コレゴヌス・ムクスンの放流後の体成分変化

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Changes of Body Components of Whitefish *Coregonus muksun* after Transplantation in Reservoir

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Whitefish *Coregonus muksun* is one of the newly introduced fresh-water fishes to Japan. Little is known about the body components. The present investigation described the changes of chemical composition of the transplanted fish in a reservoir to cultured fish. Though the proximate composi tion did not differ much from that of the control fish during 3 months after transplantation, crude fat content thereafter decreased to about one half. Nonprotein nitrogen content was always lower than that of the control. With regard to free amino acid and fatty acid compositions, increase of anserine and polyenoic fatty acids contents and decrease of monoenoic fatty acids contents were characteristic during 2 months after transplantation.

When the fish was starved, increase of moisture and anserine contents and decrease of crude protein, crude fat, nonprotein nitrogen and histidine contents were remarkable.

Whitefish (Family Coregonidae) are distributed widely in cooler parts of Europe, North America and Soviet Union. Recently, several species, like *Coregonus muksun*, *C. lavaretus maraena*, *C. lavaretus ludoga*, *C. peled* and Arctic cisco *C. autumnalis migratorius*, were introduced to Japan for fish-culture. There are some studies on growth, feeding habit and natural propagation of transplanted *C. peled*,[1] as well as protein requirement of *C. muksun*[*3] and diet for rearing of *C. lavaretus* and *C. peled*.[2] However, no data are available on the chemical compositions not only of cultured but also of transplanted *C. muksun*.

This investigation describes the changes in proximate composition, fatty acid and free amino acid compositions both of cultured fish and the fish transplanted to a reservoir for eight months.

Materials and Methods

Materials

Eyed-stage eggs of whitefish *C. muksun* were introduced from Soviet Union in February 1983, and cultured on an artificial diet at the Inland Fisheries Branch, Fisheries Research Institute of Mie. About five thousand age-0 whitefish juveniles were transplanted in Isaka Reservoir in December 1983. The reservoir, situated in Yokkaichi, Mie Prefecture, is 60.5 m above sea level, 255,000 m^2 in area with a maximal depth of 25 m. Water temperature varied from 4.5 to 29.7°C at the surface and from 5.1 to 24.8°C at a depth of 20 m during the experimental period.

The transplanted fishes were recaptured by gill net monthly from February through August 1984. Size of the recaptured and cultured fishes is listed in Table 1. Alive fishes for analysis were kept in ice and carried to the laboratory as soon as possible. Dorsal and ventral muscles were collected each month from 5 fishes of average size, minced and samples from 5 fishes were pooled in a cold room at about 4°C. The muscle samples were stored at −80°C until analyzed. Whitefish cultured in the Inland Fisheries Branch were used as a control.

Analyses

Crude protein was determined by the micro-Kjeldahl method. Moisture content was determined by heating a sample at 105°C, and crude ash by combustion at 550°C. Crude fat was extracted and determined according to the procedure of Bligh and Dyer.[3] Free amino acids was analyzed on trichloroacetic acid extract by an automatic amino acid analyzer,[4] trimethylamine oxide (TMAO) and trimethylamine (TMA) by the

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*3 S. Arai, T. Kijima, T. Maruyama, H. Maeda, and K. Nose: The abstract paper of the Spring Meeting of Japan. Soc. Sci. Fish., 1984, p. 97.

method of Hashimoto and Okaichi,[5] creatine and creatinine by the picrate method[6] and total extractive nitrogen by the micro-Kjeldahl method. Nucleotides levels were determined by subjecting perchloric acid extract to column chromatography.[7] Fatty acid composition was determined by gas chromatography as described in the previous paper.[4]

Results

Growth of Transplanted Fish

As indicated in Table 1, the body length of transplanted fish is maximal in July. Their body weight increased till June and decreased thereafter. The condition factor was the maximal in May. The transplanted fish were not recaptured after September. The total numbers of recaptured fish were 257 (about 5.1% of the number of transplanted fish). On the other hand, body weight, body length and condition factor of control animals increased through the research period.

