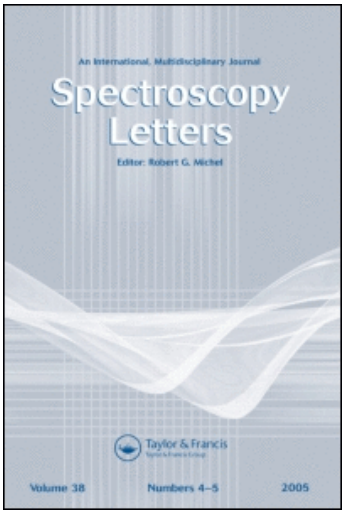

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Fourier Transform Infrared and Conformational Analysis of Cholesteryl 4-*n*-Alkoxybenzoates in Solution

Guan-Yeow Yeap,[1,*] Sie-Tiong Ha,[1] Yoshiyuki Nakamura,[2] Peng-Lim Boey,[1] Wan Ahmad Kamil Mahmood,[1] Masato M. Ito,[3] Hironori Nakai,[3] and Masayoshi Yamaki[3]

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ABSTRACT

An investigation of cholesteryl 4-*n*-alkoxybenzoates via Fourier transform IR at ambient temperature revealed that the cholesteryl fragment in the solid crystals is rigid, and the terminal alkyl chains of different lengths attached to the benzoyloxy group are fully extended. Conformational analysis in chloroform ($CDCl_3$) at the same temperature was

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done for the first time via high resolution ^{1}H and ^{13}C NMR spectra using DEPT, 2D COSY, NOESY, ROESY, gradient heteronuclear multiple quantum-coherence spectroscopy (gradient HMQC spectroscopy), and gradient heteronuclear multiple bond correlation spectroscopy (gradient HMBC spectroscopy). Normal 1D NMR, on the other hand, has disclosed that in $CDCl_3$ solution, there exists conformations wherein the O═C–O bridging the benzoyloxy group and the cholesteryl fragment is kinked, which entailed the cholesteryl fragment to fold up.

Key Words: IR; NMR; ^{1}H NMR; ^{13}C NMR; Cholesteryl 4-*n*-alkoxybenzoates; Gradient heteronuclear multiple bond correlation spectroscopy.

INTRODUCTION

The cholesteryl 4-*n*-alkoxybenzoates ($C_nH_{2n+1}OC_6H_4COOCh$ or R*n*OBCh, where Ch represents the cholesteryl moeity) were synthesized by Dave and Vora thirty years ago with the aim to study the mesomorphic properties of thirteen members of R*n*OBCh homologous compounds ($n = 1–10$, 12, 16, and 18).[1] These compounds have attracted interest since 1970 owing to the presence of various types of mesophases associated with the different structural moieties attached to the main core system, as exemplified by other types of liquid crystals.[2–7] The crystal structure of cholesteryl acetate, for instance, has been reported by Sawzik in 1979.[8]

Yakubov carried out a systematic study of the infrared spectra of R*n*OBCh within a confined frequency region of $1800–700\,cm^{-1}$ and found a number of correlations between spectra, structure, and mesomorphic characteristic of these compounds in different phases.[9] However, the spectroscopic characterization of these compounds in solutions of common organic solvents has, hitherto, not been reported in the literature.

In this paper, we report a comprehensive study of a series of R*n*OBCh, which consists of seven members ($n = 6$, 8, 10, 12, 14, 16, and 18) derived from the direct esterification as reported by Sudhakar.[10] This report aims at generalizing and comparing the conformations of those molecules that exist as solid crystals as well as in solution. The spectroscopic technique used involves IR over the frequency range of $4000–400\,cm^{-1}$, and high-resolution 1D and 2D multinuclear magnetic resonance methods. The complete ^{1}H and ^{13}C NMR assignments for these compounds were done to substantiate the molecular structure for each compound in chloroform ($CDCl_3$). The abbreviation of the R*n*OBCh homologs represents a general formulation for the title compounds, where Ch is the cholesteryl moiety and

R is C_nH_{2n+1}. The value n represents different numbers of carbons at the terminal chain, and a simplified abbreviation for each compound is denoted as nOBCh (where $n = 6$, 8, 10, 12, 14, 16, and 18) in the following sections.

