The carotenoid content in certain plants from Abisko National Park (Swedish Lapland)

B. CZECZUGA

Department of General Biology, Medical Academy, Białystok, Poland

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Abstract

By means of columnar and thin-layer chromatography, the presence of carotenoids in Lichens (2 species), *Sphagnaceae* (1 species), *Lycopodiaceae* (1 species) and in 23 species of the higher plants from Abisko National Park (Swedish Lapland) was studied. 34 carotenoids were identified and total content ranged from 0.05 mg/g to 0.85 mg/g dry mass.

INTRODUCTION

Vitamins belong to the group of biologically active substances in the organism of animals and man. An important role is played by vitamin A, the sources of which are plants which contain substances, its provitamins, called carotenoids. With this in view, the problem of the carotenoid content in plants of the far north, in a country in which the plant life is comparatively sparse and the period of vegetation is considerably shorted than in other climates seemed to warrant investigation. In these studies, the leaves, flowers, and fruit of plants growing within the Arctic circle in the specific conditions of the severe northern climate were investigated. In undertaking these investigations, we also wished to determine whether the conditions prevalent in the far north have an unfavourable effect on the carotenoid content and, if so, to what extent. Another problem which seemed to be of interest was that of which carotenoids previously found in plants are predominant in the species of that region.

MATERIAL AND METHODS

Material

The material, investigated by means of chromatographic analysis, was collected from the National Park in Abisko, Sweden, 125 miles within the Arctic circle. It was collected in August during the author's stay there. The plant species studied are given in Tables 1-4. The parts of the plants chosen for the analysis were dried immediately and the chromatographic analysis was carried out later in our laboratory.

Pigments

The carotenoid pigments were extracted by means of 95% acetone in a dark room. Saponification was carried out by means of 6% KOH in ethanol at a temperature of about 40°C for several minutes in the dark in a nitrogen atmosphere.

Chromatography

Columnar and thin-layer chromatography, described in detail in our previous papers (Czczuga 1975, 1976) were used for the separation of the various carotenoids. A glass column approximately 1 cm dia. and 15-20 cm in length, filled with Al_2O_3 , was used in column chromatography. The extract was passed through the column after which the different fractions were eluted with the solvent. Silica gel was used for the thin-layer chromatography, with the appropriate solvent systems, the R_f values being determined for each spot. For identification of β -carotene and lutein co-chromatography was applied using identical carotenoids.

Identification of pigments

The pigments were identified by the following methods: (a) behaviour on column chromatography; (b) absorption spectra of the pigments in various solvents were recorded by a Beckman spectrophotometer model 2400 DU; (c) the partition characteristics of the carotenoid between hexane and 95% methanol; (d) comparison of R_f on thin-layer chromatography with authentic carotens and lutein; (e) the presence of allylic hydroxyl groups was determined by the acid chloroform test; and (f) the epoxide test.

Quantitative determination

Quantitative determinations of the concentrations of carotenoid solutions were made from the quantitative absorption spectra. These determinations were based on the extinction coefficient E 1%/cm at the wavelengths of maximal absorbance in petroleum ether or hexane.

RESULTS

The results of the chromatographic analysis of the carotenoid content in the various parts of the species of plants investigated are presented in Tables 1-4, from which it can be seen that 34 carotenoids were identified and the total content ranged from a few hundredths to tenths of mg/g dry mass. In the shoots of the plants, the lowest content was noted in the *Cassiope hypnoides* (0.05 mg/g) and the highest in the *Viola biflora* shoots (0.85 mg/g). Of the flowers analyzed, the *Trollius europaeus* contained least carotenoids (0.17 mg/g) and the richest in carotenoids were found to be the flowers of the *Dryas octopetala* (0.83 mg/g). Again, the lowest carotenoid content in the fruit was noted in the service tree, *Sorbus aucuparia* (0.12 mg/g), and the highest in the *Rubus chamaemorus* (0.54 mg/g).

