table 5. ^{13}C NMR spectral data of compounds **5** and **6** (in $CDCl_3$)

C	**5** [ppm]	**6** [ppm]
	Ring type A	
	Ring I	Ring I
1	136.2[a]	136.3[c]
2,6	143.4(5)[b]	143.5(2)[d]
3,5	114.9	114.9
4	146.5	146.6
	Ring type E	
	Ring II	Ring II
1	154.8	154.8
2	106.7	106.6
3	148.9	149.0
4	129.2	129.2
5	144.1	144.1
6	105.6	105.5
	Ring type C	
	Ring III	Ring III, V
1	146.2	146.1/147.8
2	136.1[a]	134.4[e]/136.2[e]
3	138.0	137.8/138.1
4	132.5	131.3/132.6
5	140.2	140.1/140.2
6	112.0	109.1/112.2
	Ring type B	
	Ring IV	Ring IV
1	153.5	153.7
2,4	109.4	109.3
3,5	143.5(2)[b]	143.5(4)[d]
6	134.4	134.1[e]
	Ring type D	
	Ring V	Ring VI
1	154.4	154.8
2,6	109.0	108.7
3,5	143.7	143.7
4	130.1	130.3

[a] [e] Assignments with same letter may be interchanged.

teristic for the ring-type B is a singlet for two aromatic protons at δ 6.60–6.70. For fuhalols, the proton of C-6, ring-type C, typically showed a chemical shift between δ 6.64 and 6.70. In contrast to the ring type C involved in pseudofuhalol structures described above, this fuhalol ring-type C is substituted by a 2,6-diacetoxyphenoxy unit at C-1. The exact chemical shift depends on the position of this ring-type C in the molecule. If the ring is placed in the middle part of the molecule, an upfield shift results [1]. Characteristic signals for the ring types B and C were also visible in the ^{13}C NMR of **6** (Table 5). In contrast to **5**, the spectrum of **6** contained two sets of signals belonging to the ring-type C (III and V).

A M_r of 1674 ($C_{78}H_{66}O_{42}$) could be deduced from the FAB-mass spectrum of pseudoheptafuhalol-A octadeca-acetate (**9**), which has the same M_r as **7**. However, the ^1H NMR spectra showed significant differences. Instead of two singlets for two protons each at δ 6.70 and 6.71 (chloroform-*d*), the spectrum of **9** showed an AB-system at δ 6.56/6.71 and a singlet for two protons at δ 6.79 (Table 6), which is typical for a ring-type E substituted by the ring-type D (see structure **B**, Fig. 2 and Table 1). The AB-system belongs to the aromatic protons at C-2 and C-6 of the ring-type E of **9**. Because of similar chemical shifts for the rings I to V of **7** and **9**, ring V of **9** is connected by the ring-type E, resulting in the following sequence of ring types: A–E–C–B–C–E–D.

Like **3** and **5**, pseudopentafuhalol-C trideca-acetate (**10**) has a M_r of 1200 ($C_{56}H_{48}O_{30}$), which was determined by FAB-mass spectrometry. The ^1H NMR (chloroform-*d*) of **10** showed singlets at δ 6.94 (2H), δ 6.65 (2H) and 6.64 (1H). These resonances are characteristic for rings I, II and III of fuhalols belonging to

Table 6. ^1H NMR spectral data of compound **9**

H	**9** $CDCl_3$	**9** d_6-Me_2CO
	Ring I	
3,5	6.94	7.02
Ac-2, Ac-6	2.08	2.08
Ac-4	2.27	2.28
	Ring II	
2	6.58[a]	6.66[b]
6	6.45[a]	6.57[b]
Ac-4	2.03	*
Ac-5	2.24(5)[e]	2.25[h]
	Ring III	
6	6.89	6.97
Ac-3	2.17[f]	2.15[i]
Ac-4	2.25(5)[e]	2.25[h]
Ac-5	2.21[g]	2.23[j]
	Ring IV	
2,6	6.63	6.77
Ac-3, Ac-5	2.02(5)	2.01
	Ring V	
6	6.65	6.65
Ac-3	2.18(5)[f]	2.17[i]
Ac-4	2.23(5)[e]	2.24[h]
Ac-5	2.19[g]	2.20[j]
	Ring VI	
2	6.71[c]	6.74[d]
6	6.56[c]	6.66[d]
Ac-4	2.12	2.11
Ac-5	2.24(5)[e]	2.25[h]
	Ring VII	
2,6	6.79	6.84
Ac-3, Ac-5	2.22	2.21
Ac-4	2.27[e]	2.25[h]

