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Fish carotenoids

CAROTENOID CONTENT IN SOME BODY PARTS OF PIKE (*ESOX LUCIUS* L.) BEFORE, DURING, AND POST-SPAWNING

ZAWARTOŚĆ KAROTENOIDÓW W NIEKTÓRYCH CZĘŚCIACH CIAŁA SZCZUPAKA (*ESOX LUCIUS* L.) PRZED, W OKRESIE I PO TARLE

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The authors investigated carotenoids in selected body parts of pike before, during, and post-spawning period.

INTRODUCTION

According to the studies carried out on salmonid fishes, carotenoid content in respective body parts changes in annual cycle, and most significantly in the spawning season. Such phenomenon has been reported in the representatives of the salmonid species performing reproductive migration (Crozier 1970; Kitahara 1983; Czeczuga and Chełkowski 1984). However, quite recently we have revealed a carotenoid shift in the period prior to the spawning season in *Coregonus lavaretus*—a typical representative of lacustrine coregonids (Czeczuga et al. 1991).

The aim of this work was to investigate if this kind of phenomenon occurs also in other species, in which such striking dimorphous variations are not observed. We chose pike, still a relatively common species in European waters. Preliminary data on carotenoids found in *Esox lucius* have been already published (Czeczuga 1978).

MATERIAL AND METHODS

Eggs of *Esox lucius* L. collected in April, during the spawning season were analysed. Young and adult fish of both sexes were caught in Suwałki lakes in autumn, winter, and in spring before, during, and after the spawning season.

In each period three pike specimens were examined.

The content of carotenoids was determined separately for fins, skin, muscles (dorsal, lateral, ventral), liver, intestine, intestinal fat, and gonads.

Tissue samples from each fish were homogenised, placed in a dark bottle, soaked in 95% acetone, and kept in a refrigerator until analysed. Carotenoid pigments were separated by means of column- and thin layer chromatography. Prior to separation, each sample was hydrolysed for 24 h with 10% KOH in nitrogen at room temperature. The details of the chromatographic techniques used are given in one of the previous papers of the series (Czeczuga and Czerpak 1968). The hydrolysed extract was transferred to an Al_2O_3-filled column, 15 to 25-cm long, 1.8 cm in diameter. The fractions were eluted with different solvent combinations (Czeczuga and Czerpak 1976).

In addition to the column chromatography, the acetone extracts were separated with layer chromatography as well. Silica gel covered glass plates and different solvent combinations were used. The R_f values were determined according to the commonly used procedures.

Carotenoids were identified on the basis of:

a) the nature of column chromatograms,
b) absorption peaks in various solvents,
c) epi- to hypophase ratio determined in hexane and 95% methanol,
d) comparisons of thin layer chromatogram R_f values with standards (Hoffman-La Roche and Co. LTD, Switzerland and Sigma Chemical Co. USA) to identify α-, β-carotene, β-cryptoxanthin, canthaxanthin, lutein, zeaxanthin, β-doradexanthin, and astaxanthin,
e) presence of allohydroxy groups determined with acidic chloroform,
f) epoxy test.

Carotenoid contents were determined from quantitative absorption spectra. The assays were based on the absorption coefficient E 1%/cm in corresponding peaks of absorbance in petroleum ether or hexane (Davies 1976).

RESULTS

In various body parts of pike examined, 27 carotenoids were identified (Tab. 1, Fig. 1). The greatest variety of carotenoids was observed in adult individuals of both sexes. In the eggs only 7 carotenoids (Tab. 2), and in the juveniles 10 carotenoids (Tab. 3) were found. Total carotenoid content in the fins, skin, and muscles of young fish did not vary significantly, being almost twice as high in the liver and intestine. In the adults, significant differences in the total carotenoid content in respective body parts were observed according to the season of the year. In all fish collected before winter (Oct–Dec) (Tabs. 4–6), the skin, fins, and intestine had the highest carotenoid content, while those collected in spring (Apr–May) (spawning season), revealed the highest carotenoid content in the inner organs, particularly in the liver (Tabs. 7–9) and in post spawning period (Jul–Aug) in the skin (Tabs.

10–11). In the adults—the highest carotenoid content in the intestinal fat (Tab. 9–10).In the females in spawning season, carotenoid content in intestinal fat decreased (Tab. 8).

