^{13}C NMR SPECTRA OF BROMINE DERIVATIVES OF FATTY ACIDS

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Fourier transform ^{13}C NMR spectroscopy is being used ever more widely for the analysis of lipids from various natural materials. At the present time, the spectra of more than 50 fatty acids [1-3], a whole series of carotenoids [4, 5], and individual representatives of the phospholipids [6] and triglycerides [3, 7] have been obtained by this method and interpreted.

The present paper describes the features of the ^{13}C NMR spectra of natural and synthetic bromine derivatives of stearic acid and a synthetic dibromoundecanoic acid.

Natural di- and tetrabromostearic acids have been detected in minor amounts in the oil of the seeds of *Eremostachys moluccelloides* (family Labiatae) [8]. There is information [9] on the presence of halogen-containing fatty acids among the metabolites of the fungus *Verticillium dahliae* Kleb. when it is grown on Czapek–Dox medium.

The spectrum of the methyl ester of natural 9,10-dibromostearic acid (Fig. 1a) has a number of strong signals of ^{13}C nuclei which shows their shorter relaxation time in comparison with those of the other nuclei. Under the conditions of incomplete proton decoupling [10], the signal at 58.8 ppm gives a doublet structure, which shows that it belongs to carbon nuclei to each of which a bromine atom and one proton are directly attached. The somewhat weaker signals in this spectrum at 34.1 and 27.8 ppm give triplet structures under the conditions of incomplete proton decoupling as do the other weaker signals, with the exception of the signals of the nuclei of the carbon atoms of methyl (14.0 ppm, quartet), O-methyl (50.6 ppm, quartet), and carboxy (171.8 ppm, singlet) groups. Taking into account the falling off of the influence of halogen atoms with distance [10], the signal at 34.1 ppm must obviously be assigned to nuclei of carbon atoms in the β position to bromine atoms and the signal at 27.8 ppm to those in the γ position. With the accumulation of the high-field part of this spectrum, the individual peaks of the carbon atoms of the methylene chain appear distinctly over an extended range in the 30 ppm region. The close values of the chemical shifts in the group of signals in the 29-30 ppm region is in agreement with the fact that the halogen atoms are present in the center of the methylene chain of this acid and, consequently, an influence of them on the effects of the terminal groups is excluded.

It is known that the cis position of the olefinic hydrogens in oleic acid is characterized by an upfield shift of the resonance of the β carbons as compared with the situation when they are in the trans position [3]. For halogen atoms present as substituents in the fatty acid chain, there is no such information in the literature. Consequently, in order to determine the mutual positions of the bromine atoms in natural samples, we obtained the spectra of the synthetic cis and trans isomers of methyl 9,10-dibromostearate. The ^{13}C NMR spectrum of the synthetic cis isomer was identical with the spectrum of the methyl ester of natural 9,10-dibromostearic acid given in Fig. 1a.

In the spectrum of the methyl ester of the synthetic trans isomer of this acid that we obtained, the values of the chemical shifts of the carbon nuclei in the α, β, and γ positions with respect to the bromine atom differed from those for the cis isomer (Table 1). A comparison of these values in the two isomers shows their considerable dependence on the configuration of the bromine atoms in the chain, particularly for the carbon nuclei in the

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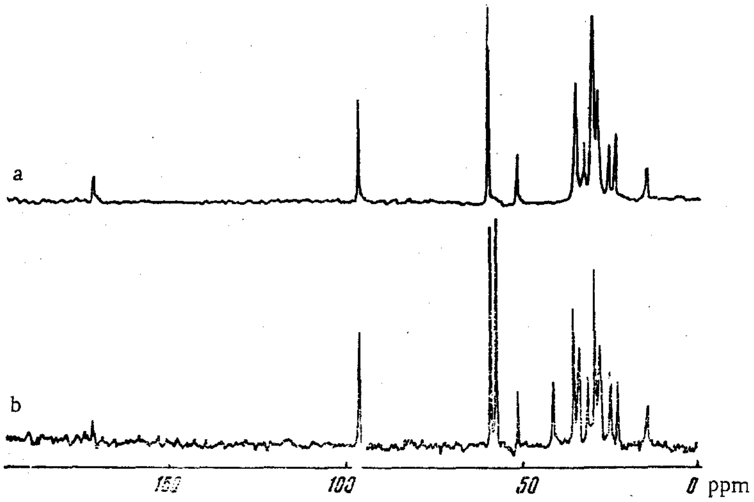

Fig. 1. ^{13}C NMR spectra of the methyl esters of 9,10-dibromostearic acid (a) and 9,10,12,13-tetrabromostearic acid (b) in CCl_4.