[a]: AB System, J = 2.9 Hz.
[b]: AB System, J = 3.1 Hz.
[c]: AB System, J = 3.0 Hz.
[d]: AB System, J = 3.2 Hz.
[e–j]: Assignments with same letter may be interchanged.
*: Hidden by solvent.

the fuhalol A-series [1]. Similar to **1**, **3** and **9**, a singlet for two protons at δ 6.79 and an AB-system at δ 6.55/6.71 was observed in the spectrum of **10** (Table 7). This proves a typical pseudofuhalol structural element consisting of the ring-types E and D, which is linked with the fuhalol moiety by an ether bridge giving the ring-type sequence: A–B–C–E–D.

A M_r of 1466 ($C_{68}H_{58}O_{37}$), 1674 ($C_{78}H_{66}O_{42}$) and 1940 ($C_{90}H_{76}O_{49}$) could be deduced from the FAB-mass spectra of pseudohexafuhalol-C hexadeca-acetate (**11**), pseudoheptafuhalol-C octadeca-acetate (**12**) and pseudooctafuhalol-C henicosa-acetate (**13**), respectively, which are homologous to **10**. The ^{1}H NMR spectra of **10**–**13** showed nearly the same resonances for the protons of rings I–III. Ring IV was determined as ring-type E and the aromatic protons at C-2 and C-6 showed a characteristic AB-system in the range between δ 6.46 and 6.71 (chloroform-*d*). Analogous to **2**, **5** and **6**, the following rings (V, VI, ...) are alternatively 1,2-diphenoxylated and 1,4-diphenoxylated benzene units (type C and B). The last ring of the chain is always an 1-phenoxylated 3,4,5-

Table 7. ^{1}H NMR spectral data of compounds **10**–**13**

	10		**11**		**12**		**13**	
H	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO	$CDCl_3$	d_6-Me_2CO
Ring I								
3,5	6.94	7.04	6.94	7.04	6.94	7.05	6.94	7.04
Ac-2, Ac-6	2.11(5)	2.10	2.11	2.10	2.11	2.10	2.11	2.10
Ac-4	2.28	2.26(5)	2.28	2.27	2.28	2.27	2.28	2.27
Ring II								
2,6	6.65	6.75	6.65(5)[g]	6.74(5)[h]	6.66[k]	6.75[n]	6.65(3)	6.76
Ac-3, Ac-5	2.03	2.02	2.00	2.00	2.01	2.01	2.00(3)	2.00
Ring III								
6	6.64	6.65	6.63	6.64	6.63	6.64	6.62(5)	6.64
Ac-3	2.18	2.17	2.15	2.15	2.18	2.16	2.17(5)[q]	2.16[t]
Ac-4	2.24(5)[e]	2.24[f]	2.23(7)	2.25(5)[i]	2.26[l]	2.25(5)[o]	2.24[r]	2.25(5)[u]
Ac-5	2.21	2.21(5)	2.20	2.21[j]	2.20[m]	2.21[p]	2.20(2)[s]	2.21[v]
Ring IV								
2	6.71[a]	6.74[b]	6.68[c]	6.75(5)[d]	6.68[b]	6.77[b]	6.67[c]	6.75[a]
6	6.55[a]	6.66[b]	6.49[c]	6.61[d]	6.49[b]	6.62[b]	6.46[c]	6.60[a]
Ac-3	2.12	2.11	2.03	2.05	2.06	2.07	2.00	2.05(5)
Ac-4	2.25[e]	2.26[f]	2.20	2.20(5)[i]	2.21[m]	2.22[p]	2.20(3)[s]	2.23[v]
Ring V								
2	6.79	6.84						
6	6.79	6.84	6.94(5)	6.97	6.90	6.95	6.91	6.96
Ac-3	2.23	2.22	2.14	2.14	2.15	2.15	2.14	2.14(5)
Ac-4	2.26[e]	2.26[f]	2.23(7)	2.24[i]	2.24[l]	2.24(5)[o]	2.23(5)[r]	2.24(7)[u]
Ac-5	2.23	2.22	2.20	2.22(5)[j]	2.21[m]	2.23[p]	2.19(5)[s]	2.20[v]
Ring VI								
2,6			6.66[g]	6.74[h]	6.65(5)[k]	6.73[n]	6.63	6.75
Ac-3, Ac-5			2.23(5)	2.23	2.07	*	2.03	2.03(5)
Ac-4			2.26	2.26				
Ring VII								
2					6.70	6.79		
6					6.70	6.79	6.69	6.69
Ac-3					2.23	2.22	2.16(5)[q]	2.15(5)[t]
Ac-4					2.27[l]	2.26[o]	2.24(7)[r]	2.25(7)[u]
Ac-5					2.23	2.22	2.19(5)[s]	2.20[v]
Ring VIII								
2,6							6.72	6.76
Ac-3, Ac-5							2.23(5)	2.23(5)
Ac-4							2.25(8)[r]	2.26[u]