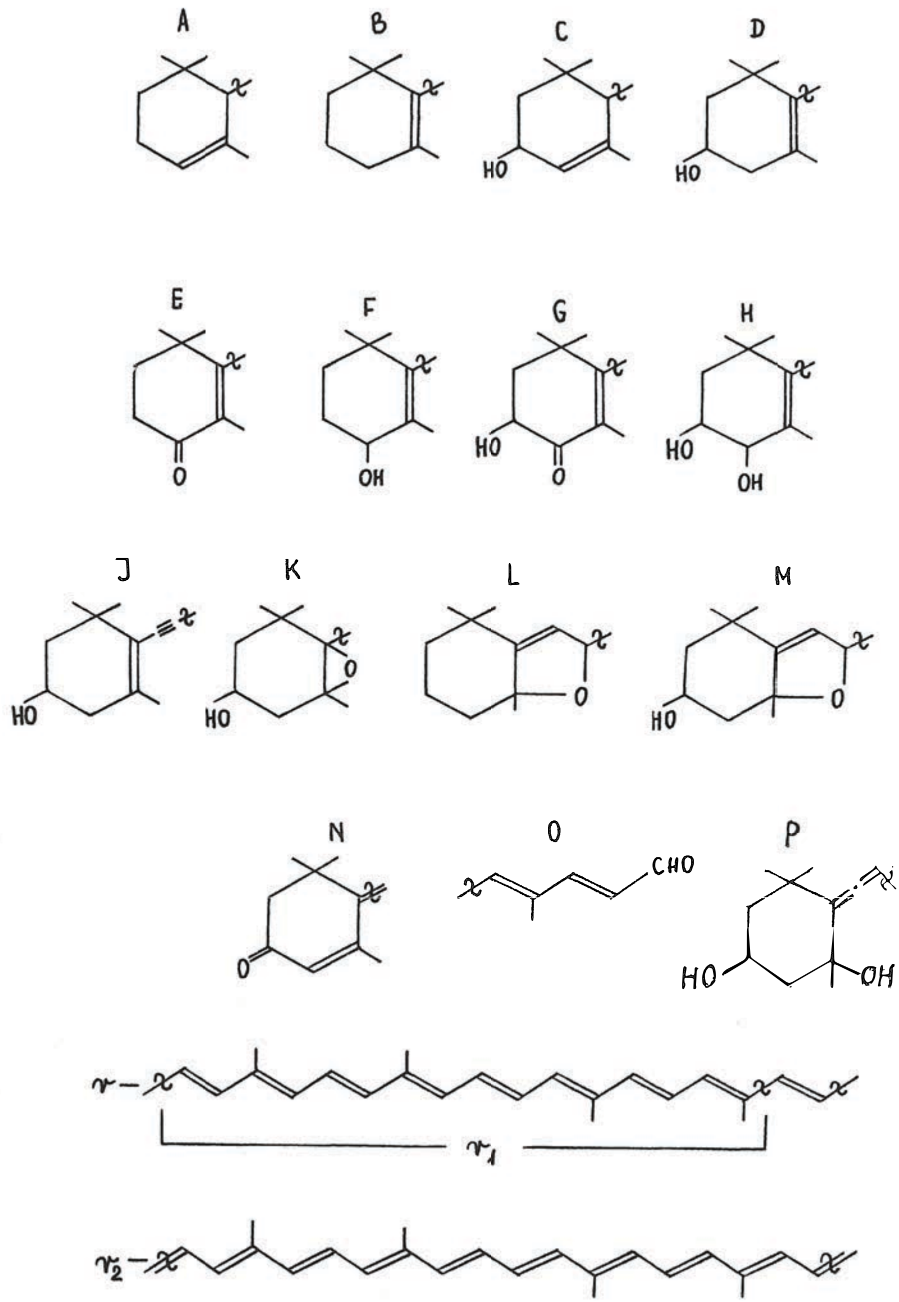

Fig. 1. Structural features of carotenoids from material studied

Table 1

List of the carotenoids from the material studied

Carotenoid	Summary formula	Structure (see Fig. 1)	Semisystematic name	Spring	Summer	Autumn
α-Carotene	$C_{40}H_{56}$	A - r - B	β,ε-Carotene	×		×
β-Carotene	$C_{40}H_{56}$	B - r - B	β,β-Carotene	×	×	×
ε-Carotene	$C_{40}H_{56}$	A - r - A	ε,ε-Carotene	×		×
α-Cryptoxanthin	$C_{40}H_{56}O$	A - r - D	β,ε-Caroten-3-ol			×
β-Cryptoxanthin	$C_{40}H_{56}O$	B - r - D	β,β-Caroten-3-ol	×	×	×
Neothxanthin	$C_{40}H_{56}O$	A - r - C	ε,ε-Caroten-3-ol	×		×
Lutein	$C_{40}H_{56}O_2$	C - r - D	β,ε-Carotene-3,3'-diol	×	×	×
3'-Epilutein	$C_{40}H_{56}O_2$	C - r - D	β,ε-Carotene-3,3'-diol (stereoisomeric)		×	×
Zeaxanthin	$C_{40}H_{56}O_2$	D - r - D	β,β-Carotene-3,3'-diol	×	×	×
Tunaxanthin	$C_{40}H_{56}O_2$	C - r - C	ε,ε-Carotene-3,3'-diol	×	×	×
Echinenone	$C_{40}H_{54}O$	B - r - E	β,β-Caroten-4-one	×		×
3'-Hydroxyechinenone	$C_{40}H_{54}O_2$	D - r - E	3'-Hydroxy-β,β-caroten-4-one		×	
4'-Hydroxyechinenone	$C_{40}H_{54}O_2$	F - r - E	4'-Hydroxy-β,β-caroten-4-one	×		×
Canthaxanthin	$C_{40}H_{52}O_2$	E - r - E	β,β-Caroten-4,4'-dione	×	×	×
Phoenicoxanthin	$C_{40}H_{50}O_3$	E - r - G	3-Hydroxy- β,β-caroten-4,4'-dione		×	
α-Doradexanthin	$C_{40}H_{54}O_3$	C - r - G	3,3'-Dihydroxy-β,ε-carotene-4-one	×	×	×
β-Doradexanthin	$C_{40}H_{54}O_3$	D - r - G	3,3'-Dihydroxy-β,β-carotene-4-one	×	×	×
Astaxanthin	$C_{40}H_{52}O_4$	G - r - G	3,3'-Dihydroxy-β,β-carotene-4,4'-dione	×	×	×
Idoxanthin	$C_{40}H_{54}O_4$	G - r - H	3,3',4'-Trihydroxy-β,β-caroten-4-one			×
Diatoxanthin	$C_{40}H_{54}O_2$	D - r_1 - I	7,8-Didehydro-β,β-carotene-3,3'-diol		×	×
Lutein epoxide	$C_{40}H_{56}O_3$	C - r - K	5,6-Epoxy-5,6-dihydro-β,ε-carotene-3,3'-diol	×	×	×
Antheraxanthin	$C_{40}H_{56}O_3$	D - r - K	5,6-Epoxy-5,6-dihydro-β,β-carotene-3,3'-diol	×	×	×
Mutatochrome	$C_{40}H_{56}O$	B - r_1 - L	5,8-Epoxy-5,8-dihydro-β,β-carotene	×		