EXPERIMENTAL

Reagents and Techniques

4-Hydroxybenzoic acid and 4-dimethylaminopyridine (DMAP) were obtained from Merck (Germany). 1-Bromohexane, 1-bromooctane, 1-bromotetradecane, 1-bromohexadecane, and 1-bromooctadecane were purchased from Aldrich Chemical Company (USA). Whilst cholesterol was obtained from Acros Organics (USA), 1-bromodecane, 1-bromododecane, and *N*,*N*′-dicyclohexylcarbodiimide (DCC) were purchased from Fluka Chemie (Switzerland).

IR spectra for the samples, mixed with KBr, were recorded on a Perkin Elmer 2000-FTIR spectrophotometer over a frequency range of $4000-400\,cm^{-1}$.

NMR spectra were recorded in $CDCl_3$ at 298K on a Bruker 400 MHz Ultrashield™ equipped with a 5 mm BBI inverse gradient probe. Chemicals shifts were referenced to internal TMS. The concentration of solute molecules was 25 mg in 0.8 mL $CDCl_3$. The NMR experiments were done by use of 1D (^1H, ^{13}C, and DEPT) and 2D (COSY, NOESY, ROESY, HMQC, and HMBC) techniques.

Preparation of Cholesteryl 4-*n*-Alkoxybenzoates

All title compounds were prepared by use of a published synthetic method.[10] For the preparation of 6OBCh, 4-hydroxybenzoic acid was reacted with bromoalkane in the presence of KOH. The mixture was refluxed and the resulting solution was neutralized with aqueous HCl, which led to the formation of the intermediate 4-hexyloxybenzoic acid. This intermediate was recrystallized in glacial acetic acid before undergoing esterification with cholesterol in the presence of DCC and DMAP. The compounds 8OBCh, 10OBCh, 12OBCh, 14OBCh, 16OBCh, and 18OBCh were synthesized using a similar method. The atomic positions in 6OBCh were numbered in a sequential manner (Fig. 1) for later discussion purposes.

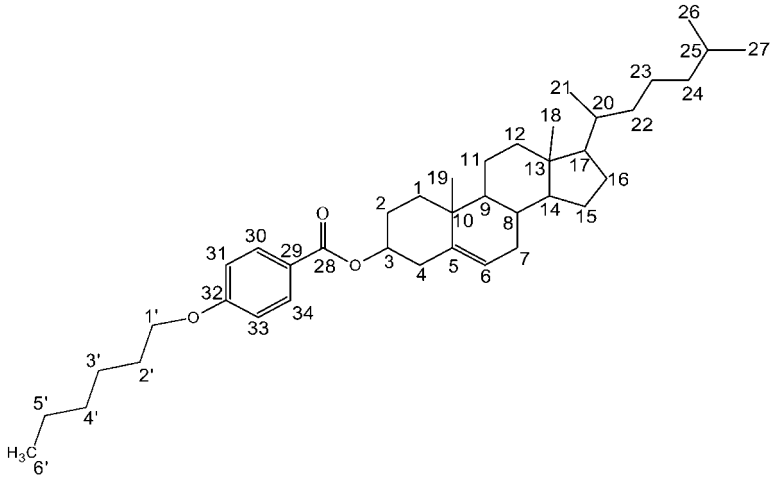

Figure 1. Molecular structure with numbering scheme for 6OBCh.