[a]: AB System, J = 3.2 Hz.
[b]: AB System, J = 3.0 Hz.
[c]: AB System, J = 3.1 Hz.
[d]: AB System, J = 2.8 Hz.
[e–v]: Assignments with same letter may be interchanged.
*: Hidden by solvent.

Table 8. ^{13}C NMR spectral data of compound **11** (in $CDCl_3$)

C	[ppm]
	Ring-type A (I)
1	136.5
2,6	143.6[a]
3,5	115.0
4	146.6
	Ring-type B (II)
1	153.5
2,6	109.6
3,5	143.5(7)[a]
4	134.1
	Ring-type C (III)
1	147.7
2	134.4
3	137.9
4	131.3
5	140.3
6	108.8
	Ring-type E (IV)
1	155.1
2	106.3
3	148.8
4	129.3
5	144.2
6	105.7
	Ring-type C (V)
1	146.5
2	135.7
3	138.1
4	132.5
5	140.3
6	111.9
	Ring-type D (VI)
1	154.5
2,6	108.6
3,5	143.7[a]
4	130.3

[a] Assignments may be interchanged.

triacetoxybenzene unit (type D). Therefore, the proton chemical shifts of the rings V and VI in **11** are comparable to the shifts of rings III and IV of **2**, the shifts of rings V, VI and VII in **12**, to those of III, IV and V of **5**, and those for V, VI, VII and VIII in **13** with those of III, IV, V and VI of **6**. The different ring types (A–D) of **11** were proven by a ^{13}C NMR spectrum (Table 8).

The FAB-mass spectrum of pseudopentafuhalol-D trideca-acetate (**14**) showed a $[M+H]^+$ at *m/z* 1201 ($C_{56}H_{48}O_{30}$). In contrast with **10**–**13**, the structure of **14** contains a deshydroxyfuhalol-moiety, in addition to the pseudofuhalol element. The chemical shifts of ring I and II are comparable to those of pentafuhalol-B trideca-acetate, which has also been isolated from *S. spinuligerum* [2]. A shift of δ 6.91(5) (chloroform-*d*) for two protons indicates an 1,2-diphenoxylated benzene unit at C-1 of a 2,4,6-triacetoxybenzene unit (ring I). An AB-system at δ 6.73/6.48 with a coupling constant of 2.8 Hz is typical for an 1,2-diphenoxylated 3,5-diacetoxybenzene unit (ring II). Ring II carries an E-type ring at C-2. The resonances of the protons of ring III, IV and V (Table 9) are nearly identical to those of rings IV, V and VI of **11** (Table 7).

Pseudoheptafuhalol-D octadeca-acetate (**15**) and pseudo-octafuhalol-D heneicosa-acetate (**16**) have the same molecular formula as **12** and **13**, $C_{78}H_{66}O_{42}$ and $C_{90}H_{76}O_{49}$, respectively. In spite of all similarity to **12** and **13**, nevertheless, the rings of **15** and **16** are arranged in a different manner. The ^1H NMR spectrum (chloroform-*d*) of **15** showed a singlet for two protons at δ 6.79 and an AB-system at δ 6.57/6.71. This indicates substitution of a ring of type E by a ring of type D, as in the case of **1**, **3**, **9** and **10**. Consequently, the fuhalol moiety consists of the rings I–V. The spectrum showed singlets for the aromatic protons of the ring types A (δ 6.94 for 2H), B (δ 6.65 and 6.68 2H each) and C (δ 6.64(5) for 2H).

