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On comparison of physiological and biochemical indices in wild and farmed Atlantic salmon

by

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ABSTRACT

Morphophysiological and biochemical indices in wild Atlantic salmon from the Tuloma River during spawning migration and in those farmed in the Barents Sea from seed material to a marketable weight were studied.

External morphological features and indices of internal organs in salmon farmed are similar to those in wild. However, differences in chemical composition of muscular tissue were elucidated: content of moisture is somewhat higher in fish farmed and that of fat is lower compared to wild. Content of protein, extraction of miofibrillar and sarcoplasmic proteins of muscular tissue in fish compared are similar. Total dissolved protein is similar to that in most traditional fishes. Content of carotenoids in wild fish muscles is by 6 times higher than in farmed. Protein of muscular tissue in fish compared is in accordance with a standard protein and answers the needs for indispensable aminoacids.

Biological importance of lipids, determined by a content of polyunsaturated fatty acids is higher in farmed fish compared to wild.

INTRODUCTION

Atlantic salmon Salmo salar L. is not only a valuable commercial species but is of special interest for sea farming. Development of biological technology of this species farming is based on the data on natural biological cycle of growth, studying of dynamics of morphophysiological and biochemical indices at different stages of ontogeny, data on feeding under natural conditions (Martynov, 1983; Shestopal, Martynov, 1985).

The comparisons between wild and farmed fish allow to estimate adequacy of farming conditions and diet, as well as to determine food value for fish farmed.

Distinctions between the farmed and wild fish result not only from differences in food, accessibility of its components for consumption, but from formation of definite meat consistency, its fatness and colour. The last parameters depend on food and regimes of feeding allowing to form muscular tissue in fish farmed with the parameters of density and fatness given, and use of agents containing carotenes - to provide specific colour of meat (Refstie, 1983).

The paper aimed at a comparative analysis for morphophysiological and biochemical indices in wild Atlantic salmon during spawning migration and farmed in the Barents Sea from seed material to a marketable weight.

MATERIAL AND METHODS

Morphophysiological and biochemical indices in wild Atlantic salmon, caught during a spawning run into the Tuloma River (June-July) and in salmon farmed in the Barents Sea from seed material to a marketable weight (October-November) were studied.

In total 24 specimens of wild salmon, including 9 females and 15 males, and 14 specimens of farmed (9 females and 5 males) have been examined.

External morphological features of fish were estimated after Martynov (1985) and fish were aged by scale. Indices of internal organs (Smirnov et al., 1972), chemical composition of muscular tissue (Lazarevsky, 1965) were studied; aminoacidic composition was determined by LKB amino-analyser, fatty acidic composition of lipids was studied by HITACHI chromatograph, carotenoids were determined in lipid extracts of muscular tissue by spectra of absorbtion using SF-26 spectrophotometer (wave length range is from 420 to 450 n.m.(Yarzhombeck, 1970).

RESULTS

External morphological features of Atlantic salmon farmed to a marketable weight (1.5-2.0 kg) have evidenced no distinctions from those in spawning migrants of the Tuloma River (Martynov, 1985). Fish had silver colour, bright gill covers and fins.

Table 1 presents morphophysiological indices for fish compared.

Atlantic salmon farmed reached the same length and weight of body as wild. No distinctions were found in the indices of internal organs of fish examined. Maturation coefficient for wild Atlantic salmon is by 4 times higher compared to the fish farmed.

Age composition of fish species examined was represented by a considerable variety of groups (Table 2). Thus, a group at age 6+2+(40%) predominated in wild fish and 4+1+(61.6) - in fish farmed. Percentage of the group at age 5+1+ was the most similar, i.e. their portion made up 20% in wild fish and 15.4% - in farmed. No age group 3+1+, 4+2+, 5+2+ were found in wild salmon, whereas in fish farmed they were represented by 7.7%, 7.7% and 3.8%, respectively.

Chemical composition of meat of Atlantic salmon farmed in cages is characterized by a higher percentage of moisture in tissue and lower fatness (Table 3).

The indices for protein content, extraction of miofibrillar and sarcoplasmic proteins of muscular tissue of fish compared are similar. Total dissolved protein is similar to that in most traditional fishes (Kizevetter, 1973).

According to the balanced feeding formula the muscular tissue of Atlantic salmon farmed differs insignificantly from that of wild (Table 4) (Pokrovsky, 1976).

Estimation of quality of muscular tissue protein compared to a standard one showed a real value of protein of both farmed and wild salmon (Table 5) (Pokrovsky, 1976).

Colour of meat of fish farmed was pale pink which determined considerable differences in carotenoid content. Compared to the fish farmed they were by 5-6 times higher in wild salmon.

Data on fatty acidic composition of muscular tissue lipids are presented in Table 6.