RESULTS AND DISCUSSION

An extensive study of cholesteryl 4-*n*-alkoxybenzoates with different benzoyloxy moieties was done by identifying the functional group present in these compounds, mixed with KBr, over a frequency range (4000–400 cm^{-1}). This frequency range is greater than, but encompasses, the region (1800–700 cm^{-1}) reported by Yakubov, who focused on the molecular structure and interaction in *n*OBCh with $n = 3$–6, 10, and 16.[9] Selected IR data (Table 1) show that all compounds (*n*OBCh with $n = 6$, 8, 10, 12, 14, 16, and 18) were isolated that contained the phenolic hydroxyl group (OH) substituted by various alkyl groups R (R = C_nH_{2n+1} and $n = 6$, 8, 10, 12, 14, 16, and 18). The present study shows the same appearance of characteristic bands of the aliphatic alkyl chain, within the frequency ranges of 2939–2918 and 2870–2849 cm^{-1}, as those reported by Wiberley and his coworkers.[11] The bands with medium intensities observed for all compounds at 1468–1466 cm^{-1} are indicative of the methylene groups of the cholesterol fragment.[12] A strong band, which occurs within the frequency range of 1275–1271 cm^{-1}, is attributable to the stretching of C_{29}–C_{28}–O. This observation resembles that reported by Smith et al.[13] In addition to this band, there is another band appearing at 1256–1249 cm^{-1}, which can be associated with the stretching of C_{32}–O in ether bond.[10,13] The 1,4-disubstituted aromatic ring attached to the cholesteryl fragment can also be substantiated

Table 1. Frequencies (cm^{-1}) and relative intensities of the observed bands of *n*OBCh series ($n = 6$, 8, 10, 12, 14, 16, and 18).

Compounds	$\nu_{C-H\,stretching}$		$\nu_{C=O}$	ν_{CH_2}[a]	$\nu_{C_{29}-C_{28}-O}$	$\nu_{C_{32}-O}$	$\nu_{arom(1,4)}$
6OBCh	2938.9 s	2869.6 s	1709.5 s	1467.1 m	1274.9 s	1249.7 s	846.0 m
8OBCh	2928.8 s	2851.2 s	1702.4 s	1467.2 m	1274.4 s	1255.2 s	848.0 m
10OBCh	2931.7 s	2852.7 s	1701.6 s	1466.8 m	1275.0 s	1254.5 s	847.1 m
12OBCh	2927.0 s	2850.6 s	1702.5 s	1467.0 m	1271.3 s	1253.6 s	850.9 m
14OBCh	2928.2 s	2851.4 m	1705.1 m	1466.6 m	1271.5 s	1253.9 s	850.0 m
16OBCh	2924.8 s	2852.5 s	1699.1 s	1467.4 m	1274.5 s	1254.4 s	847.2 m
18OBCh	2918.3 s	2849.1 s	1712.4 m	1470.3 m	1273.7 m	1251.8 s	849.6 m

Note: s, strong; m, medium; w, weak.
[a]Methylene groups in cholesteryl fragment.

from the diagnostic band observed within the frequency range of 851–846 cm^{-1}. These bands fall within the frequency range reported by Landgrebe.[14]

The structural characterization of these compounds in the crystal phase via IR resembles that observed by Yakubov, who focused on a smaller frequency range (1800–700 cm^{-1}) wherein the samples were filmed between NaCl or KBr substrates.[9] The derivatives obtained in our laboratory were subsequently used for studying the conformations of these compounds in chloroform ($CDCl_3$). In order to further investigate the molecular structures of cholesteryl 4-*n*-alkoxybenzoates (*n*OBCh, where $n = 6$, 8, 10, 12, 14, 16, and 18) present in $CDCl_3$, at ambient temperature, we used two-dimensional techniques such as 2D COSY, NOESY, ROESY, HMQC, and HMBC experiments, along with normal ^1H NMR, ^{13}C NMR and DEPT, which have not been reported in the literature earlier. The assignment was made in comparison with the signals inferred from the NMR spectrum of cholesterol.[15]

Whilst the normal 1D ^1H NMR data and selected coupling constants for cholesterol and *n*OBCh, where $n = 6$, 8, 10, 12, 14, 16, and 18, are shown in Table 2, the ^{13}C chemical shift are summarized in Table 3. The homonuclear cross peaks as observed from COSY, NOESY, and ROESY are tabulated in Table 4. Whilst the type of ^{13}C nuclei was determined by DEPT, the ^{13}C assignments, except for the quaternary carbons, were deduced from HMQC experiments (Table 5). The remaining signals attributed to the quaternary carbons were derived from HMBC correlations (Table 5).