TABLE 1. Chemical Shifts of the ^{13}C Nuclei of the Methyl Esters (MEs) of Stearic Acid and Its Bromine Derivatives (solutions in CCl_4), δ_{TMS} = 0 ppm)

Position of the nucleus	ME of stearic acid	ME of 9,10-dibromostearic acid				ME of 9,10,12,13-tetrabromostearic acid	
		cis isomer		trans isomer			
	δ_i	δ_i	A_i	δ_i	A_i	δ_i	A_i
C—1	171,8	171,8		171,8		171,9	
C—2	33,7	33,6		33,6		33,7	
C—3	24,9	24,6		24,8		24,7	
C—4	29,2	29,2		29,1		29,0	
C—5	29,4	29,4		29,4		29,0	—0,4
C—6	29,7	29,0	—0,7	29,0	—0,7	28,5	—1,2
C—7	29,7	27,8	—1,9	26,6	—2,9	27,6	—2,1
C—8	29,7	34,1	4,4	37,1	7,4	35,1	5,4
C—9	29,7	58,8	29,1	58,9	29,2	58,0	28,3
C—10	29,7	58,8	29,1	58,9	29,2	56,6	26,9
C—11	29,7	34,1	4,4	37,2	7,5	40,6	10,9
C—12	29,7	27,8	—1,9	26,7	—3,0	56,6	26,9
C—13	29,7	28,6	—1,1	28,7	—1,0	58,0	28,3
C—14	29,7	28,8	—0,9	29,0	—0,7	35,1	5,4
C—15	29,4	29,6		29,2		27,6	—1,8
C—16	31,9	31,8		31,8		30,9	—1,0
C—17	22,7	22,5		22,5		22,4	—0,3
C—18	14,2	14,0		14,0		14,0	
OMe	50,8	50,7		50,7		50,7	

β and γ positions. The trans configuration of the bromine atoms in the synthetic sample leads to a difference in the magnitudes of the γ and σ contributions [10, 11] to the chemical shifts of carbon nuclei located on different sides of the link bearing the bromine atoms. This is expressed in a difference of the chemical shifts $\Delta = 0.1$ ppm for the resonances of the C-8 and C-11 and, respectively, the C-7 and C-12 carbon atoms in the trans isomer, while in the spectrum of the cis isomer there is no such difference.

The assignment of all the signals given in Table 1 was based on an estimate of the influence of the bromine atoms on the screening constant of the ^{13}C nuclei. To characterize this influence it is possible to use [11] the parameter of the shift due to the substituent $A_i = \delta_i^{Br} - \delta_i^{H}$, where δ_i^{Br} and δ_i^{H} are the chemical shifts of the nucleus of the carbon atom in the i-th position when bromine atoms are present in and absent from the molecule; the corresponding values of A are given in Table 1. The negative signs of A_i for the carbon atoms C-6, C-7, C-12, and C-13 in both isomers are obviously due to the high contribution of the γ and σ effects from the bromine atoms.

In the ^{13}C NMR spectrum of the methyl ester of natural 9,10,12,13-tetrabromostearic acid (Fig. 1b) there are two strong signals at 58.0 and 56.6 ppm. The positions of these signals and their behavior under the conditions of incomplete proton decoupling show that they belong to the carbons of —CHBr— groups. It can be seen from Table 1, which gives the assignments of all the signals in the spectrum of this methyl ester, that for the "outer" carbon atoms C-9 and C-13 to which bromine atoms are attached, the value of the parameter of the shift due to the substituent A_i is 1.4 ppm greater than for the "inner" carbon atoms of the same type, C-10 and C-12. A similar magnetic nonequivalence appears in the ^{13}C NMR spectrum of octadeca-9,12-dienic acid [3]. For the nuclei of the C-8 and C-14 carbon atoms, which are present in the α position to the "outer" —CHBr— group no difference in the values of A_i is observed, which is obviously connected with the cis configuration of the bromine atoms in the molecules of this sample. The ^{13}C NMR spectrum of the methyl ester of synthetic cis,cis-9,10,12,13-tetrabromostearic acid coincides completely with the spectrum described for the natural sample. The presence of signals of the C-4 and C-5 carbon nuclei in this spectrum is due to the influence of the high contributions from the bromine atoms on the resonance position of the C-5 carbon. It can be seen from Table 1 that in the spectra of all representatives of the methyl esters for the ^{13}C nuclei at a distance of more than four carbon-carbon bonds from the bromine atom the value of A_i is within the limits of the error of measurement of the chemical shift (±0.1 ppm).