Total content of saturated acids in lipids of farmed and wild salmon is similar. Essential differences have been elucidated by number of mono- and polyunsaturated fatty acids, i.e. in wild salmon monounsaturated acids are by 1.4 times higher than in fish farmed, whereas in latter - the content of polyunsaturated acids is higher by 1.7 times. Content of docosahexanoic acid in lipids of fish farmed is by 4.5 times higher compared to wild, i.e. only small quantities of arachidic acid were found in salmon farmed, whereas in wild - 4.48%.

DISCUSSION

Atlantic salmon farmed to a marketable weight in the Barents Sea during 2 years do not differ from wild ones by external features and indices for internal organs. Identity of external morphological features was determined by genetics and a lack of differences in the indices for internal organs indicates , probably, absence of extreme factors when farming Atlantic salmon (Smirnov et al., 1972).

Low maturation coefficient of Atlantic salmon farmed, compared to wild prespawning migrants of similar weight may be resulted from most factors. In nature a period of juvenile feeding in the sea varies from 1 to 3 years (Shestopal, Martynov, 1985) and in most portion of fish analysed the freshwater period and period of feeding in the sea essentially exceeded those indices in the main bulk of salmon farmed (Table 2).

Period of Salmo salar farming during 2 years was, probably, insufficient for reaching the specific stage of gonad maturation. Food insufficient by some components as well as the norms and regimes not sutable for feeding could considerably influence a delaying of gonad maturation.

Most distinctions (by 5-6 times) have been elucidated in content of carotenoids in muscles of wild and farmed fish.

Analysing the dynamics of the carotenoids in salmon body during ontogeny Yarzhombeck (1970) estimated the acumulation of carotenoid pigment in muscular tissue to maximum to take place proportionally with increase in weight prior to the gonad maturity stages II and III. Then the carotenoid concentration in muscular tissue remains constant prior to the spawning period when the carotenoids from musculars mobilize in ovaries plus their membranes and skin.

No carotenoid pigments in muscular tissue have been found in the farmed salmon specimens examined and no transferring of carotenoids from musculars to other organs and tissue has been registered which are evidenced by their low concentration in skin. A lack of carotenoids in food should be regarded a single reason for poor colouring of muscular tissue of salmon farmed (Yarzhombeck, 1970; Murayama and Yanaze, 1961).

Probably, a lack of carotenoid pigments in food for Salmonidae results in fractional using of potential ability of fish growth. Supplement of krill and shrimp meal to artificial food contributes to better increments and survival compared to control specimens which consumed food without supplement (Kanidjev, Gerasimchuk,1971; Slepnev et al., 1977; Gamygin et al., 1978; Jahn et al., 1978; Petrova, 1979; Ibragimov, Krasavina, 1982).

10% supplement of shrimp carapace in usual food gives 12-35 mg of astaxantine per 1 kg of dry substance as it was set by the Norwegian specialists (Prospectus of T.Scretting A/C in Stavanger, Norway, 1983-1984).

Norwegian specialists use food with colour agents during a long time which give better and more stable red colour of meat and increase a marketable value of salmon (Refstie, 1983).

Problem of colouring of muscular tissue of Atlantic salmon under the Barents Sea farming conditions has not yet developed and requires additional research.

Such indices for Atlantic salmon farmed as the protein content, extraction of miofibrillar and sarcoplasmic proteins in Atlantic salmon farmed do not differ from those in wild fish.

No distinctions were found when comparing the contents of irreplaceable aminoacids in standard protein and that one of Atlantic salmon farmed, but value of protein in fish examined was shown.

Similar contents of protein in muscular tissue of fish compared indicate the balanced content of protein in food, which ensures its optimum quantity in salmon muscles when farming. Probably, these data prove the point of view of some researchers noting that aminoacidic composition of protein in muscles is relatively stable and insignificantly depends on taxonomic position of fish, pattern of feeding, maturity stages and other ecologophysiological factors (Korzhenko, Novikov, 1967; Bolgova, 1980).

High inheritable differences in fat content are observed in salmon. Due to this index is considered to be easily regulated (Refstie, 1983). Our data on lower content of fat in muscles of salmon farmed compared to that in wild indicate a necessity of additional research for regulating the index mentioned.

Distinctions in fatty acidic relationships between wild and farmed salmon have been registered by most authors (Bolgova et al., 1980; Sidorov, 1983). Comparative analysis for composition of fatty acids in wild and farmed young salmon, taken for analysis in the same time and adapted to similar temperatures elucidated a low content of linolenate in food and lipids of farmed juveniles. Lipid content in muscles and liver of farming fish is determined by the relationship between the fatty acids in lipids of food. The distinctions elucidated in composition of mono- and polyunsaturated fatty acids reflect different physiological fish state. Coefficients of gonad maturity in fish compared prove this. High content of polyunsaturated fatty acids in lipids of fish farmed indicates a high quality of lipid component of food as well as a higher food value of lipids in salmon farmed.