The aliphatic portion of the ^1H NMR for the series of *n*OBCh exhibits complexity, which cannot be resolved using homonuclear decoupling. The occurrence of the triplet at δ 4.0–4.1 ppm can be ascribed to the methylene protons at C-1′ in *n*OBCh ($n = 6$, 8, 10, 12, 14, 16, and 18). This assignment is based on correlation with other aliphatic protons within the range of δ 2.1–0.8 ppm, and aromatic protons H-31, which is identical with H-33. The signal corresponding to the proton on C-3 in cholesterol is shifted to higher frequency upon replacement of OH by OCOR′ in 6OBCh where R′ is $-C_6H_4OC_6H_{13}$. Further investigation via COSY and NOESY experiments allows the determination of the position of the protons at C-4, C-6, and C-30 that is identical with C-34.

The coupling constants (Table 2) between the protons at C-3 and C-4 indicate that both protons are in close proximity. The coupling constants, ^3J, between the protons at C-30 and C-31, and between the other two aromatic protons at C-33 and C-34 (8.6–9.0 Hz) are identical for each *n*OBCh indicating that the para-substituted aromatic $C_6H_4OC_6H_{13}$ is symmetrical in solution.

Table 2. ^{1}H NMR data and selected coupling constants for *n*OBCh series.

	Chemical shift: δ (ppm), solvent $CDCl_3$							
Atom	Cholesterol	6OBCh	8OBCh	10OBCh	12OBCh	14OBCh	16OBCh	18OBCh
H-4	2.19–2.33,[a] m, 2H	2.48, m, 2H	2.48, m, 2H	2.48, m, 2H	2.47, m, 2H	2.48, m, 2H	2.48, m, 2H	2.48, m, 2H
H-1′	—	4.01, t, 2H	4.01, t, 2H	4.01, t, 2H	4.00, t, 2H	4.01, t, 2H	4.01, t, 2H	4.02, t, 2H
H-3	3.50[a], m, 1H	4.79–4.90, m, 1H	4.81–4.89, m, 1H	4.79–4.90, m, 1H	4.82–4.91, m, 1H	4.83–4.89, m, 1H	4.80–4.88, m, 1H	4.81–4.89, m, 1H
H-6	5.36[a], d, 1H	5.44, d, 1H	5.44, d, 1H	5.44, d, 1H	5.43, d, 1H	5.44, d, 1H	5.43, d, 1H	5.44, d, 1H
H-31 and 33	—	6.92, d, 2H	6.92, d, 2H	6.92, d, 2H	6.91, d, 2H	6.92, d, 2H	6.92, d, 2H	6.92, d, 2H
H-30 and 34	—	7.98, d, 2H	8.00, d, 2H	8.01, d, 2H	8.00, d, 2H	8.01, d, 2H	8.01, d, 2H	8.01, d, 2H
$^{3}J_{30,31}$ or $^{3}J_{33,34}$	—	8.59	8.86	8.43	8.73	8.97	8.83	8.97
$^{3}J_{3,4}$	—	7.83	7.83	7.60	7.82	7.72	7.65	7.80

Note: d, doublet; t, triplet; m, multiplet.
[a]Reported by Bhacca et al. (1962).[16]

Table 3. ^{13}C NMR assignments for cholesterol and *n*OBCh series based on normal ^{13}C NMR, DEPT, HMQC, and HMBC.