Mutatoxanthin	$C_{40}H_{56}O_3$	D - r_1 - M	5,8-Epoxy-5,8-dihydro-β,β-carotene-3,3'-diol	×		×
Rhodoxanthin	$C_{40}H_{50}O_2$	N - r_2 - N	4',5'-Didehydro-4,5'-retro-β,β-carotene-3,3'-dione		×	×
β-Apo-2'-carotenal	$C_{37}H_{48}O$	B - r - O	3',4'-Didehydro-2'-apo-β-caroten-2'-al			×
Deepoxyneoxanthin	$C_{40}H_{56}O_3$	D - r_1 - P	6,7-Didehydro-5,6-dihydro-β,β-carotene-3,5,3'-triol		×	×
Total number of carotenoids				18	17	24

Table 2

Carotenoid content in eggs of *Esox lucius* L. (mean from 3 females)

Carotenoid	%
β-Carotene	3.1
β-Cryptoxanthin	25.5
Zeaxanthin	21.8
Lutein	14.6
Lutein epoxide	10.2
Neothxanthin	3.8
Astaxanthin	21.0
Total content in $\mu g\ g^{-1}$ wet weight	0.862

Table 3

Carotenoid content in some parts of *Esox lucius* L. (%), (young specimens, mean total length 23 cm, 26 October 1997)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine
β-Carotene		6.0	7.0	7.2	4.0
β-Cryptoxanthin	25.0	13.1	36.6	13.9	23.5
Zeaxanthin		18.0	7.0	12.6	53.0
Lutein			11.6		
Lutein epoxide	66.3		10.4		4.0
Diatoxanthin		7.5			
Canthaxanthin					4.2
α-Doradexanthin				22.2	
Astaxanthin	8.7	55.0	27.4	44.1	9.4
Rhodoxanthin		0.4			1.9
Total content in $\mu g\ g^{-1}$ wet weight	0.184	0.162	0.160	0.315	0.274

Table 4

Carotenoid content in some parts of *Esox lucius* L. (%), (mean total length 32 cm, 10 October 1997)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Eggs
ε-Carotene	1.0			6.4	4.5	3.1
α-Carotene		1.4	2.4	4.7	3.2	3.3
β-Carotene	1.4	1.7	3.1	4.6	2.7	2.6
Neothxanthin		8.5				
β-Cryptoxanthin				8.9		
Tunaxanthin	19.4	13.9	5.1	19.8	2.8	29.4
Lutein		28.8		15.5	26.9	33.3
Zeaxanthin	40.3	18.2	33.6	11.1	15.1	7.9
Lutein epoxide	18.0	9.3	9.1	14.2	20.7	14.0
Antheraxanthin	9.9					
β-Doradexanthin		8.7	39.3			
Astaxanthin		9.5	7.4			
Mutatoxanthin				14.8	5.0	6.4
Deepoxyneoxanthin	10.0				19.1	
Total content in $\mu g\ g^{-1}$ wet weight	7.452	8.783	0.912	0.908	1.614	0.686