Substance **16** is homologous to **15**. Analogously to **2**, **11** and **14**, ring VI (type E) of **16** is substituted by the ring types C (VII) and D (VIII), which gave characteristic resonances in the ^1H NMR spectrum (Table 10). The aromatic proton at C-6 of ring VII

Table 9. ^1H NMR spectral data of compound **14**

H	$CDCl_3$	d_6-Me_2CO
	Ring I	
3,5	6.91(5)	7.01
Ac-2, Ac-6	1.99	2.00
Ac-4	2.27	2.27
	Ring II	
4	6.73[a]	6.86[b]
6	6.48[a]	6.48[b]
Ac-3	2.14[d]	2.14
Ac-5	2.22[e]	2.20[g]
	Ring III	
2	6.65[a]	6.70[c]
6	6.48(5)[a]	6.62[c]
Ac-3	2.04	*
Ac-5	2.19[e]	2.20[g]
	Ring IV	
6	6.92	6.96
Ac-3	2.15[d]	2.12
Ac-4	2.24[f]	2.25[h]
Ac-5	2.20(5)[e]	2.22[g]
	Ring V	
2,6	6.65(5)	6.74
Ac-3, Ac-5	2.23(5)	2.23
Ac-4	2.25[f]	2.26[h]

[a]: AB System, J = 2.8 Hz.
[b]: AB System, J = 2.6 Hz.
[c]: AB System, J = 3.0 Hz.
[d–h]: Assignments with same letter may be interchanged.
*: Hidden by solvent.

Table 10. ^{1}H NMR spectral data of compounds **15** and **16**

H	**15** $CDCl_3$	d_6-Me_2CO	**16** $CDCl_3$	d_6-Me_2CO
Ring I				
3,5	6.94	7.05	6.94	7.05
Ac-2, Ac-6	2.11	2.10	2.11	2.10
Ac-4	2.28	2.27	2.28	2.26(5)[j]
Ring II				
2,6	6.65	6.75	6.66	6.74
Ac-3, Ac-5	2.03	*	2.04	*
Ring III				
6	6.64(5)	6.65(5)	6.63	6.65
Ac-3	2.18(5)[c]	2.18[e]	2.17[g]	2.18[k]
Ac-4	2.25[d]	2.25(3)[f]	2.25[h]	2.25[j]
Ac-5	2.21(5)	2.22	2.22[i]	2.22
Ring IV				
2,6	6.68	6.79	6.68	6.76
Ac-3, Ac-5	2.01	2.02	1.99	2.00
Ring V				
6	6.64(5)	6.66	6.64(7)	6.66
Ac-3	2.18[e]	2.17[e]	2.16	2.16
Ac-4	2.24(5)[d]	2.25[f]	2.25(5)[h]	2.26(2)[j]
Ac-5	2.18(7)	2.18(5)	2.18[g]	2.18(5)[k]
Ring VI				
2	6.71[a]	6.73[a]	6.68(5)[b]	6.75[b]
6	6.57[a]	6.66[a]	6.50[b]	6.63[b]
Ac-4	2.12	2.11	2.03	*
Ac-5	2.23(5)[d]	2.24[f]	2.20(3)[i]	2.22
Ring VII				
2	6.79	6.84		
6	6.79	6.84	6.94(7)	6.97
Ac-3	2.21	2.21	2.14	2.14
Ac-4	2.25[d]	2.27[f]	2.25[h]	2.24[j]
Ac-5	2.21	2.21	2.18[g]	2.18(5)[k]
Ring VIII				
2,6			6.65(2)	6.80
Ac-3, Ac-5			2.24	2.22
Ac-4			2.25[h]	2.26(2)[j]

[a]: AB System, $J = 3.1$ Hz.
[b]: AB System, $J = 2.9$ Hz.
[c–j]: Assignments with same letter may be interchanged.
*: Hidden by solvent.

was indicated by a singlet at δ 6.94(7), and the protons at C-2 and C-6 of ring VIII gave a singlet at δ 6.65(2) (chloroform-*d*).