	Chemical shift: δ (ppm), solvent $CDCl_3$							
C no.	Ch	6OBCh	8OBCh	10OBCh	12OBCh	14OBCh	16OBCh	18OBCh
1	37.67	37.47	37.49	37.48	37.45	37.46	37.45	37.48
2	32.02	29.50	29.51	29.53	29.51	29.52	29.52	29.53
3	72.13	74.57	74.55	74.57	74.57	74.58	74.58	74.57
4	42.68	38.71	38.71	38.71	38.69	38.70	38.70	38.71
5	141.17	140.17	140.18	140.17	140.18	140.19	140.20	140.19
6	122.07	123.05	123.04	123.05	123.04	123.05	123.04	123.05
7	32.30	31.96	32.30	32.30	32.31	32.32	32.33	32.34
8	32.30	32.29	32.31	32.30	32.28	32.29	32.29	32.31
9	50.54	50.45	50.48	50.47	50.45	50.46	50.45	50.47
10	36.89	37.05	37.05	37.05	37.05	37.05	37.05	37.06
11	21.49	21.46	21.48	21.47	21.45	21.45	21.45	21.47
12	40.19	40.16	40.16	40.16	40.15	40.15	40.15	40.17
13	42.72	42.73	42.73	42.73	42.71	42.76	42.72	42.73
14	57.17	57.11	57.10	57.11	57.10	57.11	57.10	57.12
15	24.69	24.70	24.69	24.70	24.68	24.70	24.69	24.70
16	28.64	28.65	28.65	28.65	28.62	28.63	28.63	28.65
17	56.57	56.56	56.55	56.56	56.54	56.55	56.54	56.56
18	12.26	12.27	12.28	12.27	12.25	12.25	12.25	12.27
19	19.80	19.78	19.79	19.78	19.77	19.78	19.77	19.78
20	36.20	36.21	36.22	36.21	36.19	36.20	36.20	36.21
21	19.13	19.13	19.13	19.13	19.10	19.12	19.11	19.13
22	36.60	36.60	36.61	36.60	36.57	36.59	36.59	36.60
23	24.25	24.25	24.25	24.26	24.22	24.24	24.22	24.25

24	39.92	39.93	39.95	39.93	39.93	39.91	39.92	39.93
25	28.41	28.41	28.42	28.42	28.40	28.41	28.41	28.42
26	22.97	22.97	22.96	22.97	22.94	22.96	22.95	22.96
27	23.22	23.23	23.23	23.20	23.21	23.22	23.23	23.22
28		166.20	166.20	166.20	166.20	166.23	166.23	166.21
29		123.40	123.39	123.40	123.38	123.39	123.39	123.42
30, 34		131.90	131.90	131.90	131.88	131.90	131.89	131.90
31, 33		114.35	114.35	114.36	114.35	114.36	114.36	114.36
32		163.22	163.21	163.22	163.21	163.22	163.22	163.23
1′		68.58	68.59	68.58	68.59	68.59	68.60	68.59
2′		28.36	28.34	28.36	28.34	28.59	30.04	23.10
3′		29.50	26.06	26.06	26.37	26.38	23.04	26.39
4′		31.96	29.73	29.73	29.94	29.76	28.58	27.31
5′		26.06	29.51	29.79	29.51	29.17	26.37	28.36
6′		14.42	32.30	29.97	30.08	29.85	29.52	28.60
7′			23.07	29.54	29.98	29.95	29.94	29.18
8′			14.52	32.34	30.05	30.02	29.74	29.31
9′				23.08	29.75	29.85	29.76	29.78
10′				14.51	32.31	29.99	30.02	29.96
11′					23.08	29.53	29.52	30.00
12′					14.50	33.25	29.98	30.03
13′						23.08	28.35	30.07
14′						14.51	32.33	30.11
15′							21.45	33.08
16′							14.50	33.26
17′								34.38
18′								14.52

Table 4. $^{1}H-^{1}H$ correlations from 2D COSY, NOESY, and ROESY on *n*OBCh series.

