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DETERMINATION OF THE GEOMETRICAL CONFIGURATION OF THE POLYEN CHAIN OF MONOCIS C_{40}-CAROTENOIDS—I

A ^{13}C NMR STUDY OF MONOCIS ZEAXANTHINS AND MONOCIS CAPSORUBINS

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Abstract—^{13}C NMR studies reveal that the polyen chain of *neo*-zeaxanthin A (**2**) and that of *neo*-capsorubin A (**5**) have 13-*cis* configuration, while those of *neo*-zeaxanthin B (**3**) and *neo*-capsorubin B (**6**) have 9-*cis* geometrical configuration. ^{13}C NMR data on the corresponding *all-trans* carotenoids (**1** and **4**) are also reported.

In the field of structural research into the geometrical isomers of isoprenoid compounds a new powerful method, ^{13}C NMR spectroscopy, has recently been introduced and successfully used in the structural study of the *cis* isomers of retinal[1,2] and more recently in the configurational assignment of violeoxanthin.[3]

The present ^{13}C NMR study of *cis*-carotenoids was begun with the investigation of zeaxanthin and capsorubin (symmetrical types), whose *monocis* isomers are known in the literature.[4-6] Tentative spacial structures were suggested for their *neo*-A and *neo*-B forms by Zechmeister *et al.*;[4] *neo*-zeaxanthin A, **2** (m.p. 98°; λ_{max} (ϵ_{max}) in benzene: 487 (70·200), 458 (86·300) and 347 (39·000) nm)† and *neo*-capsorubin A, **5** (m.p. 84°; λ_{max} (ϵ_{max}) in benzene: 517 (71·000), 483 (86·000) and 378 (40·000) nm)† with high *cis*-peaks represent 13-*cis* isomers, while *neo*-zeaxanthin B, **3** (m.p. 107°; λ_{max} (ϵ_{max}) in benzene: 488 (94·700), 458 (111·700) and 348 (8·800) nm)† and *neo*-capsorubin B, **6** (m.p. 120°; λ_{max} (ϵ_{max}) in benzene: 519 (99·000), 485 (111·000) and 380 (16·000) nm)† with low *cis*-peaks represent 9-*cis* isomers. We found that ^{13}C NMR data gave exact evidence for the location of the *cis* double bonds in these molecules, confirming the earlier hypothetical assignments.

Natural abundance ^{13}C NMR spectra were obtained at 25·16 MHz using a Varian XL-100-15 spectrometer equipped with Varian S124-XL Fourier transform accessory and a 620L computer. The samples were prepared as 0·04 to 0·05 M solutions in $CDCl_3$ with TMS as internal reference. The probe temperature was maintained at 32°. Because of its poor solubility, *all-trans* zeaxanthin (**1**) was previously transformed into 3,3'-diacetate derivative. Depending on the sample from 6000 to 16,000 transients were accumulated with acquisition time 0·8 sec, spectral digitization 1·25 Hz/point and pulse flip angle 25–30°. The chemical shift values are believed to be accurate to ±0·04 ppm.

The ^{13}C chemical shift values for the compounds studied are given in Table 1. The individual resonance values for the *all-trans* zeaxanthin (**1**) were assigned on the analogy of the data published for β-carotene[7] and taking into account changes due to the presence of the 3-OAc function. In addition to information derived from standard FT procedures, the designation of the carbon resonances in the *all-trans* capsorubin (**4**) was further facilitated by the alternating shifts of sp^2 resonances due to the polarizing effect of the carbonyl end group: With respect to their values in *all-trans* zeaxanthin (or β-carotene), even numbered polyenic carbons exhibited upfield shifts, while odd numbered carbons downfield shifts in a similar way as noted in a recent study on apocarotenoids.[7] The magnitude of these shifts decreased with the number of bonds separating the relevant carbons from the carbonyl group.[8]