Moisture in muscular tissue of fish farmed, exceeding the index given in wild salmon, also indicates a difference in meat quality.

Thus, the analysis has elucidated a number of distinctions and similarities in morphophysiological and biochemical indices in wild and farmed Atlantic salmon. External morphological indices are similar in fish compared. Such biochemical indices as content of aminoacids in protein, fatty acidic content of lipids show a high food value of salmon farmed. However, lower content of fat, higher percentage of moisture in meat compared to wild fish and pale pink colour of meat show a necessity to study the relationship between food composition, norms and regimes of feeding, supplements of carotine substances and meat quality.

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REFERENCES

BOLGOVA, O.M. 1980. Aminoacidic composition of muscles in wild and farmed young salmon and their food. -In: Biological chemistry of freshwater fishes in Karelia.- Petrozavodsk, 95-107 (in Russian).

CHEMICAL composition of food products. 1976. -Reference book edited by A.A.Pokrovsky.- In: Pischevaya promyshlennost, Moskva, p.227 (in Russian).

IBRAGIMOV, I.I., and KRASAVINA, G.A.1982. Krill meal applecation under tank rearing of carp fry. - In: Sbornik nauchnykh trudov. Vsesoyuznyi N.-I. Institut Prudovogo rybnogo khozyaistva. 34:112-115 (in Russian).

GAMYGIN, E.A., PODOSKIN, A.G., and KANID'EV, A.H. 1978. Krill meal in content of granulated food for trout.- In: Rybnoye khozyaistvo . 10:22-24 (in Russian).

JAHNSEN,T.L., BORCH, O.J., LJUNGGREN, T.A. 1988. Kvalitet pa oppdrettstorsk-effecter av lusvillkar, handtering og lagring. Marked-smulligheter for oppdrettstorsk - Torsk som oppdrettstorsk.-Torsk som oppdrettstorsk Tromsϕ, Norge, 105-143.

JAHN,F., LUKOWIEZ,M.LORZ,R. 1978. Erfahrungen mit Krillmehl jim Forellenfuttur. Praktischer Futterungsversuch. -Fisher und Teichwit, Bd.29 N 4, P. 67-68.

KANID'EV,A.N., GERASIMCHUK, S.I.1971. Krilland mollusks in trout ration.-In: Rybnoye khozyaistvo, 9:20-22 (in Russian).

KIZIVETTER, I.V. 1973. Biological chemistry of raw materials of water origin.- Moskva, Pischevaya promyshlennost, p.411 (in Russian).

KORZHENKO, V.P., NOVIKOV,G.G. 1967. On stability of aminoacidic composition of total muscular proteins in fish. -In: Metabolism and fish biochemistry.-Moskva, 56-92 (in Russian).

LAZAREVSKY,A.A. 1955. Technochemical control in fish-processing industry.-Moskva, Pischepromizdat, p.519 (in Russian).

MARTYNOV,V.G. 1983. Salmon from the Urals tributories of the Pechora. Ecology, morphology, reproduction.- Leningrad, Nauka Press, p.128 (in Russian).

MARTYNOV, V.G. 1985. External morphological variations in Atlantic salmon spawners during spawning migration and spawning. - Problemy izucheniya ratsionalnogo ispolzovaniya i ochrany prirodnykh resursov Belogo morya: Tezisy dokladov regionalnoi konferencii.- Arkhangelsk, 246-248 (in Russian).

MYRAYAMA,S.,JANAZE,M. The Amounts of Chemical Constituents of Eyed Eggs of Rainbow Trout from Various Sources.Bull.Tokai Reg. Fish.Res.L ab.- N31.-P. 42-46.

PETROVA, T.G. 1979. Increased content of krill meal in bester's ration. -In: Sbornik nauchnykh trudov . Vsesoyuznyi N.-I. Institut Prudovogo Rybnogo Khozyaistva. 24:60-65 (in Russian).

REFSTIE,T. Grunnlaget for avlsarbeidet og hvilke avlsmal skal vi ha for norsk og ørret "Fiskeoppdrett 83", Konferanse 2.

SIDOROV, V.S. 1983. Ecological biochemistry of fishes. Lipids. - Leningrad, Nauka Press, p.240 (in Russian).

SLEPNEV, V.A., SHCHERBINA,M.A., IBRAGIMOV, I.I. 1977. Metabolism intensity in carp fry raised on rations with crustacean meal. -Sbornik nauchnykh trudov. Vsesoyuznyi N.-I. Institut Prudovogo Rybnogo Khozyaistva. 18:165-173 (in Russian).