Compounds	Atom H	COSY	NOESY	ROESY
6OBCh	4	3, 6	3, 6	3, 6
	1′	—	31, 33	31, 33
	3	4	4	4
	6	4	4	4
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 33	31 or 33	31 or 33
8OBCh	4	3, 6	—	3, 6
	1′	—	31 or 33	31 or 33
	3	4	—	4
	6	4	—	4
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 33	31 or 33	31 or 33
10OBCh	4	3, 6	6	6
	1′	—	31 or 33	31 or 33
	3	4	4	4
	6	4	4	4
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 33	31 or 33	31 or 33
12OBCh	4	3, 6	6	6
	1′	—	31 or 33	31 or 33
	3	4	—	—
	6	4	4	—
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 33	31 or 33	31 or 33
14OBCh	4	3, 6	3	3, 6
	1′	—	31 or 33	31 or 33
	3	4	4	4
	6	4	—	4
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 33	31 or 33	31 or 33
16OBCh	4	3, 6	3, 6	3, 6
	1′	—	31 or 33	31 or 33
	3	4	4	4
	6	4	4	4
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 34	31 or 33	31 or 33
18OBCh	4	3, 6	3, 6	3, 6
	1′	—	31 or 33	31 or 33
	3	4	4	4
	6	4	4	4
	31 or 33	30 or 34	1′, 30 or 34	1′, 30 or 34
	30 or 34	31 or 33	31 or 33	31 or 33

Table 5. 2D $^{1}H-^{13}C$ HMQC and HMBC correlations for *n*OBCh series.

Compounds	Atom	HMQC ^{1}J	HMBC [J(C, H)] ^{2}J	^{3}J	^{4}J	J^{a}
6OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	C4	—	—	—
	H6	C6	C7	C4, C8, C10	C1	C34
	H31	C31	C30, C32	C29, C33	C28, C34	—
	H33	C33	C32, C34	C29, C31	C28, C30	C6
	H30	C30	C31, C29	C28, C32, C34	C33	—
	H34	C34	C33, C29	C28, C30, C32	C31	—
8OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	C4	C28	—	—
	H6	C6	C7	C4, C8, C10	C1	—
	H31	C31	C32	C29, C33	C28	—
	H33	C33	C32	C29, C31	C28	C6
	H30	C30	C31, C29	C28, C32, C34	C33	—
	H34	C34	C33, C29	C28, C30, C32	C31	—
10OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	C4	C28	—	—
	H6	C6	C7	C4, C8, C10	C1	—
	H31	C31	C30, C32	C29, C33	C28, C34	—

(*continued*)

Table 5. Continued.

Compounds	Atom	HMQC	HMBC [J(C, H)]			
		^{1}J	^{2}J	^{3}J	^{4}J	J^{a}
	H33	C33	C32, C34	C29, C31	C28, C30	C6
	H30	C30	C31, C29	C28, C32, C34	C33	—
	H34	C34	C33, C29	C28, C30, C32	C31	—
12OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	C4	C28	—	—
	H6	C6	C7	C4, C8, C10	C1	—
	H31	C31	C32	C29, C33	C28	—
	H33	C33	C32	C29, C31	C28	C6
	H30	C30	C31	C28, C32, C34	C33	—
	H34	C34	C33	C28, C30, C32	C31	—
14OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	—	C28	—	—
	H6	C6	C7	C4, C8, C10	C1	—
	H31	C31	C32	C29, C33	C28	—

	H33	C33	C32	C29, C31	C28	C6
	H30	C30	C31, C29	C28, C32, C34	C33	—
	H34	C34	C33, C29	C28, C30, C32	C31	—
16OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	—	—	—	—
	H6	C6	C7	C4, C8, C10	C1	—
	H31	C31	C32	C29, C33	C28	—
	H33	C33	C32	C29, C31	C28	C6
	H30	C30	C31, C29	C28, C32, C34	C33	—
	H34	C34	C33, C29	C28, C30, C32	C31	—
18OBCh	H4	C4	C3, C5	C2, C6	C1	—
	H1′	C1′	C2′	C32, C3′	C4′	—
	H3	C3	—	C28	—	—
	H6	C6	C7	C4, C8, C10	C1	C34
	H31	C31	C32	C29, C33	C28	—
	H33	C33	C32	C29, C31	C28	C6
	H30	C30	C31	C28, C32, C34	C33	—
	H34	C34	C33	C28, C32, C34	C31	—

[a]Intramolecular interaction.