Reductive cleavage of acetates. It has been shown that the phenolic groups must be acetylated directly after extraction to allow effective HPLC separation and structural elucidation [1, 3]. However, for bioactivity testing free phenols are needed. Ester cleavage using lithium aluminium hydride and tetrahydrofuran as solvent seems to be a suitable way. In the presence of potassium disulphite, rapid oxidation of free phenols was avoided during hydrolysis by using a surplus of lithium aluminium hydride. This method was tested for hexafuhalol-A hexadeca-acetate and heptafuhalol-A octadeca-acetate [1], which were closely related to the now described pseudofuhalols. The formed phenolic products were investigated by ^{1}H NMR. No signal was observed at *ca* δ 2, indicating complete desacetylation. After renewed acetylation, products formed were compared by HPLC with authentic peracetylated material of hexafuhalol-A and heptafuhalol-A [1] and found to be identical with the corresponding authentic samples. Consequently, neither the arrangement of the ring elements nor the pattern of phenolic groups was changed during this procedure. This method was also successfully applied to a fraction containing highly polymerized phlorotannins.

EXPERIMENTAL

EI-MS. 70 eV, 200–300°; positive ion FAB-MS: Xe gun, 3-nitrobenzylalcohol as matrix. ^{1}H NMR spectra (90 and 300 MHz) and ^{13}C NMR (75 MHz) were recorded using solvents as int. standards. NOE-difference and NOESY (mixing time 400 ms) were recorded at 500 MHz at 20°.

Extraction and isolation. Extraction and separation methods are described in ref. [1]. HPLC R_t of pseudo-fuhalols are 1–5 min longer than those of fuhalols belonging to the A-series with the same number of rings.

Reductive ester cleavage. A mixt. of hexafuhalol-A hexadeca-acetate and heptafuhalol-A octadeca-acetate (3:1, 123 mg) [1] was treated by 150 mg $LiAlH_4$ dissolved in 30 ml THF. After homogenization in an ultrasonic bath for 5 min, the suspension was heated for 1 hr under reflux with stirring. Hydrolysis was done at −15° in the presence of 5 g $K_2S_2O_5$ dissolved in 100 ml EtOH–H_2O (1:9) to avoid decomposition. The reaction resulted in a yellow suspension, which was extracted ×3 with 50 ml EtOAc, in order to remove a small amount of lipophilic impurities. The aq. layer was acidified (pH 1) with dil. H_2SO_4 (10%) and immediately extracted 4 times with 50 ml EtOAc. The combined EtOAc layers were dried (Na_2SO_4) and the solvent evapd under red. pres. to yield 35 mg product (*ca* 53%). ^{1}H NMR data of deacetylated products measured in CD_3OD (WH 90): δ 7.10, 7.11, 7.13, 7.14, 7.15, 7.25, 7.28, 7.30, 7.31 (all signals singlets). The substance was reacetylated by $(Ac)_2O$/C_5H_5N (1:1) and the product analysed by HPLC. HPLC-conditions: column: 250 × 8 mm, LiChrosorb® silica 60, 5 μm particle size. Solvent system (isocratic run): $CHCl_3$–*n*-hexane–MeCN (50:30.5:19.5), flow 2.5 ml min^{-1}. R_t of hexafuhalol-A hexadeca-acetate: 30.2 min. R_t of heptafuhalol-A octadeca-acetate: 36.3 min. Detection UV 275 nm.

Model substances. 3,4,5,3′,4′,6′-Hexa-acetoxydiphenylether (substance **A**): synthesis and identification described in ref. [4]. NMR data: Table 2. 2,3,4,3′,4′,5′-Hexa-acetoxydiphenylether (substance **B**): synthesis and identification described in refs [5, 6]. NMR data: Table 2.