Table 5

Carotenoid content in some parts of *Esox lucius* L. (%),
(mean total length 43 cm, 23 December 1997)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Eggs
β-Carotene					11.0	
ε-Carotene	1.8					
β-Cryptoxanthin	1.4	9.3	13.7	27.2	13.5	4.2
α-Cryptoxanthin	2.3		5.8			5.8
Zeaxanthin		31.1	4.7			22.2
Lutein	14.2	9.7			10.5	9.9
3'-Epilutein	17.5		5.9	11.9		
Neothxanthin		12.5				5.2
Tunaxanthin			14.0			
Antheraxanthin	6.7			9.5		
Lutein epoxide	51.2	25.5	12.1	3.7	31.9	trace
Idoxanthin					2.6	
β-Doradexanthin	4.9	7.0	9.7	21.5	trace	6.8
Diatoxanthin						7.6
Canthaxanthin		4.9	3.2	7.0	22.6	10.2
Astaxanthin			30.9	12.8		21.8
Rhodoxanthin						6.3
Mutatoxanthin				6.4	7.9	
β-Apo-2'-carotenal						
Total content in $\mu g\ g^{-1}$ wet weight	2.294	3.362	0.628	0.586	0.724	0.513

Table 6

Carotenoid content in some parts of *Esox lucius* L. (%),
(mean total length 60 cm, 20 December 1997)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Milt
α-Carotene			14.9			7.4
β-Carotene	10.2	6.9	16.8	2.5	4.2	10.5
β-Cryptoxanthin	13.1	10.1		12.6	7.7	12.3
Neothxanthin	3.4	10.9		3.8	4.5	4.2
Zeaxanthin	13.5	11.6	7.6			9.4
Tunaxanthin	3.9	8.1	9.4	12.7	4.7	12.7
Lutein epoxide				10.4	8.3	9.6
Antheraxanthin	9.6					4.9
Echinenone				4.6		
4'-Hydroxyechinenone			3.9	5.4		
Canthaxanthin	23.9	9.5	20.3	11.1	20.2	11.8
β-Doradexanthin		22.6		10.0		
Astaxanthin	14.6	20.3	14.5	16.9	35.2	12.3
Idoxanthin			12.6	2.8		2.1
Mutatoxanthin						2.8
Deepoxyneoxanthin	7.8			7.2	15.2	
Total content in $\mu g\ g^{-1}$ wet weight	0.940	2.777	0.202	0.862	0.592	0.372

Table 7

Carotenoid content in some parts of *Esox lucius* L. (%), (mean total length 63 cm, 21 April 1998)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Eggs
β-Carotene	6.3	10.5	29.1	7.9		9.7
ε-Carotene				4.1	15.9	
β-Cryptoxanthin	5.7	16.4				7.6
Tunaxanthin	4.0	21.9	19.1	5.6	22.0	36.2
Zeaxanthin	11.5	6.4	19.6			
Lutein	55.0		12.4	10.5	1.9	27.7
Antheraxanthin	15.0		8.3	36.4	20.4	
Lutein epoxide	2.5	3.6	11.5	18.1	15.5	11.2
β-Doradexanthin		41.2		17.4	24.3	7.6
Total content in μg g^{-1} wet weight	1.723	1.272	0.664	2.472	1.178	0.614

Table 8

Carotenoid content in some parts of *Esox lucius* L. (%), (post-spawning female, mean total length 54 cm, 8 May 1998)

Carotenoid	Fins	Muscles and skin	Liver	Intestine	Fat
α-Carotene			7.0		
β-Carotene		6.1		2.3	7.1
β-Cryptoxanthin	17.2	13.3			
4'-Hydroxyechinenone			3.3		
Lutein	8.2	6.7	21.3		
Lutein epoxide		26.0		12.5	32.8
Zeaxanthin	30.8	20.5	5.6	14.1	7.3
Neothxanthin	9.9				
α-Doradexanthin			12.0		
β-Doradexanthin		6.6	8.1	12.6	
Astaxanthin	29.1	20.8	32.2	50.6	48.5
Mutatochrome	4.8		4.7		
Mutatoxanthin			5.8	7.9	4.3
Total content in μg g^{-1} wet weight	0.171	0.229	0.422	0.300	0.284

Table 9

Carotenoid content in some parts of *Esox lucius* L. (%), (mean total length 58 cm, 5 May 1998)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Fat	Eggs
β-Carotene		6.4	2.8	8.9	19.7		
β-Cryptoxanthin	1.7	7.8	15.8				12.2
Lutein	38.2						
Zeaxanthin			15.6				
Lutein epoxide	20.3	20.0		5.1	38.9	10.1	19.7
Echinenone		2.9					
4'-Hydroxyechinenone					3.9		
Canthaxanthin	12.2	10.9	9.6	14.1	11.0	8.3	21.7
α-Doradexanthin			0.9	14.0			
β-Doradexanthin			24.0	15.5	16.7		28.4
Astaxanthin	27.6	52.0	31.3	42.4	9.8	81.6	18.0
Total content in μg g^{-1} wet weight	0.674	0.665	0.457	1.652	0.743	2.364	0.345