Proximate Composition

Table 2 shows the proximate composition of the muscles of transplanted and cultured fish.

In the dorsal muscle of transplanted fish, the moisture content decreased gradually from 80.0% of the initial value of December (at transplantation) to 79.0% in June with the growth of fish, and then increased sharply to 81.5% in August. The moisture content of ventral muscle likewise increased sharply in August. In the cultured fish, however, its content of dorsal muscle was somewhat lower and decreased constantly from the

Table 1. Growth of transplanted and cultured whitefish*1

Specimen	Date of sampling	Body length (cm)	Body weight (g)	Condition factor*2
At transplant				
	Dec. 12, 1983	13.0	30.4	13.84
Recaptured				
1	Feb. 21, 1984	15.6	52.0	13.70
2	Mar. 22	16.9	70.5	14.61
3	Apr. 28	18.0	90.4	15.50
4	May 22	19.8	126.3	16.27
5	Jun. 21	21.7	152.4	14.91
6	Jul. 23	22.1	143.5	13.29
7	Aug. 23	21.6	125.0	12.40
Cultured				
1	Feb. 21, 1984	17.5	76.3	14.24
2	Mar. 22	18.6	97.0	15.07
3	Apr. 28	21.0	140.0	15.12
4	May 22	23.3	192.7	15.23
5	Jun. 21	25.2	244.7	15.29
6	Jul. 23	27.5	318.7	15.32
7	Aug. 23	28.8	371.6	15.56

*1 Average value(n=5—57).

*2 $\frac{\text{Body weight}}{(\text{Body length})^3} \times 1000$

Table 2. Proximate composition of muscle from transplanted and cultured whitefish

(%)

Specimen	Dorsal muscle				Ventral muscle			
	Moisture	Crude protein	Crude fat	Crude ash	Moisture	Crude protein	Crude fat	Crude ash
At transplant								
Dec.	80.0	17.5	1.3	1.1	79.6	17.3	1.7	1.1
Transplanted								
Feb.	79.9	18.6	1.8	1.2	79.7	18.5	2.1	1.2
Mar.	79.8	18.9	1.6	1.1	79.5	18.7	2.3	1.1
Apr.	79.7	19.1	0.8	1.3	79.4	18.8	1.2	1.1
May	79.4	19.3	0.8	1.1	79.1	18.9	1.0	1.1
Jun.	79.0	19.5	0.7	1.1	78.9	19.2	0.8	1.1
Jul.	79.4	19.2	0.6	1.1	79.3	18.9	0.6	1.1
Aug.	81.5	17.5	0.4	1.1	81.2	17.1	0.4	1.1
Cultured								
Feb.	79.6	18.6	1.5	1.1	79.2	18.6	1.9	1.2
Mar.	79.4	19.0	1.6	1.1	79.0	18.9	2.1	1.1
Apr.	79.0	19.1	1.6	1.1	78.8	18.9	2.1	1.1
May	78.7	19.3	1.6	1.1	78.5	19.1	2.1	1.1
Jun.	78.5	19.7	1.6	1.1	78.3	19.6	2.1	1.0
Jul.	78.3	20.1	1.7	1.1	78.1	19.8	2.2	1.0
Aug.	78.1	20.2	1.8	1.1	78.0	20.1	2.3	1.0

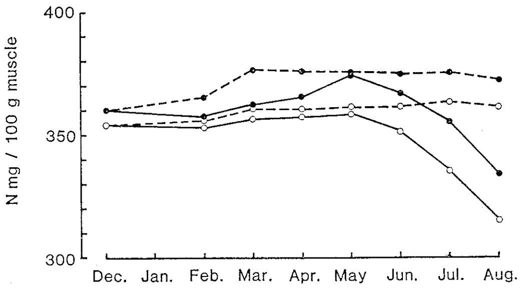

Fig. 1. Variation of nonprotein nitrogen levels in the muscle of transplanted (solid line) and cultured (broken line) whitefish. ●; Dorsal muscle, ○; Ventral muscle.

initial value (80.0% in December) to August (78.1%) with growth.