Isolated compounds. Yields from 20 kg frozen alga. Pseudotrifuhalol-A octa-acetate, 1,2-diacetoxy-3-(3,4,5-triacetoxyphenoxy)-5-(2,4,6-triacetoxy-phenoxy) benzene (**1**). 6 mg. EI-MS ketene elimination series: *m/z* 726 → 390, 666 → 372, 476 → 266, 290 → 248. ^{1}H NMR: Table 1. ^{13}C NMR: Table 3. Pseudotetrafuhalol-A undeca-acetate, 2,3,3′,4′,5′-penta-acetoxy-5-(2,4,6-triacetoxyphenoxy)-2-(3,4,5-triacetoxyphenoxy) diphenylether (**2**). 9 mg. MS in refs [8, 12]. ^{1}H NMR: Fox Table 1. ^{13}C NMR: Table 3. Pseudopentafuhalol-A trideca-acetate, 3,4,5-triacetoxy-1-[2,3-diacetoxy-5-(2,4,6-triacetoxyphenoxy)phenoxy]-2-[4,5-diacetoxy-3-(3,4,5-triacetoxyphenoxy]phenoxy]-benzene (**3**). 1 mg. FAB-MS ketene elimination series: *m/z* 1223 $[M+Na]^+$, 1201 $[M+H]^+$ → 697. ^{1}H NMR: Table 1. Pseudohexafuhalol-A hexadeca-acetate, 2,3,4,4′,5′-penta-acetoxy-6-[2,3-diacetoxyphenoxy-5-(2,4,6-triacetoxyphenoxy)phenoxy]-3-[3,4,5-triacetoxy-2-(3,4,5-triacetoxyphenoxy) phenoxy]diphenylether (**4**). 15 mg. EI-MS ketene elimination series: *m/z* 950 → 530, 848 → 722, 808 → 514, 742 → 406, 726 → 390, 682 → 388, 434 → 266, 226 → 142. FAB-MS ketene elimination series: *m/z* 1505 $[M+K]^+$, 1489 $[M+Na]^+$ → 1447, 1467 $[M+H]^+$ → 1173. ^{1}H NMR: Table 1. ^{13}C NMR: Table 3. Pseudopentafuhalol-B trideca-acetate, 3,4,5-triacetoxy-1-[2,3-diacetoxy-5-(2,4,6-triacetoxyphenoxy)phenoxy]-2-[3,5-diacetoxy-4-(3,4,5-triacetoxyphenoxy)phenoxy] benzene (**5**). 10 mg. EI-MS ketene elimination series: *m/z* 1116 → 822, 684 → 390, 682 → 388, 624 → 392, 476 → 266, 226 → 142. FAB-MS ketene elimination series: *m/z* 1239 $[M+K]^+$, 1223 $[M+Na]^+$ → 1139, 1201 $[M+H]^+$ → 655. ^{1}H NMR: Table 4. ^{13}C NMR: Table 5. Pseudohexafuhalol-B hexadeca-acetate, 2,3,4,3′,5′-penta-acetoxy-6-[2,3-diacetoxy-5-(2,4,6-triacetoxyphenoxy)phenoxy]-4′-[3,4,5-triacetoxy-2-(3,4,5-triacetoxyphenoxy)phenoxy]diphenylether (**6**) 33 mg. EI-MS ketene elimination series: *m/z* 742 → 406, 684 → 390, 682 → 388, 492 → 282, 476 → 266, 418 → 250, 226 → 142. FAB-MS ketene elimination series: *m/z* 1505 $[M+K]^+$, 1489 $[M+Na]^+$ → 1405, 1467 $[M+H]^+$ → 963. ^{1}H NMR: Table 4. ^{13}C NMR: Table 5. Pseudoheptafuhalol-B octadeca-acetate, 1,3-diacetoxy-2-{3,4,5-triacetoxy-2-[3,5-diacetoxy-4-(3,4,5-triacetoxyphenoxy)phenoxy]phenoxy}-5-{2,3,4-triacetoxy-6-[2,3-diacetoxy-5-(2,4,6-triacetoxyphenoxy) phenoxy]phenoxy}benzene (**7**). 5 mg. FAB-MS ketene elimination series: *m/z* 1713 $[M+K]^+$, 1697 $[M+Na]^+$ → 1655, 1675 $[M+H]^+$ → 1339. ^{1}H NMR: Table 4. Pseudo-octafuhalol-B henicosa-acetate: 2,6,3′,4′,5′-penta-acetoxy-4-{2,3,4-triacetoxy-6-[2,3-diacetoxy-5-(2,4,6-triacetoxyphenoxy)phenoxy] phenoxy}-2′-{3,5-diacetoxy-4-[3,4,5-triacetoxy-2-(3,4,5-triacetoxyphenoxy)phenoxy]phenoxy} diphenylether (**8**). 3 mg. FAB-MS ketene elimination series: *m/z* 1963 $[M+Na]^+$, 1941 $[M+H]^+$ → 1689. ^{1}H NMR: Table 4. Pseudoheptafuhalol-A octadeca-acetate, 1,3-diacetoxy-2-{3,4,5-triacetoxy-2-[4,5-diacetoxy-3-(3,4,5-triacetoxyphenoxy)phenoxy] phenoxy}-5-{2,3,4-triacetoxy-6-[2,3-diacetoxy-5-(2,4,6-triacetoxyphenoxy)phenoxy]phenoxy}benzene (**9**). 1 mg. FAB-MS ketene elimination series: *m/z* 1713 $[M+K]^+$, 1697 $[M+Na]^+$ → 1655, 1675 $[M+H]^+$ → 1297. ^{1}H NMR: Table 6. Pseudopentafuhalol-C trideca-acetate, 3,4,5-triacetoxy-1-[2,6-diacetoxy-4-(2,4,6-triacetoxyphenoxy)phenoxy]-2-[4,5-diacetoxy-3-(3,4,5-triacetoxyphenoxy)phenoxy]benzene (**10**). 6 mg. EI-MS ketene elimination series: *m/z* 850 → 414, 684 → 390, 682 → 388, 624 → 414, 476 → 266, 416 → 248, 376 → 250, 184 → 142. FAB-MS ketene elimination series: *m/z* 1239 $[M+K]^+$, 1223 $[M+Na]^+$ → 1139, 1201 $[M+H]^+$ → 655. ^{1}H NMR: Table 7. Pseudohexafuhalol-C hexadeca-acetate, 2,3,4,4′,5′-penta-acetoxy-6-[2,6-diacetoxy-4-(2,4,6-triacetoxyphenoxy)phenoxy]-3′-[3,4,5-triacetoxy-2-

