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FATTY ACID PROFILE AND MEAT UTILITY OF WILD AND CULTURED ZANDER, *Sander lucioperca* (L.)

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ABSTRACT

In this study, meat utility and fatty acid profiles were compared between the zander living under natural conditions (in a lake) and in cultures, the latter fed either natural food (roach, perch, rudd) or an artificial feed (a commercial pelleted trout feed). The three groups differed in the fat content of their meat, the highest and the lowest fat contents (2.87 and 0.96%, respectively) being shown in the commercial feed-kept and in the wild zander, respectively. Protein and mineral compounds contents showed no significant differences. Muscle lipids of the three groups differed in the total contents of MUFA and PUFA: the lowest MUFA content (21.36%) was typical of the wild zander meat, while the lowest PUFA content (41.06%) was revealed in the commercial feed-fed fish. No differences were detected between the total contents of n-3PUFA, n-6PUFA, and the n-3/n-6 ratio. The content of long-chain n-3 PUFA in the meat was 2-4 times that in the food, while the content of long-chain n-6 PUFA was equal to or lower than that of the food. This suggests that the shorter-chain (C18) n-3 fatty acids become elongated and desaturated in the zander body, which leads to the formation of long-chain acids, particularly DHA.

Key words: zander (*Sander lucioperca*), meat utility, body composition, fatty acids.

INTRODUCTION

The increasing demand for fish in general and stabilisation of marine fish landings have contributed to a widening gap between the demand for fish and supply of fish products. Increase of the fish culture output is assumed to be one of the ways in which the fish supply may be increased [18]. However, it is commonly

accepted that aquaculture will not develop only by expanding the area occupied by culture facilities, but generally by improvement of fish production methods. The improvement should rely on broadened knowledge on fish biology and physiology, and on implementation of increasingly more effective culture and selection programmes as well as the measures aimed at aquatic organism disease prevention. One of the ways in which the production output can be increased is by mastering culture methods and by culturing novel fish species. Research aimed at the potential of fish culture has so far targeted more than 200 species [7]. Of a particular recent interest in fish culture science and practice are percids: the yellow perch, *Perca flavescens* Mitch., European perch, *Perca fluviatilis* L., and walleye *Stizostedion vitreum* Mitch. [4, 13, 16, 22]. Research carried out at the Institute of Inland Fisheries in Olsztyn showed the European zander *Sander lucioperca* (L.) to be a species offering potentially good returns when fed artificial feeds and kept in recirculation-based systems [26]. So far, effects of diet on the zander body composition have not been studied. The meat of cultured fish, fed artificial feed, is known to differ significantly in its composition from that of fish living under natural conditions. The differences involve primarily the lipid content and the fatty acid profiles [11].

The aim of this study was to compare fatty acid profiles and meat utility of zander living under natural conditions and kept in culture, the latter fed either artificial feed or natural food.

MATERIALS AND METHODS

The fish used in the study had been kept in an intensive culture in recirculated water system and fed commercial trout feeds [25]. After the fish attained a mean individual weight of about 550 g (at the age of 13 months), they were screened to select the best fish in terms of condition and appearance of the body. The individuals selected were transferred from the grow-out tanks into basins located in a greenhouse, connected with the recirculation system. The basin stock biomass ranged within 8-10 $kg \cdot m^{-3}$. The fish were divided into two groups. One group was continuing to be fed the pelleted trout feed CLASSIC 7 (TROUVIT, Nutreco Aquaculture, Holland) containing 46% crude protein; 11% raw fat; 21.5% carbohydrates; 9.0% ash; 1.5% cellulose; 1.0% total phosphorus; and 17.0 $MJ \cdot kg^{-1}$ digestible energy. The feed ration ranged from 0.70 to 0.25% stock biomass. Fish of the other group were fed live fish (roach, *Rutilus rutilus* (L.); perch, *Perca fluviatilis* L.; and rudd, *Scardinius erythrophthalmus* (L.)). Fatty acid profiles of the artificial feed and the natural food are shown in Table 1.