The *cis*-configured double bonds in the isomers (**2**, **3**, **5** and **6**) were located on the basis of known *cis-trans* isomerization shifts.[1,2] The appearance of a Me resonance, 19 or 20Me, which was shifted downfield by about 8 ppm with respect to its value in the corresponding *all-trans* isomer (12·8 ppm), suggested 9- or 13-*cis* double bonding in each case. (Isomerization at position 11 is known to be evidenced by a lesser downfield shift of the 20Me signal[1,2] while the occurrence of a *cis* double bond at 15 should give rise to a symmetrical spectrum differing from that of the parent *all-trans* isomer.) Minor steric shifts detected for some of the sp^3 resonances and sizable resonance doublings of the signals due to carbons 5 and 6 in **3** or to the carbonyl group in **6** indicated that in these molecules the isomerization occurred at position 9. A more detailed evaluation of the isomerization shifts in the molecules studied provided corroboration for this qualitative assignment. The chemical shifts or the *cis* end carbon resonances relative to the corresponding *trans* end values are summarized in Table 2. Also presented in Table 2 are the chemical shift changes relative to the parent *all-trans* molecules (in parentheses); for the zeaxanthin isomers (**2** and **3**) many of the latter values are affected by the

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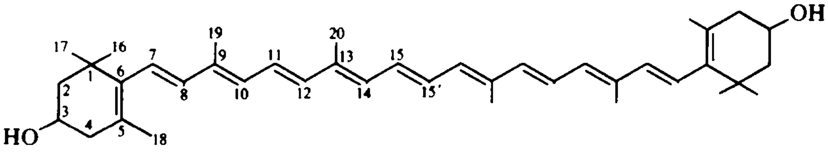
†The data refer to the isomers obtained by iodine catalysis[4] in our laboratory.



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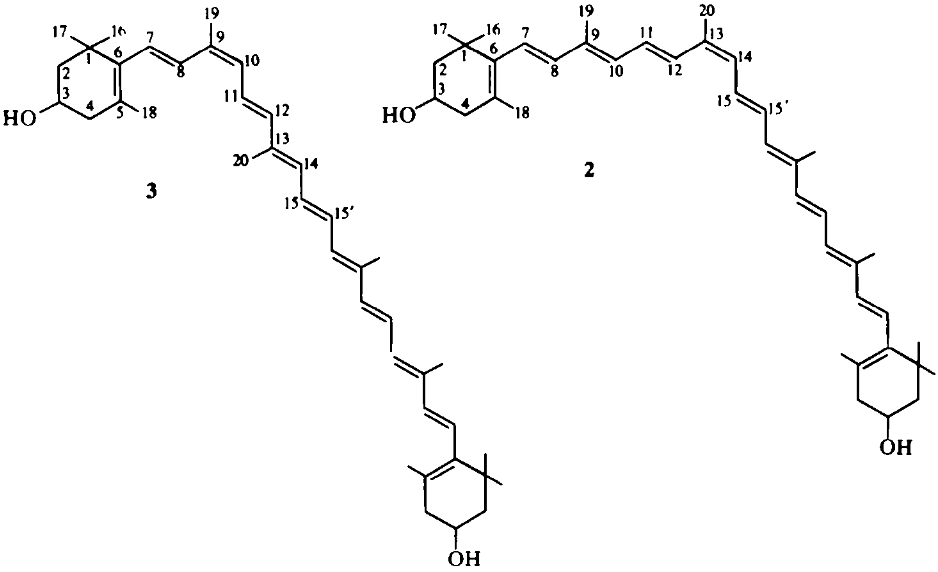

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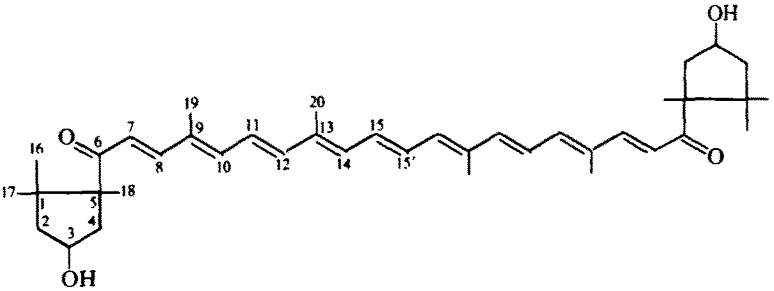
Table 1. ^{13}C chemical shifts[a]