Table 10

Carotenoid content in some parts of *Esox lucius* L. (%), (mean total length 46 cm, 20 July 1998)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Fat	Eggs
β-Carotene	3.8	2.5	4.2		8.6	5.0	17.6
β-Cryptoxanthin	3.5	12.4	16.8	11.7	38.2	0.2	5.6
Canthaxanthin	13.6	10.5	12.3	22.6	12.4	26.3	16.8
Lutein					4.3	19.5	
3'-Epilutein					4.6		11.5
Lutein epoxide						15.1	
Zeaxanthin	51.4	21.2	17.4	21.2	7.5	6.9	14.3
3'-Hydroxyechinenone							0.9
β-Doradexanthin	8.4	16.4	18.2	8.2	8.7	10.4	3.5
Phoenicoxanthin						10.0	0.3
Rhodoxanthin						2.5	
Diatoxanthin				10.6			11.7
α-Doradexanthin	3.0	2.8	1.5	6.8	3.8		
Astaxanthin	16.3	34.2	29.6	18.9	11.9	4.1	17.8
Total content in μg g^{-1} wet weight	0.603	1.628	0.705	0.819	1.248	2.529	0.258

Table 11

Carotenoid content in some parts of *Esox lucius* L. (%), (mean total length 68 cm, 30 August 1998)

Carotenoid	Fins	Skin	Muscles	Liver	Intestine	Eggs
β-Carotene		6.7				10.3
β-Cryptoxanthin		14.8	10.3		6.5	18.6
Lutein	6.4					
Zeaxanthin	2.9		16.2	14.5		10.3
Lutein epoxide			6.2	12.2		
Tunaxanthin		19.3	11.5		16.4	24.2
Antheraxanthin	24.1	12.3		12.5	18.7	
Canthaxanthin	21.8	46.9	46.6	39.1	3.3	17.3
α-Doradexanthin					9.6	19.3
β-Doradexanthin				5.4		
Astaxanthin	44.8		9.2	16.3	41.3	
Deepoxyneoxanthin					4.2	
Total content in $\mu g\ g^{-1}$ wet weight	0.505	1.519	0.636	0.921	0.682	0.606

DISCUSSION

Among 27 carotenoids found in the pike specimens examined, worth noting is the presence of α-cryptoxanthin, α-carotene derivative, detected in the autumn period. α-Cryptoxanthin is rare in fishes. Up to now it has been found in the fins and the skin of several species of clupeids (Matsuno and Katsuyama 1976), in tropical marine yellow fish (Tanaka et al. 1978) and in a few salmonids inhabiting Polish waters (Czeczuga and Bartel 1989).

According to the present study, the number of carotenoids in pike is relatively high, which may be justified by the biology of this species. As it is known, pike, as predators, feed on other species. In north-eastern waters of Poland they feed mainly on roach and perch (Brylińska 1986), the species with intense red coloration of carotenoid origin (Czeczuga 1979, 1994). Among additional items constituting the diet of pike, important role is played by carotenoid-reach "small fry" of other species (Czeczuga and Czerpak 1976). Carotenoids taken with food may be transformed into other, more oxidised forms; hence, a wide variety of carotenoids was observed, particularly in the adult pike specimens examined.