Crude fat content in the ventral muscle of transplanted fish increased over a period of 3 months after transplantation, and thereafter decreased to 0.4% in August as opposed to the moisture content. In the case of cultured fish, the content was higher in ventral muscle than in dorsal muscle and gradually increased in both dorsal and ventral muscles with growth.

Crude protein content was higher in dorsal muscle than in ventral muscle in both transplanted and cultured fishes. From December to June, the content in transplanted fish increased from 17.5 to 19.5% in dorsal and from 17.3 to 19.2% in ventral muscle, respectively. However, reversed tendency of the content was found from July to August. Thus the content decreased from 19.5 to 17.5 and from 19.2 to 17.1% in dorsal and ventral muscle, respectively. In cultured fish crude protein levels did not significantly differ from those of transplanted fish. The levels showed an increasing trend with growth in both dorsal and ventral muscles.

The content of crude ash ranged from 1.0 to 1.2%, and no difference was observed in the content between dorsal and ventral muscles and also between transplanted and cultured fishes.

Nitrogenous Extracts

Nonprotein nitrogen. Nonprotein nitrogen content is higher by 0.6–6% in dorsal muscle than in ventral muscle as shown in Fig. 1. The content decreased slightly after transplantation, increased till May and decreased markedly (about 11–12% lower than the maximum) until August. In contrast, in cultured fish the level remained almost constant after March.

Except the levels of nonprotein nitrogen the nitrogenous constituents of dorsal muscle showed similar figures to those of ventral muscles. Therefore, only the results obtained from the dorsal muscle are shown in Table 3.

Amino acids. Taurine, glycine, alanine, histidine and anserine were abundant, accounting for 77–86% of the total free amino acids (Table 3). Compared with cultured fish, transplanted fish showed lower levels of proline, hydroxyproline and histidine, and higher levels of alanine and anserine.

Drastic variations in levels were observed with taurine, histidine and anserine in transplanted fish. Taurine decreased gradually till June (68.4% of initial level) with increase in body weight and then increased till August (121% of initial level) with decrease in body weight. Histidine decreased from 140 to 71 mg/100 g muscle in February (50.7% of the initial value), increased to 127 mg in May and decreased again to 16 mg in August. Anserine levels in contrast, increased throughout the experimental period, increasing spectacularly after May. In cultured fish histidine decreased gradually till May and increased thereafter. Taurine and anserine did not show any particular trend.

Nucleotides. As evident from Table 3, the content of inosine-5′-monophosphate (IMP) was abundant, representing 69–78% of the total nucleotides. The content of total nucleotides in transplanted fish did not significantly differ from that of cultured fish.

Creatine and creatinine. Creatine levels in transplanted fish increased gradually till May and decreased thereafter. Creatine levels of transplanted fish were 15–16% higher from February to June and 6–8% higher from July to August than those of cultured fish. On the other hand, creatinine levels of both group were not different.

Fatty Acid Composition

As fatty acid composition of dorsal muscle was very similar to that of ventral muscle, only the results obtained from dorsal muscle are shown in Table 4. As seen from Table 4, $C_{18:1}$ and $C_{16:0}$ are the most abundant followed by $C_{22:6}$, $C_{20:5}$ and $C_{16:1}$. The contents of these five acids accounted for 62.5–78.0% of the total fatty acids. The contents of $C_{18:2}$ and $C_{18:3}$ amounted to 9.3–14.5%. Compared with cultured fish, the levels of $C_{16:0}$, $C_{18:1}$, $C_{18:2}$, $C_{20:1}$, $C_{22:1}$ and $C_{22:6}$ were generally lower in transplanted fish, whereas $C_{14:0}$,

Table 3. Nitrogenous constituents in the extracts from dorsal muscle of transplanted and cultured whitefish

(mg/100 g muscle)