Compound		Position								
		1	2	3	4	5	6	7	8	9
All-trans Zeaxanthin-3,3'-diacetate		36.73	44.24	68.47	38.57	125.66	138.03	125.36	138.73	135.55
Neo-Zeaxanthin B /9-cis-Zeaxanthin/	trans end	37.16	48.64	65.16	42.71	126.22	137.90	125.68	138.56	135.67
	cis end	37.16	48.64	65.16	42.71	126.47	138.15	127.52	130.80	134.28
Neo-Zeaxanthin A /13-cis-Zeaxanthin/	trans end	37.18	48.66	65.15	42.72	126.37	137.92	125.71	138.58	135.63
	cis end	37.18	48.66	65.15	42.72	126.26	137.92	125.71	138.58	135.71
All-trans Capsorubin		44.02	51.03	70.35	45.46	59.01	203.00	121.27	146.87	134.10
Neo-Capsorubin B /9-cis-Capsorubin/	trans end	44.03	50.95	70.40	45.41	59.00	202.98	121.17	146.87	133.98
	cis end	44.03	50.95	70.40	45.41	59.09	203.55	122.58	138.10	132.15
Neo-Capsorubin A /13-cis-Capsorubin/	trans end	44.00	50.93	70.37	45.36	59.01	203.00	121.19	146.85	133.97
	cis end	44.00	50.93	70.37	45.36	59.01	203.00	121.55	146.75	134.07

[a] In ppm as measured from internal TMS in deuterochloroform solution

[b] For these resonances two, clearly separated lines were observed, with shift differences of approx. 0.1 ppm. remains to be clarified. The figures reported in this Table represent mean values.



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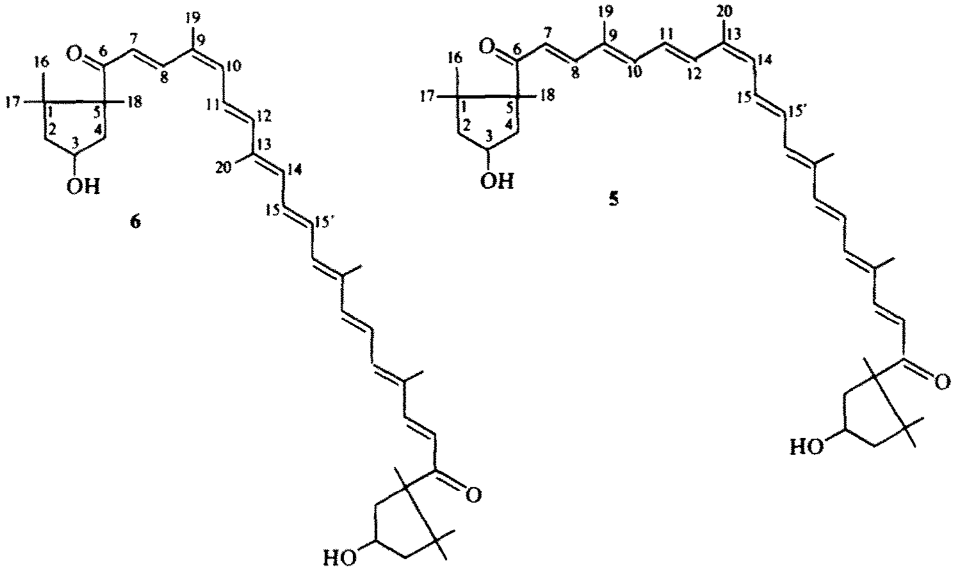

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of isomeric carotenoids

10	11	12	13	14	15	16Me	17Me	18Me	19Me	20Me	Other Resonances OCOMe	OCO
131.52	124.96	137.74	136.46	132.68	130.18	28.58	30.07	21.40	12.75	12.75	21.39	170.63
131.38	124.98	137.65	136.38	132.63	130.05	28.84	30.34	21.59	12.83	12.83		
129.91	123.79	136.38	136.90	132.49	130.14	28.84	30.34	21.69	20.70	12.83		
131.38	124.96^b	137.70	136.43^b	132.57^b	130.19	28.82	30.34	21.59	12.78	12.78		
131.38	126.05	129.43^b	134.92	131.02	128.93	28.82	30.34	21.59	12.78	20.68		
140.50	124.67	141.75	137.00	134.94	131.25	25.14	25.94	21.37	12.83	12.83		
140.59	124.54	141.87	136.70	135.07	130.86	25.13	25.90	21.35	12.84	12.84		
139.09	123.70	140.59	137.26	134.35	131.42	25.13	25.90	21.27	20.44	13.00		
140.38	124.52	141.84	136.73	134.82	131.05	25.12	25.93	21.34	12.87	12.87		
140.58	125.88	133.38	135.24	133.28	129.90	25.12	25.93	21.34	12.87	20.61		