(3,4,5-triacetoxyphenoxy)phenoxy]diphenylether (**11**). 19 mg. EI-MS ketene elimination series: *m/z* 742 → 406, 684 → 390, 682 → 388, 476 → 266, 474 → 264, 334 → 250, 226 → 142. FAB-MS ketene elimination series: *m/z* 1505 $[M+K]^+$, 1489 $[M+Na]^+$ → 1405, 1467 $[M+H]^+$ → 1131. ^1H NMR: Table 7. ^{13}C NMR: Table 8. Pseudoheptafuhalol-C octadeca-acetate, 1,2-diacetoxy-3-{3,4,5-triacetoxy-2-[3,5-diacetoxy-4-(3,4,5-triacetoxyphenoxy)phenoxy]phenoxy}-5-{2,3,4-triacetoxy-6-[2,6-diacetoxy-4-(2,4,6-triacetoxyphenoxy)phenoxy]phenoxy}benzene (**12**). 3 mg. FAB-MS ketene elimination series: *m/z* 1713 $[M+K]^+$, 1697 $[M+Na]^+$ → 1655, 1675 $[M+H]^+$ → 1339. ^1H NMR: Table 7. Pseudo-octafuhalol-C henicosa-acetate, 2,3,3′,4′,5′-penta-acetoxy-5-{2,3,4-triacetoxy-6-[2,6-diacetoxy-4-(2,4,6-triacetoxyphenoxy)phenoxy]phenoxy}-2′-{3,5-diacetoxy-4-[3,4,5-triacetoxy-2-(3,4,5-triacetoxyphenoxy)phenoxy]phenoxy}diphenylether (**13**). 14 mg. FAB-MS ketene elimination series: *m/z* 1979 $[M+K]^+$, 1963 $[M+Na]^+$ → 1879, 1941 $[M+H]^+$ → 1395. ^1H NMR: Table 7. Pseudopentafuhalol-D trideca-acetate, 1,2-diacetoxy-3-[3,4,5-triacetoxy-2-(3,4,5-triacetoxyphenoxy)phenoxy]-5-[2,4-diacetoxy-6-(2,4,6-triacetoxyphenoxy)phenoxy]benzene (**14**). 7 mg. EI-MS elimination series: 1158 → 654, 1098 → 930, 1030 → 694, 892 → 514, 890 → 512, 790 → 496, 682 → 388, 642 → 390, 624 → 372, 542 → 374, 434 → 266, 432 → 264, 416 → 248, 376 → 292, 226 → 142, 168 → 126. FAB-MS ketene elimination series: *m/z* 1239 $[M+K]^+$, 1223 $[M+Na]^+$ → 1181, 1201 $[M+H]^+$ → 781. ^1H NMR: Table 9. Pseudoheptafuhalol-D octadeca-acetate, 1,3-diacetoxy-2-{3,4,5-triacetoxy-2-[4,5-diacetoxy-3-(3,4,5-triacetoxyphenoxy)phenoxy]phenoxy}-5-{2,3,4-triacetoxy-6-[2,6-diacetoxy-4-(2,4,6-triacetoxyphenoxy)phenoxy]phenoxy}benzene (**15**) 5 mg. FAB-MS ketene elimination series: *m/z* 1713 $[M+K]^+$, 1697 $[M+Na]^+$ →1613, 1675 $[M+H]^+$ → 1129. ^1H NMR: Table 10. Pseudo-octafuhalol-D heneicosa-acetate, 2,6,3′,4′,5′-penta-acetoxy-4-{2,3,4-triacetoxy-6-[2,6-diacetoxy-4-(2,4,6-triacetoxyphenoxy)phenoxy]phenoxy}-2′-{4,5-diacetoxy-3-[3,4,5-triacetoxy-2-(3,4,5-triacetoxyphenoxy)phenoxy]phenoxy}diphenylether (**16**). 3 mg. FAB-MS ketene elimination series: *m/z* 1979 $[M+K]^+$, 1963 $[M+Na]^+$ → 1921, 1941 $[M+H]^+$ → 1731. ^1H NMR: Table 10.