	At trans-plant	Transplanted							Cultured						
	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Amino acids:															
o-Phosphoserine	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Taurine	76	75	74	64	53	52	60	92	83	72	117	95	84	65	93
o-Phospho-ethanolamine	+	+	1	+	1	+	2	+	+	1	+	+	+	+	+
Hydroxyproline	20	4	2	3	6	3	2	—	19	21	18	6	23	15	9
Aspartic acid	3	3	3	1	1	1	2	3	3	2	2	1	1	1	1
Threonine	18	20	9	12	13	8	8	9	19	14	17	7	8	6	7
Serine	22	19	11	9	12	30	26	8	23	27	22	19	22	15	8
Glutamic acid	25	12	12	8	14	24	23	26	23	25	26	32	31	23	27
Glutamine	—	—	—	+	+	—	—	+	—	+	+	1	1	4	3
Sarcosine	—	—	+	+	+	+	—	—	—	+	+	2	—	—	—
Proline	30	18	6	7	12	5	5	6	33	25	32	5	14	6	11
α-Aminoadipic acid	1	+	+	1	+	+	1	3	1	1	1	1	1	+	1
Glycine	95	112	130	135	115	166	140	118	101	119	130	145	140	135	97
Alanine	15	64	40	40	39	32	35	45	16	23	15	23	14	14	15
α-Amino-*n*-butyric acid	1	2	2	1	1	1	1	2	1	1	1	1	1	1	1
Valine	5	5	4	7	6	4	5	7	6	5	6	4	4	3	4
Cystine	+	+	—	1	—	—	—	1	+	—	—	+	—	—	—
Methionine	+	+	1	1	1	2	1	2	+	1	1	1	1	1	1
Cystathionine	6	10	2	9	3	+	1	2	6	4	6	1	3	1	1
Isoleucine	2	3	2	4	3	3	3	4	2	2	2	2	2	2	2
Leucine	5	4	4	6	5	5	5	4	5	4	5	3	4	3	4
Tyrosine	2	2	2	5	3	1	2	2	2	2	1	1	1	1	2
Phenylalanine	2	1	2	3	3	2	2	1	2	2	2	1	2	1	2
β-Alanine	3	9	8	11	7	6	7	2	3	2	3	5	3	5	5
β-Amino-iso-butyric acid	1	1	1	2	2	1	1	+	1	+	1	1	+	+	1

Table 3. (Continued)

(mg/100 g muscle)

	At transplant	Transplanted							Cultured						
	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
γ-Aminobutyric acid	1	1	1	1	1	1	1	+	1	1	1	1	+	+	+
Histidine	140	71	84	99	127	63	31	16	135	129	123	79	97	115	104
3-Methylhistidine	—	—	—	1	—	+	+	—	—	—	+	+	—	—	—
1-Methylhistidine	1	1	+	+	1	+	1	1	1	+	+	+	+	+	+
Ethanolamine	3	4	2	3	2	2	2	3	3	2	2	1	3	1	1
Ornithine	3	1	1	1	1	1	1	1	3	2	2	1	1	1	2
Lysine	15	6	6	22	9	11	12	10	14	14	17	12	9	12	15
Arginine	3	1	1	2	1	2	3	2	2	5	6	4	4	5	6
Peptides:															
Carnosine	3	17	3	6	7	—	—	—	2	3	1	2	1	4	3
Anserine	130	168	186	192	201	236	271	280	135	154	158	175	160	172	183
Nucleotides:															
Inosine+ Hypoxanthine*	13	37	35	46	43	41	60	70	16	12	15	13	10	15	15
IMP	200	187	180	175	189	192	180	160	195	203	199	197	205	201	203
AMP	11	9	10	11	15	12	8	2	10	13	12	9	11	7	12
ADP	8	8	7	9	10	6	5	—	6	9	7	10	11	6	10
Other basis:															
TMA	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
TMAO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Creatine	370	428	436	437	443	425	415	403	373	377	376	385	388	385	379
Creatinine	35	40	32	32	27	29	29	30	39	30	26	24	28	25	25
NH_3	9	8	10	10	10	10	10	8	9	11	12	10	11	9	10
Total extractive nitrogen	360	357	362	365	374	367	355	334	365	376	375	375	374	375	372
Nitrogen recovered (%)	83.5	91.2	90.8	92.3	92.1	91.3	94.0	96.7	83.3	81.4	81.6	80.2	81.2	80.2	80.6

*Expressed as Hypoxanthine.