The ^{13}C NMR signals were identified by DEPT before being assigned by analysis of the HMQC spectrum for the protonated carbons on the basis of the chemical shift theory and substituent effects. The assignments were supported by HMBC cross peaks. The ^{13}C spectra of cholesteryl 4-*n*-alkoxybenzoates exhibit signals in the carbonyl, aromatic, and aliphatic regions (see Table 3). The ^{13}C spectrum of 6OBCh, for example, contained 38 distinct signals. All ^{13}C chemical shifts for this series of compounds were unchanged in $CDCl_3$ under ambient temperature. The only difference is the increase in the number of signals by two when we change from 6OBCh to 8OBCh leading to a maximum of 50 signals in 18OBCh.

The quaternary carbons, C-5, C-29, and C-32 in 6OBCh, were assigned through HMBC correlations from the methylene protons H-4, aromatic protons H-33 (or H-31) and H-34 (or H-30), and aliphatic protons H-1′. C-29 and C-32 were easily distinguished from the correlations to H-1′ and H-34 or H-30 in different experiments. Whilst Fig. 2 shows a representative

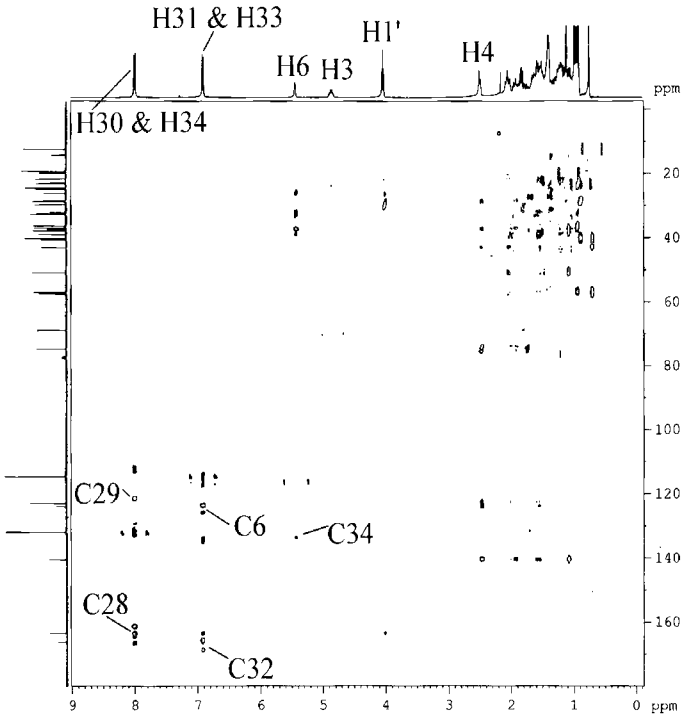

Figure 2. HMBC spectrum of 6OBCh in $CDCl_3$.

HMBC spectrum of 6OBCh, Fig. 3 exhibits the NOESY spectrum of the same compound. The data obtained from the NOE and ROE relationships agree very well with the postulated structure shown in Fig. 4.

The carbon C-28 and C-3′ were assigned via correlations with the protons in the aromatic (H-34 and H-30) and aliphatic regions (H-1′). A cross peak was observed between the H-33 proton and a carbon located at δ 123.05 ppm, which was attributed to C-6 in 6OBCh. The signal attributed to C-34 correlated to the H-6 proton. On the basis of this analysis, long range connectivity through intramolecular interaction between the C-6 carbon and the H-33 proton was established, even though the C-6 atom is far away from H-33. One of the probabilities of having this kind of interaction is to bring together the atoms into close proximity. As shown in Fig. 4, C-34 or C-30 and H-6 are likely to be brought near to each other by folding at the O═C–O linkage. This observation is found to be different from the conformation shown by x-ray diffraction of one of these compounds (cholesteryl *p-n*-hexyloxybenzoate) in the crystal phase