Thus, the introduction of bromine atoms into the middle of the chain of a fatty acid leads to the magnetic nonequivalence of the ^{13}C nuclei at a distance of three carbon—carbon bonds from the nucleus of the carbon atom to which the halogen is directly attached. In combination with the effects of the terminal groups, this leads to the resolution of the signals of almost all the ^{13}C nuclei of the methylene group in chains of fatty acids of high and, all the more, medium molecular weight. As a confirmation of this may serve the spectrum we obtained of the methyl ether of synthetic 10,11-dibromoundecanoic acid, in which the signals of carbon nuclei were observed at the following values of the chemical shifts (ppm): 171.6 (C-1), 51.9 (C-10), 50.4 (OMe), 35.4 (C-2), 35.2 (C-9), 33.2 (C-8), 28.7 (C-4, C-6), 28.6 (C-5), 28.3 (C-7), 26.1 (C-3) and 24.4 (C-11). As can be seen from the figures given, the signal of the C-6 carbon, at a distance of four carbon—carbon bonds from the —CHBr— bond, overlaps with the signal of the nucleus of the C-4 carbon, and all the other carbon nuclei give individual resolved signals.

The results presented show that ^{13}C NMR spectra can be used to determine the position and geometric arrangement of the halogen atoms in the molecule of a halogenated fatty acid. The characteristic pattern of chemical shifts and the ratio of the intensities of the signals in the ^{13}C NMR spectra of halogen-substituted fatty acids will enable them to be detected in narrow fractions obtained in the separation of natural fatty acid mixtures.

EXPERIMENTAL

The isolation of the natural bromine-containing fatty acids and the production of their synthetic analogs has been described previously [8].

The ^{13}C NMR spectra of all the samples (40% solutions in CCl_4) were obtained on a Varian XL-100-15 spectrometer under pulsed conditions in a field of 23.5 kilogauss. For the accumulation of the free induction decay signal and to perform the Fourier transform we used a "Data 620 i" minicomputer with an 8 K memory. The spin—spin coupling of the protons with the ^{13}C nuclei was suppressed by the feed of power from an individual noise decoupling generator. To preserve constancy of the field/frequency ratio we used 2 ml of heavy water in a coaxial tube. The spectra were recorded at 40°C with a scan width of 5000 G; the duration of the pulses used was 70 μsec, the time of recording the induction signal 0.4 sec, and the interval between pulses for the restoration of equilibrium in the spin system of the sample 5 sec. To convert the readings of the computer into chemical shifts we used the signal of the nucleus of the solvent (δ_{CCl_4} = 96 ppm relative to tetramethylsilane). In the assignment of the signals we used the method of incomplete resonance irradiation of the protons [11] and literature information on fatty acids [2, 3] and alkane derivatives [10-15].

SUMMARY

The ^{13}C spectra of the methyl esters of the cis and trans isomers of 9,10-dibromostearic, of cis,cis-9,10,12,13-tetrabromostearic, and of 10,11-dibromoundecanoic acid have been obtained, and the assignment of all the signals has been performed. It has been shown

that the presence of bromine atoms in the chain of a fatty acid leads to the magnetic nonequivalence of the ^{13}C nuclei of the methylene groups present at a distance of three carbon—carbon bonds from the nucleus to which the halogen is directly attached. A dependence has been found of the shift parameter of the carbon nuclei in a fatty acid chain on the relative arrangement of the bromine atoms.

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THE STRUCTURE OF THE LACTONES α- AND β-REOLONES

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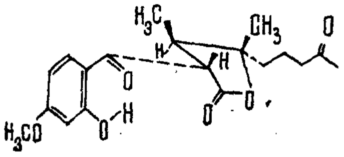
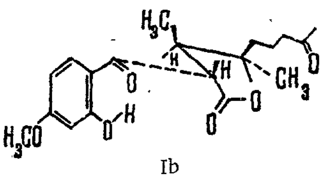
From the resin of the roots of *Ferula pseudooreoselinum* (Rgl. et Schmalh) K. Pol. two stereoisomeric substances $C_{19}H_{24}O_4$, mol. wt. 348, $[\alpha]_D^{22}$ 0, mp 107 and 138°C have been isolated, and they have been called α- and β-reolones, respectively [1]. On the basis of spectral and chemical characteristics, formulas (Ia) and (Ib), differing by the orientation of the constituent at C_4, have been proposed for them



Ia



Ib

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