Table 4. Fatty acid composition of lipid extracted from dorsal muscle of transplanted and cultured whitefish

(%)

Fatty acid	At transplant	Transplanted							Cultured						
	Dec.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
14:0	2.0	2.3	2.2	2.3	2.8	3.0	2.7	1.8	2.0	1.9	1.9	1.8	1.9	1.8	2.0
16:0	19.3	19.5	18.4	18.6	18.0	18.5	17.9	20.5	19.2	20.0	19.9	19.7	20.9	20.1	20.3
18:0	4.4	3.8	3.8	3.8	4.0	4.0	3.9	4.6	4.4	4.1	3.8	4.1	3.5	4.2	3.7
20:0	+	+	0.2	0.6	0.6	0.5	0.6	0.3	+	0.2	+	+	0.2	+	0.3
Saturates	25.7	25.6	24.6	25.3	25.4	26.0	25.1	27.2	25.6	26.2	25.6	25.6	26.5	26.1	26.3
16:1	8.7	6.7	6.7	7.6	8.0	7.7	6.7	5.7	8.7	7.0	7.0	5.9	5.7	6.9	8.0
18:1	31.8	21.7	19.1	19.2	19.5	20.6	20.6	20.4	31.8	24.3	24.1	24.5	23.9	27.0	28.9
20:1	5.3	3.4	2.1	2.1	1.7	2.0	2.1	1.8	5.3	3.5	3.7	3.8	3.5	3.5	4.0
22:1	1.2	0.9	0.7	0.8	1.0	0.8	0.6	0.5	1.3	1.3	1.4	2.0	1.6	1.6	1.6
Monoenes	47.0	32.7	28.6	29.7	30.2	31.1	30.0	28.5	47.1	36.1	36.2	36.2	34.7	39.0	42.5
18:2	10.2	6.6	5.1	7.6	7.2	6.7	6.7	7.0	10.2	8.7	9.4	11.1	10.4	9.7	9.6
18:3	1.8	4.2	5.1	6.1	6.9	6.2	6.2	4.7	1.9	1.6	1.6	1.4	1.5	1.4	1.4
18:4	1.1	3.4	5.3	4.3	4.1	5.2	3.5	1.6	1.1	0.8	0.9	1.0	0.9	0.9	0.9
20:4	1.2	3.2	3.2	3.6	3.8	3.7	4.2	4.2	1.1	1.3	1.2	1.2	1.1	1.1	1.0
20:5	3.1	8.0	11.0	7.9	8.4	8.5	9.4	8.5	3.2	4.8	5.1	3.6	4.7	4.0	3.1
22:5	0.7	1.4	2.0	1.5	1.8	1.7	1.9	1.5	0.6	1.1	1.3	1.0	1.1	1.0	0.8
22:6	9.2	14.9	15.1	14.0	12.2	10.9	13.0	16.8	9.2	19.4	18.7	18.9	19.1	16.8	14.4
Polyenes	27.3	41.7	46.8	45.0	44.4	42.9	44.9	44.3	27.3	37.7	38.2	38.2	38.8	34.9	31.2
Lipid content	1.3	1.8	1.6	0.8	0.8	0.7	0.6	0.4	1.5	1.6	1.6	1.6	1.6	1.7	1.8

$C_{18:3}$, $C_{18:4}$, $C_{20:4}$ and $C_{20:5}$ were higher in the latter group of fish. In August, however, this trend was reversed in $C_{14:0}$, $C_{16:0}$ and $C_{22:6}$. Thus the contents of monoenes and polyenes were markedly different between transplanted and cultured fish. In transplanted fish the monoenes were lower and polyenes higher in levels than in cultured fish. These differences were apparent after 2 months of transplantation.