The introduction of radioactively labelled carotenoids to the feed of certain fish species has allowed accurate investigation of their transformation pathways. In one fish species the same carotenoid is transformed into others, while in another fish species it only accumulates in some tissues (Storebakken and Choubert 1991). Some fish species reduce certain oxidated carotenoids to less oxidated ones or even to carotenes. In common carp, *Cyprinus carpio* β-carotene taken with feed is not transformed into astaxanthin ester (Katayama et al. 1972a). Similar behaviour of this carotene is observed in some sea fish species, including sea bream, *Chrysophorus major* (cf. Katayama et al. 1972b) as well as in red sea bream, *Evynnis japonica* (cf. Katayama et al. 1974). In goldfish, *Carassius auratus*, echinenone, canthaxanthin, and lutein are not transformed into astaxanthin (Hata and Hata 1972). However, in goldfish, *Carassius auratus*, astaxanthin is formed from β-carotene through isocryptoxanthin, isozeaxanthin, and echinenone (Rodriguez et al. 1973). Canthaxanthin or astaxanthin taken with feed accumulate in tissues, mainly in the muscles giving them red, almost natural colour, which is important in salmonid fish farms of. In fish muscles these carotenoids are found within muscle cells (Henmi et al. 1987), where, together with contractile proteins, form the actiomyosin complex (Henmi et al. 1989). Vitamin E (α-tocopherol) added to the feed contributes to the stabilisation of canthaxanthin concentration in the muscles of rainbow trout, *Oncorhynchus mykiss* (cf. Pozo et al. 1988). Canthaxanthin in rainbow trout accumulates mainly in the skin and muscles (Choubert et al. 1987) thus increasing their economic value (Hardy et al. 1990). β-Carotene, however, in rainbow trout accumulates in the digestive tract, zeaxanthin in integument, digestive tract, and flesh, while lutein, in the smallest amounts of the three carotenoids, accumulates in the digestive tract and integument (Hata and Hata 1973). Not only canthaxanthin and astaxanthin, but also apocarotenales are used to increase the economic value of salmonids through administration of artificial feed (Hirao et al. 1962). In certain conditions, such as reproductive migrations when fishes do not take up feed, some species reduce astaxanthin to zeaxanthin. This was observed in *Oncorhynchus keta* (cf. Kitahara 1983) and *Oncorhynchus masou* (cf. Kitahara 1985). In other salmonids astaxanthin is reduced to adonixanthin and canthaxanthin to β-carotene (Schiedt et al. 1985; Ando 1986). Thus in various fish species carotenoids taken up with feed can undergo oxidation or reduction, but most often they accumulate in certain organs. This depends on the biology of a particular fish species (Czeczuga and Bartel 1998a, b; Czeczuga and Czeczuga-Semeniuk 1999).

The data obtained reveal that in the autumn–winter period, the highest number of carotenoids is found in the skin and fins, from which, just before the spawning season, they shift to inner organs—most of them to the liver, fewer to the intestine (Fig. 2). After spawning in July, the gonads contain approximately one third of the carotenoids found in the spawning season. From August on (Tabs. 10, 11), the carotenoid content in the gonads remains on the same level until the spawning season. Some fish species are known to have the same amount of carotenoids before-, during-, and after the reproductive period. Such a phenomenon was observed by Miki et al. (1983) in mature ovaries of Alaska pollack, *Theragra chalcogramma*, in the gonads of chum salmon, *Oncorhynchus keta* (cf. Kitahara 1983), and masu salmon, *Oncorhynchus masou* (cf. Kitahara 1985). Carotenoid shift from certain body parts to others has been hitherto observed only in salmonids. According to Crozier (1970), specimens of *Oncorhynchus nerka* of both sexes have the highest carotenoid content in the muscles. In the spawning season the carotenoids shift mainly from the muscles to the skin in males, and to the gonads in females, and only slightly to the skin. Similar phenomenon occurs in *Oncorhynchus keta* (cf. Kitahara 1983), and in *Oncorhynchus masou* (cf. Kitahara 1985). It is not the same, however, in brown trout, *Salmo trutta* (cf. Czeczuga and Chełkowski 1984). In males collected in the spawning period, carotenoids shifted to the skin and gonads mainly from the intestine and muscles. In females they shifted to the same body parts as in males, although mainly from the liver, intestine, fins, and less from the muscles. The same can be observed in *Salmo trutta* morpha *lacustris* (cf. Czeczuga and Bartel 1989). Data concerning the pike specimens examined indicate a pre-spawning carotenoid shift in the direction opposite to that observed in salmonids. During that time carotenoids shift from the fins and skin to inner organs, especially to the liver. According to Ando (1986), carotenoid transport between respective body parts in salmonids occurs in a form of a protein-carotenoid complex. This form of carotenoid transport should be also considered typical of other fish species.

October 1997

f. Skin ⇒ fins ⇒ intestine ⇒ muscles ⇒ liver ⇒ eggs

December 1997

f. Skin ⇒ fins ⇒ intestine ⇒ muscles ⇒ liver ⇒ eggs

m. Skin ⇒ fins ⇒ liver ⇒ intestine ⇒ milt ⇒ muscles

April 1998

f. Liver ⇒ fins ⇒ skin ⇒ intestine ⇒ muscles ⇒ eggs

May 1998

f. Liver ⇒ intestine ⇒ muscles and skin ⇒ fins

m. Liver ⇒ intestine ⇒ fins ⇒ skin ⇒ muscles ⇒ milt

July 1998

f. Skin ⇒ intestine ⇒ liver ⇒ muscles ⇒ fins ⇒ eggs

August 1998

f. Skin ⇒ liver ⇒ intestine ⇒ muscles ⇒ eggs ⇒ fins

Fig. 2. Total content (highest to lowest) of carotenoids in particular parts of *Esox lucius* in different periods: f, females; m, males

CONCLUSION

A total of 27 carotenoids was found in some body parts of pike (*Esox lucius* L.) before, during, and post spawning period.

The greatest variety of carotenoids was observed in adults of both sexes.