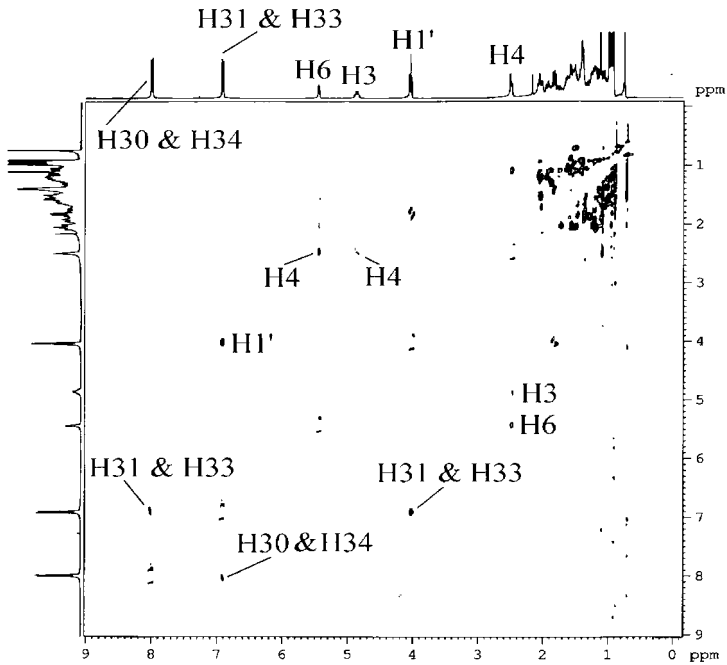

Figure 3. NOESY spectrum of 6OBCh in $CDCl_3$.

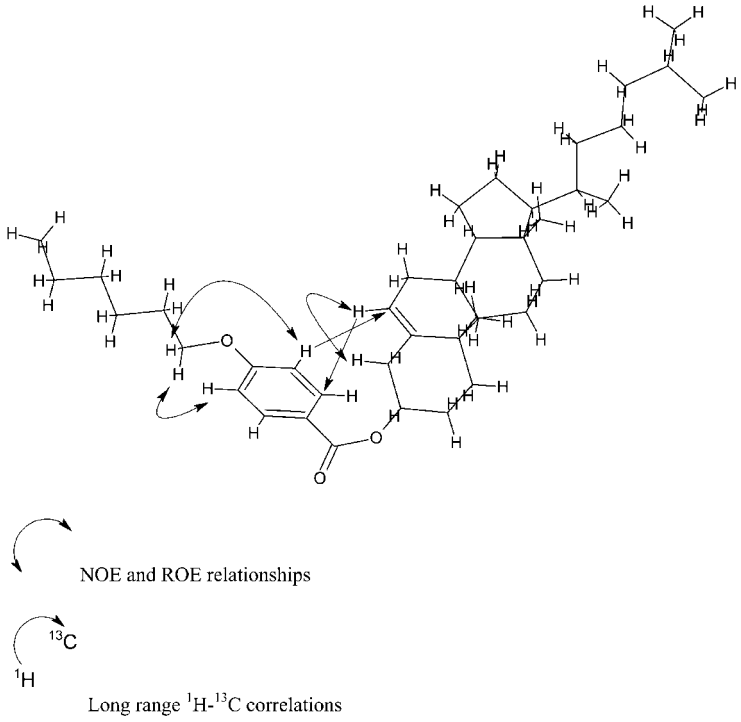

Figure 4. Selected NOE and ROE relationships and intramolecular interaction via HMBC for 6OBCh.

wherein the hexyloxy chain was fully extended leading to the formation of stacked-layer molecules.[17]

Further investigation of the molecular conformation and its orientation in the solid phase for the same compounds by using ^{13}C CP MAS NMR is now underway.

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