Discussion

The transplanted juvenile whitefish grew normally from December through June and its body components changed steadily. The growth, however, was depressed in July through August, with an increase in moisture content and decreases in crude protein, lipid and total extractive nitrogen. The fish recaptured in July and August had little or no stomach contents. The water temperature in July and August of this year (16.2–24.8°C at 20 m deep) was markedly above that of the usual year (9.8–9.9°C at 20 m deep), possibly resulting in the loss of feeding activity.

Wild fish, generally, has higher moisture and lower lipid levels than cultured fish, probably as a result of limited food supply. The present data conform these facts. The lipid levels were 0.7–2.3% by wet weight in transplanted fish recaptured from February through June and were 1.5–2.1% in cultured one. These values were consistent with those reported for other whitefish such as Lake whitefish *C. clupeaformis* (0.74–2.47%),[8] Finland cisco *C. albula* (1.8–4.3%),[9] whitefish *C. lavaretus* (4.4–6.2%),[10] and Least cisco *C. sardinella* (2.9–5.7).[10] However, high variability in the value of lipid content has been reported in Armenia whitefish (2–16%),[11] Broad whitefish *C. nasus* (6–15%),[10] *C. peled* (−13%)[10] and Arctic cisco (−15%).[10] Amur whitefish *C. ussuriensis* is known to be a fairly fat fish even soon after spawning (7.5–15.6%).[12] From their observation of lipid levels of 4.3–11.65% in the liver of Lake whitefish from Ontario, Canada, Barnes *et al.*[8] suggested that in species with low muscle lipid, the liver may be the alternative site of lipid storage. In the present study, we did not analyze the lipid levels in the liver because of insufficient sample. Whether or not the liver is a main lipid storage organ in *C. muksun* is still unknown.

Akiyama *et al.*[13] reported that the $C_{18:1}$ content in fingerling chum salmon *Oncorhynchus keta* raised artificially decreased markedly after the liberation to the natural river. This trend was also found in the present study. According to Ando *et al.*[14] monoenoic fatty acids decreased and polyenoic fatty acids (especially $C_{22:6}$) increased during spawning migration of chum salmon. With increasing sexual maturation of salmon and lack of feeding, the iodine value of fat increased. Phospholipids are vital cellular components and are expected to be conserved to the very end. When fat is consumed for energy during starvation, saturated and monoenoic fatty acids are expected to be used at first. Lower levels of monoenoic and higher levels of polyenoic fatty acids of transplanted animals in the present study suggest that a part of storage fat had been consumed even 2 months after transplantation.

Other drastic changes were found in the levels of taurine, histidine and anserine. Taurine levels decreased steadily with growth from December through June and increased when starved in July and August. In the chum salmon fry released to the natural river, taurine levels decreased with growth.[13] This trend was also found in the present study.

It was reported that histidine levels decreased markedly during spawning migration of sockeye salmon *O. nerka* and chum salmon,[15–17] and anserine levels increased slightly.[16,17] Chum salmon fry released to the natural river also showed decreased histidine and increased anserine levels when food was not enough.[13] When starved, the marked drop of histidine levels in carp *Cyprinus carpio*[18] and skipjack tuna *Katsuwonus pelamis*[19] have also been reported. With the decrease in histidine, carnosine levels increased in skipjack tuna.[19] Thus the proportionality of histidine to anserine or carnosine seems to reflect nutritional conditions in these fish. Easily metabolizable histidine may be converted to a corresponding dipeptide anserine or carnosine, which is more stable for metabolism, for the preservation of buffering capacity of muscle.[20] Whether pH of muscle of starved *C. muksun* changed like that of starved cod *Gadus morhua*[21] and chum salmon during spawning migration[17] is not known. To clarify the relationship between the variation in histidine and anserine contents and starvation of whitefish, further studies are now in progress.

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