In all individuals collected before winter, the skin, fins, and intestine had the highest carotenoid content, while those collected in spring (spawning season), revealed the highest carotenoid content in inner organs, particularly in the liver. There were fewer carotenoids in intestine and in post spawning period in skin.

In adult specimens the highest carotenoid content was observed in the intestinal fat. In females during the spawning season, carotenoid content in intestinal fat decreased.

REFERENCES

Ando S., 1986: Studies on the food biochemical aspect of changes in chum salmon, *Oncorhynchus keta* during spawning migration: mechanisms of muscle deterioration and nupital coloration. Mem. Facult. Fish. Hokkaido Univ., **33**: 1–95.

Brylińska M., 1986: Ryby słodkowodne Polski [Freshwater fishes of Poland]. PWN, Warszawa. (In Polish).

Choubert G., A. Guillou, B. Fauconneau, 1987: Absorption and fate of labeled canthaxanthin15.15'-$^3H_2$ in rainbow trout (*Salmo gairdneri* Rich.). Comp. Biochem. Physiol.,. **87A**: 717–720.

Crozier G.F., 1970: Tissue carotenoids in prespawning and spawning sockeye salmon (*Oncorhynchus nerka*). J. Fish. Res. Bd Can., **27**: 973–975.

Czeczuga B., 1978: Karotenoidy u ryb, *Esox lucius* L. [Carotenoids in fish, *Esox lucius* L.]. Rocz. Nauk Roln., **99H**: 55–62. (In Polish).

Czeczuga B., 1979: Carotenoids in fish. Percidae from Polish waters. Acta Hydrobiol., **21**: 1–7.

Czeczuga B., 1994: Carotenoids in fish. 51. Cyprinidae—phytophagus: *Rutilus rutilus, Rutilus rutilus heckeli, Scardinus erythrophtalmus*, *Chondrostoma nasus* and *Rhodeus sericeus amarus*. Acta Ichth. Piscat., **24**, 2: 43–51.

Czeczuga B., R. Bartel, 1989: Studies on carotenoids in spawning *Salmo trutta* morpha *lacustris* L. Acta Ichth. Piscat., **19**, 1: 49–58.

Czeczuga B., R. Bartel, 1998a: The occurrence of carotenoids in different—age individuals of *Pelecus cultratus* (L.) from the Vistula Lagoon. Acta Ichth. Piscat., **28**, 1: 15–23.

Czeczuga B., R. Bartel, 1998b: Carotenoid resources in lampreys (Petromyzontidae). Bull. Lampetra, **4**:

Czeczuga B., Z. Chełkowski, 1984: Carotenoids contents in adult individuals of sea-trout *Salmo trutta* L. during spawning migration, spawning and post-spawning migration. Acta Ichth. Piscat., **14**, 1–2: 187–201.

Czeczuga B., E. Czeczuga-Semeniuk, 1999: Carotenoid content in *Lota lota* (L.) individuals in various biological activity periods. Folia Biol. (Kraków), **47**: 67–72.

Czeczuga B., R. Czerpak, 1968: Carotenoids in the carapaces of the *Orconectes limosus* (Raf.), Crustaceae, Decapoda. Eur. J. Biochem., **5**: 429–432.

Czeczuga B., R. Czerpak, 1976: Carotenoids in fish. The kind of food and the content of carotenoids and vitamin A in *Carrassius carassius* L. and *Leucaspius delineatus* Heckel. Acta Hydrobiol., **18**: 1–21.

Czeczuga B., K. Dąbrowski, R. Rösch, A. Champigneulle, 1991: Investigations of carotenoids in *Coregonus lavaretus* L. specimens of differents population. Acta Ichth. Piscat., **21**, 1: 3–16.

Davies B.H., 1976: Carotenoids. In: Chemistry and biochemistry of plant pigments [T.W. Goodwin (ed.)], Academic Press, London–New York–San Francisco: 38–165.

Hardy R.W., O.J. Torrissen, T.M. Scott, 1990: Absorption and distribution of ^{14}C-labeled canthaxanthin in rainbow trout (*Oncorhynchus mykiss*). Aquaculture, **87**: 331–340.

Hata M., M. Hata, 1972: Carotenoids pigments in goldfish. IV. Carotenoids metabolism. Bull. Jap. Soc. Sci. Fish., **38**: 331–338.

Hata M., M. Hata, 1973: Studies on astaxanthin formation in some fresh-water fishes. Tohoku J. Agr. Res., **24**: 192–196.

Henmi H., T. Iwata, M. Hata, M. Hata, 1987: Studies on the carotenoids in the muscle of salmonids. I. Intracellular distribution of carotenoids in the muscle. Tohoku J. Agr. Res., **37**: 101–111.

Henmi H., M. Hata, M. Hata, 1989: Astaxanthin and / or canthaxanthin-actiomycosin complex in salmon muscle. Bull. Jap. Soc. Sci. Fish., **55**: 1583–1589.