DISCUSSION

As the data obtained shows, the following carotenoids were found to be among the most frequently occurring in the material investigated: lutein epoxide, β -cryptoxanthin, β -carotene, mutatochrome and isozeaxanthin. In a few cases such carotenoid as α -carotene, ζ -carotene, canthaxanthin, echinenone, gazaniaxanthin, neoxanthin and violaxanthin were found. All the carotenoids found in our material have previously been found in plants (Goodwin 1976).

A number of authors have drawn attention to the fact that lutein or its derivative is predominant among the carotenoids in various parts of higher orders of plants. Valadon and Mummery (1968a) noted the predominance of lutein in the crown of the flowers of three *Narcissus* species and Quackenbach and Miller (1972) in four species of the *Tagetes* genus and Hanny et al. (1972) in the leaves and buds of the *Hibiscus syriacus*. According to the data of Ignasiak and Lesins (1973) lutein comprises from 30% to 80% of all the carotenoids found in the petals of 7 species of the *Medicago* genus. In addition, the present author (Czeczuga 1974) found that about half of the carotenoids found in the green parts of the *Posidonia oceanica* and *Nelumbium nuciferum*

consists of lutein epoxide. In studies on the effect of aphids on the carotenoid content of the upper parts of nineteen plant species, lutein epoxide was also found to be the dominant carotenoid in most of these plants (Czacuga 1976). Nevertheless, there are a number of reports of the dominance of other carotenoids; Valadon and Mummery (1972) found that β -carotene and cryptoxanthin isomers comprised the largest portion of the carotenoids in the service tree, *Sorbus aucuparia*. On the other hand, in our material from Abisko, the dominant carotenoid was found to be lutein epoxide in both the leaves and the fruits. In addition, Valadon and Mummery (1968b, 1969) in investigations on carotenoids in different parts of several species of roses found neither lutein nor its derivative, lutein epoxide, was the dominant carotenoid; in the flowers of these species, large quantities of β -carotene, mutatochrome and auroxanthin were found, while in the other parts of the plants, rubixanthin or the isomer 5,6,5',6'-diepoxy- β -carotene and other carotenoids predominated. Again, Valadon and Mummery (1971) found that monoepoxy- β -carotene predominated in the flowers of 26 species of the Composite. Lutein was one of a group of carotenoids which were found to occur in almost every species of plant. β -cryptoxanthin, which has been found in most of the plants investigated, as far as the higher orders of plants are concerned, has been determined either in the leaves (Czacuga 1975, 1977) or in galls on the leaves. The same was found as regards such carotenoids as β -carotene, mutatochrome, zeaxanthin or its derivative, isozeaxanthin, which occur in quite large amounts in the investigated plants (Czacuga 1976).

As the findings of the present investigations show, the total carotenoid content of the material from Abisko varied between hundredths of a mg/g dry mass (the *Cassope hypnoides*, *Lycopodium alpinum*, and *Vaccinium myrtillus* shoots) to 0.8 mg/g dry mass (the flowers of *Dryas octopetala*, and shoots of *Viola biflora*). On comparing the data obtained from the analysis of the total carotenoid content in our material with those published by Valadon and Mummery (1968a-b, 1969, 1971, 1972), Quackenbach and Miller (1972), Hanny et al. (1972), and Ignasiak and Lesins (1973), it can be said that the total carotenoid content of the plants from the Abisko region is at a very low, minimal, level. The above authors determined a carotenoid content of a few mg/g dry mass in their material, though Valadon and Mummery (1968b) did find small amounts of carotenoids, more or less of the order found in our material, in their investigations on certain varieties of roses.

On considering the results of these investigations on numerous plant species belonging to different families, it must, however, be said that the plants of Swedish Lapland, both the shoots and the fruit, contain comparatively small quantities of carotenoids as a source of vitamin A for animals and man.