Since after recording of the spectra no decomposition product could be identified, the origin of these splittings

Table 2. Shifts of *cis*-end carbons relative to *trans*-end carbons, Δδ[a,b]

Carbon	Capsorubin				Zeaxanthin	
	9-cis /Neo B/		13-cis /Neo A/		9-cis /Neo B/	13-cis /Neo A/
1C	0.0	/0.0/	0.0	/0.0/	0.0	0.0
2C	0.0	/0.1/	0.0	/0.0/	0.0	0.0
3C	0.0	/0.0/	0.0	/0.0/	0.0	0.0
4C	0.0	/0.0/	0.0	/0.0/	0.0	0.0
5C	0.1	/0.1/	0.0	/0.0/	0.2	-0.1
6C	0.6	/0.6/	0.0	/0.0/	0.2	0.0
7C	1.4	/1.3/	0.4	/0.3/	1.8	0.4
8C	-8.8	/-8.8/	-0.1	/-0.1/	-7.8	0.2
9C	-1.8	/-1.9/	0.1	/0.0/	-1.4	0.2
10C	-1.5	/-1.4/	0.2	/0.1/	-1.5	-0.1
11C	-0.8	/-1.0/	1.4	/1.2/	-1.2	1.1
12C	-1.3	/-1.2/	-8.5	/-8.4/	-1.3	-8.5
13C	0.6	/0.2/	-1.5	/-1.8/	0.5	-1.5
14C	-0.7	/-0.6/	-1.5	/-1.7/	-0.2	-1.6
15C	0.6	/0.2/	-1.2	/-1.4/	0.1	-1.3
16Me	0.0	/0.0/	0.0	/0.0/	0.0	0.0
17Me	0.0	/0.0/	0.0	/0.0/	0.0	0.0
18Me	-0.1	/-0.1/	0.0	/0.0/	0.1	0.0
19Me	8.4	/8.4/	0.0	/0.0/	7.9	0.0
20Me	0.2	/0.2/	7.8	/7.8/	0.0	7.9

[a] $\Delta\delta = \delta_{\underline{cis}} - \delta_{\underline{trans}}$ /in ppm/

[b] Shifts relative to all-trans values in parentheses

acetylation shifts and therefore omitted. The relative shifts observed in the present study are in good agreement with the values reported for model compounds.[1,2]

It may be noted that the consistency in delineation of the *cis* and *trans* end resonances in the spectra of the *cis* isomers is closely intercorrelated with the correctness of assignment of the spectrum of the parent *all-trans* molecule. Such a consistency of our results suggests that the assignment of carbon 9 and that of carbon 13 of β-carotene are interchanged in Ref. 1 (see also Ref. 8).

REFERENCES

[1] R. Rowan, III and B. D. Sykes, *J. Am. Chem. Soc.* **96**, 7000 (1974).

[2] R. S. Becker, S. Berger, D. K. Dalling, D. M. Grant and R. J. Pugmire, *Ibid.* **96**, 7008 (1974).

[3] G. P. Moss, J. Szabolcs, G. Tóth and B. C. L. Weedon, *Acta Chim. Acad. Sci. Hung.* in press.

[4] L. Zechmeister, *cis-trans Isomeric Carotenoids, Vitamins A and Arylpolyenes.* Springer, Vienna (1962).

[5] L. Zechmeister and R. M. Lemmon, *J. Am. Chem. Soc.* **66**, 317 (1944).

[6] L. Zechmeister und L. v. Cholnoky, *Liebigs Ann.* **543**, 248 (1940).

[7] W. Bremser and J. Paust, *Org. Magn. Res.* **6**, 433 (1974).

[8] As compared with the values in β-carotene, the following relative shifts were observed: 9C: 9·8; 10C: 9·6; 12C: 4·4; 14C: 2·5; 7C: −4·4; 9C: −2·4; 11C: −0·4, and 13C: −0·3 ppm. For the sake of consistency, shift values for 9C and 13C of Ref. 1 are interchanged (see text). Both spectra were recorded in $CDCl_3$ solutions.