Acknowledgements—We thank Dr Dromgoole (University of Auckland) for introducing us to the New Zealand algae and the identification of the alga. Thanks are also due to the Central Analytic of the Chemical Institutes and the NMR department of the Pharmaceutical Institute, University of Bonn, for mass and NMR spectra. We are grateful to Dr John Walter and Mr Ping Seto at the Institute for Marine Biosciences, Halifax, for recording the NOE experiments and revising the manuscript. This research was supported by the Ministerium für Wissenschaft and Forschung, NRW.

REFERENCES

1. Glombitza, K.-W. and Keusgen, M., *Phytochemistry*, 1995, **38**, 987.
2. Keusgen, M. and Glombitza, K.-W., *Phytochemistry*, 1995, **38**, 975.
3. Ragan, M. A. and Glombitza, K.-W., in *Progress in Phycological Research*, Vol. 4, ed. Round, F. E. and Chapman, D. J. Biopress, Bristol, 1986, p. 129.
4. Sattler, E., Glombitza, K.-W., *Archiv der Pharmazie* (*Weinheim*), 1975, **308**, 813.
5. Wölwer-Rieck, U., Dissertation, University of Bonn, Germany, 1984.
6. Glombitza, K.-W. and Wölwer-Rieck, U., *Liebigs Annalen der Chemie*, 1988, 261.
7. Wegner-Hambloch, S. and Glombitza, K.-W., *Magnetic Resonance in Chemistry*, 1985, **23**, 358.
8. Glombitza, K.-W., Geisler, C. and Eckhardt, G., *Botanica Marina*, 1980, **23**, 735.
9. Glombitza, K.-W., Schnabel, C. and Koch, M., *Archiv der Pharmazie* (*Weinheim*), 1981, **314**, 602.
10. Everth, G., Dissertation, University of Bonn, Germany, 1986.
11. Glombitza, K.-W. and Li, S.-M., *Phytochemistry*, 1991, **30**, 2741.
12. Geisler-Kleindienst, C., Dissertation, University of Bonn, Germany, 1977.
13. Glombitza, K.-W., Rösener, H.-U. and Koch, M., *Phytochemistry*, 1976, **15**, 1279.