SMIRNOV, W.S., BOZHKO, A.M., RISHKOV, L.P. 1972. Application of morphophysiological indicators method in fish ecology.- Petrozavodsk, Karelia, p. 168 (in Russian).

SHESTOPAL, I.P., MARTYNOV, V.G. 1985. Length, sex, age structures and growth of Atlantic salmon Salmo salar, L. in the Norwegian and Barents Seas. - In: Ekologiya i vosproizvodstvo prokhodnykh lososevyhk ryb v basseinakh Belogo i Barentseva morei.- Murmansk, p.59-73 (in Russian).

TESS informasjon for og foring 1983-1984.

YARZHOMBECK, A.A. 1970. Carotenoids in Salmonidae and their relation to reproduction of these fishes. In: Problems of fish physiology. Trudy VNIRO, 69:234-267 (in Russian).

TABLE 1. Morphophysiological indices for wild and farmed Atlantic salmon*

INDICES	WILD ATLANTIC SALMON		FARMED ATLANTIC SALMON	
	females	males	females	males
Fork length, cm	45,0 - 67,0 54,9	47,0 - 59,5 54,5	52,5-59,0 54,7	54,3-60,5 57,I
Body weight, g	I280 - 2750 I997	I300 - 2900 I902	I5I6-I978 I766	I592-2340 I9I6
Indices, % :				
liver	I,3 - I,7 I,4	I,I - I,8 I,4	I,3-I,9 I,6	I,I-I,7 I,4
Heart	0,I3 - 0,20 0,I7	0,I7 - 0,27 0,I9	0,II-0,I8 0,I3	0,I4-0,20 0,I6
Spleen	0,08 - 0,II 0,I0	0,09-0,23 0,I3	0,08-0,I2 0,09	0,II-0,2I 0,I6
Maturity coefficient, %	0,6 - 5,8 2,56	0,8 - 4,8 2,26	0,46-0,96 0,63	0,I2-0,8 0,44

* Limits of value fluctuations are in numerator; mean values of indeces are in denominator.

TABLE 2. Age composition (% of number of specimens examined) of wild and farmed Atlantic salmon

AGE	WILD	FARMED
3+ 1+	-	7,7
3+ 2+	20	3,8
4+ 1+	20	61,6
4+ 2+	-	7,7
5+ 1+	20	15,4
5+ 2+	-	3,8
6+ 2+	40	-

TABLE 3. Biochemical characteristic of muscular tissue in wild and farmed Atlantic salmon

INDICES	Wild salmon	Farmed salmon
Chemical composition, content, % :		
moisture	69,9	7I,5
protein	2I,3	20,8
rat	7,6	6,3
ash	I,I	I,4
Calorific value,kcal/100 g	I58,5	I44,2
Extraction of protein, % of total protein:		
miofibrillar	I4,I	I7,3
sarcoplasmic	I6,2	I5,5
Content of carotenoids,	0,43	0,07

TABLE 4. Correspondence of main nutrients of salmon to ideal product

INDICES	FARMED SALMON	WILD SALMON
Proteins	48,0	49,0
including animal protein	87,0	88,7
Fat	I5,0	I7,7

TABLE 5. Content of irreplaceable aminoacids in standard protein and protein of Atlantic salmon, % to the total of aminoacids

Aminoacids	Standard protein	Protein of salmon farmed	Protein of wild salmon
Isoleucyn	4,0	4,I	3,6
Leucine	7,0	7,3	8,4
Lysine	5,5	II,4	8,2
Containing sulphur	3,5	3,8	3,3
Aromatic	6,0	7,0	6,4
Threonine	4,0	5,I	5,I
Valine	5,0	4,9	5,3
Tryptophan	I,0	I,0	I,2

TABLE 6. Fatty acidic composition of lipids in muscular tissue of farmed and wild Atlantic salmon (in % to a total)

Fatty acids	Farmed Atlantic salmon	Wild Atlantic salmon
I2:0		0,06
I4:0	3,23	4,66
I5:0	0,65	
I6:0	I6,39	I5,32
I7:0	0,75	
I8:0	3,80	2,30
20:0	0,I2	
I6:I	6,44	6,49
I7:I	0,77	0,66
I8:I	I7,I4	23,9
20:I	5,I6	I6,8I
22:I	3,3I	
24:I	I,08	
I6:3 ω 3	0,39	
I8:3 ω 3	I,70	
I8:2 ω 3	0,33	2,35
I8:2 ω 6	3,65	
20:5 ω 3	6,67	7,76
20:3 ω 3	0,86	
20:2 ω 6	0,40	
2I:5 ω 3	0,32	
22:6 ω 3	I8,09	3,97
24:5 ω 3	0,6I	
Total of		
saturated	24,94	22,37
monounsaturated	33,90	48,I5
polyunsaturated	33,02	I9,82
non-identified	8,I8	I0,I2