Table 1

Carotenoid pigments in some species of Lichens, *Sphagnaceae* and *Lycopodiaceae* family (% of total pigments)

Plant species	Part of plant	Carotenoids content in mg/g dry weight	α -carotene	β -carotene	ζ -carotene	canthaxanthin	β -cryptoxanthin	lutein	lutein epoxide	lycophyll	aurochrome	auroxanthin	capsanthin	capsorubin	gazaniaxanthin	mutatochrome	mutatoxanthin	rubixanthin	zeaxanthin	violaxanthin	4,4'-diketo-3-hydroxy- - β -caroten
Lichens																					
1. <i>Peltigera aphthosa</i> (L.) Willd.	thalli	0.20							80.7		3.2					11.1				5.0	
2. <i>Nephroma arcticum</i> (L.) Torss	thalli	0.10	3.2	15.9			2.8		45.5						5.5	21.4	4.2	1.5			
Sphagnaceae																					
3. <i>Sphagnum nemoreum</i> Scop.	shoot	0.23		6.8		18.5			26.4	7.4		11.7								6.8	22.4
Lycopodiaceae																					
4. <i>Lycopodium alpinum</i> L.	shoot	0.08	1.7	2.3	1.3			15.5	47.0				9.9	5.0	2.3				15.0		

Table 2

Carotenoid pigments in some species of *Ericaceae* family
(% of total pigments)

Plant species	Part of plant	Carotenoids content in mg/g dry weight	β -carotene	canthaxanthin	β -cryptoxanthin	echinenone	lutein	lutein epoxide	lycophyll	chrysanthemaxanthin	aurochrome	eschscholtzxanthin	capsanthin	capsorubin	flavoxanthin	mutatochrome	mutatoxanthin	neoxanthin	rubixanthin	zeaxanthin	isozeaxanthin	violaxanthin	hydroxy- ζ -carotene
1. <i>Andromeda polifolia</i> L.	shoot	0.21	3.3		23.0			18.4		8.2						38.3	5.4					3.4	
2. <i>Cassiope hypnoides</i> (L.) D. Don.	shoot	0.05	12.5					39.7			23.0									24.8			
3. <i>Cassiope hypnoides</i> (L.) D. Don.	flower	0.25	31.6					25.8			12.6					15.5							14.5
4. <i>Phyllodoce coerulea</i> (L.) Bab.	shoot	0.15			61.8		20.8	4.7				1.2		7.2	0.8					3.5			
5. <i>Rhododendron lapponicum</i> (L.) Wahl.	shoot	0.23			1.0		5.1			6.6			1.9			14.7			64.1	6.6			
6. <i>Vaccinium myrtillus</i> L.	shoot	0.08					17.1	70.4	4.2				3.3				1.8				3.2		
7. <i>Vaccinium myrtillus</i> L.	fruit	0.21	32.8	4.9	3.3	18.8	1.9	21.6										16.7					

Table 3

Carotenoid pigments in some species of *Rosaceae* family (% of total pigments)

Plant species	Part of plant	Carotenoids content in mg/g dry weight	α -carotene	β -carotene	ζ -carotene	canthaxanthin	α -cryptoxanthin	β -cryptoxanthin	lutein	lutein epoxide	lycoxanthin	aurochrome	chrysanthemaxanthin	capsanthin	capsorubin	flavoxanthin	gazaniaxanthin	mutatochrome	zeaxanthin	isoxanthin	hydroxy- ζ -carotene	dihydroxy- ζ -carotene	3,4,4'-trihydroxy- β - -carotene
1. <i>Dryas octopetala</i> L.	shoot	0.23								7.0		74.8						13.4			3.5	1.3	
2. <i>Dryas octopetala</i> L.	flower	0.83						2.5		55.3	9.0	2.2					5.3			17.0			8.7
3. <i>Rubus chamaemorus</i> L.	shoot	0.19		9.6						51.2			8.5			3.2		21.5	6.0				
4. <i>Rubus chamaemorus</i> L.	fruit	0.54		10.9	0.3	2.8		41.0								19.4	4.6		21.0				
5. <i>Sorbus aucuparia</i> L.	shoot	0.27	5.2					2.6	2.2	60.3					2.2			3.7	4.0	19.8			
6. <i>Sorbus aucuparia</i> L.	fruit	0.12		4.5			4.7		3.4	28.1	19.1			24.5	8.1			1.7		5.9			

Table 4

Carotenoid pigments in some species of other family (% of total pigments)