Hirao S., R. Kikuchi, K. Ari, T. Honsho, 1962: Feeding test of β-apo-2'-carotenal on rat and rainbow trout. Bull. Jap. Soc. Sci. Fish., **28**: 709–714.

Katayama T., T. Miyahara, M. Shimaya, C.O. Chichester, 1972a: The biosynthesis of astaxanthin. X. The carotenoids in the red carp *Cyprinus carpio* Linne and the interconversion of β-(15,15'- $^3H_2$) carotene into their body astaxanthin. Int. J. Biochem., **3**: 569–572.

Katayama T., T. Miyahara, Y. Tanaka, M. Sameshima, K.L. Simpson, C.O. Chichester, 1974: The biosynthesis of astaxanthin. XV. The carotenoids in chidai red sea bream, *Evynnis japonica* Tanaka and (the incorporation of labelled astaxanthin from the diet of the red sea bream) to their body astaxanthin. Bull. Jap. Soc. Sci. Fish., **40**: 97–103.

Katayama T.K., Shintani, M. Shimaya, S. Imai, C.O. Chichester, 1972b: The biosynthesis of astaxanthin. IX. The transformation of labelled astaxanthin from the diet of sea bream, *Chrysophrys major* Temminch and Schlegel, to their body astaxanthin. Bull. Jap. Soc. Sci. Fish., **38**: 1399–1403.

Kitahara T., 1983: Behaviour of carotenoids in the chum salmon (*Oncorhynchus keta*) during anadromus migration. Comp. Biochem. Physiol., **76B**: 97–101.

Kitahara T., 1985: Behaviour of carotenoids in the masu salmon *Oncorhynchus masou* during anadromus migration. Bull. Jap. Soc. Sci. Fish., **51**: 253–255.

Matsuno T., M. Katsuyama, 1976: Comparative biochemical studies of carotenoids in fishes. IX. On the nineteen species of fish in the division Percichthyes. Bull. Jap. Soc. Sci. Fish., **42**: 645–649.

Miki W., K. Yamaguchi, S. Konosu, 1983: Carotenoid composition of Alaska pollak roe at different stages of maturation. Bull. Jap. Soc. Sci. Fish., **49**: 1615.

Pozo R., J. Lavety, R.M. Love, 1988: The role of dietary α-tocopherol (vitamin E) in stabilising the canthaxanthin and lipids of rainbow trout muscle. Aquaculture, **73**: 165–175.

Rodriguez D., K.L. Simpson, C.O. Chichester, 1973: The biosynthesis of astaxanthin. XVII. Intermediates in the conversion or β-carotene. Int. J. Biochem., **4**: 213–222.

Schiedt K., F.J. Lenenberger, M. Vecchi, E. Glinez, 1985: Absorption, retention and metabolic transformation on carotenoids in rainbow trout, salmon and chicket. Pure Appl. Chem., **57**: 685–692.

Storebakken T., G. Choubert, 1991: Flesh pigmentation of rainbow trout fed astaxanthin or canthaxanthin at different feeding rates in freshwater and saltwater. Aquaculture, **95**: 289–295.

Tanaka Y., F. Nakano, T. Katayama, 1978: The carotenoids in tropical marine yellow fish. Mem. Fac. Fish., Kagoshima Univ., **27**: 29–33.

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ZAWARTOŚĆ KAROTENOIDÓW W NIEKTÓRYCH CZĘŚCIACH CIAŁA SZCZUPAKA (*ESOX LUCIUS* L.) PRZED, W OKRESIE I PO TARLE

STRESZCZENIE

Stosując chromatografię kolumnową i cienkowarstwową badano występowanie karotenoidów w płetwach, skórze, mięśniach, wątrobie, jelicie, tłuszczu przy jelitowym, ikrze, mleczu szczupaka, *Esox lucius* L. w okresie przed tarłem, podczas tarła i po tarle.

U badanych osobników tego gatunku ustalono obecność takich karotenoidów jak; α-, ε-, β-karoten, α-, β-kryptoksantyna, neoksantyna, 3'-epiluteina, zeaksantyna, tunaksantyna, echinenon, 3'-,4'-hydroksyechinenon, kantaksantyna, foenikoksantyna, α-, β-doradeksantyna, astaksantyna, idoksantyna, diatoksantyna, epoksyd luteiny, anteraksantyna, mutatochrom, mutatoksantyna, rodoksantyna, β-apo-2'-karotenal oraz deepoksyneoksantyna.

Największą różnorodność karotenoidów zawartych w analizowanych częściach ciała ryb stwierdzono w okresie jesiennym, najmniejszą zaś – w okresie letnim.

Ogólna zawartość karotenoidów w badanych częściach ciała szczupaka była różna przed, po i podczas tarła. Przed tarłem najwięcej karotenoidów stwierdzono w skórze i płetwach, w czasie tarła w wątrobie i jelicie, a po tarle w skórze.

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