Plant species	Part of plant	Carotenoids content in mg/g dry weight	α -carotene	β -carotene	ζ -carotene	canthaxanthin	α -cryptoxanthin	β -cryptoxanthin	isocryptoxanthin	echinenone	lutein	lutein epoxide	lycophyll	lycoxanthin	aurochrome	capsanthin	chrysanthemaxanthin	flavochrome	flavoxanthin	gazaniaxanthin	mutatochrome	mutatoxanthin	zeaxanthin	isoeaxanthin	hydroxy- ζ -carotene	4-hydroxy- α -carotene	unknown
<i>Empetraceae</i>																											
1. <i>Empetrum nigrum</i> L.	shoot	0.15						10.0				68.0	14.0								2.9						
2. <i>Empetrum nigrum</i> L.	fruit	0.32		7.7		10.8	7.4			4.3	37.2	13.3										19.3	5.1				
<i>Papaveraceae</i>																											
3. <i>Papaver radicatum</i> s. sp. <i>hyperboreum</i> Nor.	shoot	0.70		1.4				2.9			3.4	79.4							0.9		1.6		10.0				
<i>Salicaceae</i>																											
4. <i>Salix reticulata</i> L.	shoot	0.15						33.4						34.2	12.4						13.0				7.0		
<i>Serophulariaceae</i>																											
5. <i>Bartsia alpina</i> L.	shoot	0.34						6.7				55.7				15.0	0.9			10.7		1.8		9.2			
<i>Lentibulariaceae</i>																											
6. <i>Pinguicula alpina</i> L.	shoot	0.73					12.8	26.3				6.4		15.2		18.5					14.3			6.5			
<i>Violaceae</i>																											
7. <i>Viola biflora</i> L.	shoot	0.85		26.4							7.7	16.6									44.0		5.3				
<i>Saxifragaceae</i>																											
8. <i>Saxifraga oppositifolia</i> L.	shoot	0.14	6.5	13.5			1.9	6.7	4.0		33.1	14.9										9.6	9.8				
9. <i>Saxifraga aizoides</i> L.	shoot	0.20										72.3		18.6				2.7	2.0		2.4		2.0				
<i>Caryophyllaceae</i>																											
10. <i>Cerastium arvense</i> L.	shoot	0.61										57.5					3.8		2.4	26.3	2.4			7.6			
11. <i>Silene acaulis</i> (L.) Jacq.	shoot	0.13		0.8			3.2	38.0			39.4	3.7					5.9						6.8			2.2	
<i>Ranunculaceae</i>																											
12. <i>Trollius europaeus</i> L.	shoot	0.30						15.2				19.3					14.5		8.2	2.2	18.5		7.9	14.2			
13. <i>Trollius europaeus</i> L.	flower	0.17	15.5	4.4			8.5		6.3			46.0			6.9				1.1			3.7		7.6			
<i>Compositae</i>																											
14. <i>Gnaphalium norvegicum</i> Gunn.	shoot	0.61		2.1				2.1				82.9							1.5				9.8		1.6		
15. <i>Saussurea alpina</i> (L.) DC	shoot	0.25						22.2				55.3					6.9	15.6									
<i>Papilionacea</i>																											
16. <i>Astragalus alpinus</i> L.	shoot	0.33			5.2			26.7				56.2					4.7	2.4	4.7								
<i>Betulaceae</i>																											
17. <i>Betula nanna</i> L.	shoot	0.22		4.8				17.5	2.0			65.3											7.9	2.5			

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Author's address:

Prof. Dr B. Czeczuga

Department of General Biology

Medical Academy,

Kilińskiego str. 1, 15-230 Białystok, Poland

Zawartość karotenoidów u niektórych roślin
z Narodowego Parku Abisko (Laponia Szwedzka)

Streszczenie

Stosując chromatografię kolumnową i cienkowarstwową badano występowanie poszczególnych karotenoidów oraz ogólną ich zawartość u porostów (2 gatunki), *Sphagnaceae* (1 gatunek), *Lycopodiaceae* (1 gatunek) oraz 23 gatunków roślin wyższych zebranych w Narodowym Parku Abisko (Laponia Szwedzka). W wyniku badań stwierdzono występowanie 34 karotenoidów, ogólna ilość których wahała się od 0,05 do 0,85 mg/g suchej masy analizowanego materiału.