Table 1. Fat content (%) and fatty acid composition (% total fatty acids) in the artificial feed and natural food

Component	Artificial feed	Natural food
Fat	10.91	2.75
Fatty acid		
C 14:0	6.53	6.58
C 15:0	0.56	0.96
C 16:0	17.59	18.37
C 16:1	7.04	11.08
C 17:1	0.60	1.29
C 18:0	3.82	4.51
C 18:1 cis 9	12.02	13.14
C 18:1 cis 11	3.02	5.20
C 18:2 n-6	6.63	7.69
C 18:3 n-3	1.35	4.61
C 18:4 n-3	2.24	2.18
C 20:0	0.22	0.29
C 20:1 n-9	6.82	0.46
C 20:2 n-6	0.20	0.41
C 20:4 n-6	0.58	6.86
C 20:4 n-3	0.59	1.52
C 20:5 n-3	9.24	7.09
C 22:1 n-11	7.30	0.12
C 22:1 n-9	0.90	*
C 22:5 n-6	0.26	0.94
C 22:5 n-3	1.01	1.60
C 22:6 n-3	11.48	5.09

* Not found.

At the initial phase of the culture (late June – early October), water temperature ranged within 20-23.9°C. Subsequently the water was cooled down to 10°C (late November). Dissolved oxygen contents in the basin outflow did not decrease below 6.2 mg·l^{-1}; total ammonia nitrogen contents (TAN = NH_4^+-N + NH_3-N) never dropped below 0.35 mg TAN·l^{-1}, while water pH ranged within 7.7-8.1. Placing the fish in a greenhouse made it possible to maintain them under the natural photoperiod.

In mid-November (the fish aged about 17 months), 6 individuals were collected out of each group. Additional 6 individuals of a similar body weight were caught from a natural habitat (Lake Tałty-Ryńskie, Masurian Lake District, northern Poland). The fish were anaesthetised with a solution of PROPISCIN (IFI Olsztyn, Poland) [12]. They were weighed (BW ± 1g) and measured (Lc ± 1 mm). The weight and length data served to calculate the fish condition coefficient K = (BW × 100) / Lc^3. Subsequently, the fish were sacrificed by decapitation, eviscerated (gonads removed), and headed; the fins were cut off, and the carcasses were filleted. The fillets were skinned and all individual parts were weighed. The fillets were minced in a 3 mm aperture diameter meat grinder and assayed for the basic chemical components as well as for the fatty acid profiles.

Determination of basic chemical components

The fish meat water content was determined by drying the samples at 105°C to constant weight; the raw protein content was determined with the Kjeldahl technique, using conversion factor of 6.25; the fat content was determined with the Soxhlet technique, with petroleum ether as a solvent; the total ash content was determined by combusting the samples at 550-600°C [15].

Fatty acid profile

Quantitative and qualitative analyses of fatty acids were performed after muscle lipids were cold-extracted, as described by Folch *et al*. [6]. Fatty acids were methylated with a 100:100:1 chloroform:metanol:sulphuric acid (100:100:1) [17]. Chromatographic separation was performed on an HP 6890 gas chromatograph with flame-ionising detector (FID), on a 30 m 0.32 mm internal diameter capillary column. The liquid phase was made up by Supelcowax 10; the film thickness was 0.25 µm. Conditions of separation were as follows: helium as a gas carrier; flow rate: 1 ml·min^{-1}; detector temperature: 250°C; injector temperature: 225°C; column temperature: 185°C. Detector signals were recorded on a Phillips recorder scaled at 1 mV, at 10 mm min^{-1} tape speed.

The data were subjected to statistical treatment, whereby the standard error of the mean was calculated and significance of differences were tested with the Student-Newman-Keuls test. All the calculations and tests were performed with Microsoft Excel 4.0 and Statistica 6.0 PL computer software.

RESULTS

Data on the basic morphometric characters of the fish studied, summarised in Table 2, show the total length to range within 46.3-50.7 cm. The wild zander, caught from their natural habitat, averaged 1185.1 g individual weight. The mean individual weight of cultured fish fed the artificial feed was 1009.8 g; the differences between the two means were not statistically different, while the mean individual weight of the cultured fish fed natural food was significantly ($p<0.01$) lower (877.7 g). The condition coefficients of the three groups were very similar and ranged within 0.88-0.91.

Table 2. Morphometric characters of the zander studied (mean ± SEM)

Character	Wild zander	Cultured zander	
		fed artificial feed	fed natural food
Total length (cm)	50.7^a±0.91	47.2^a±1.24	46.3^a±1.15
Body weight (g)	1185.1^a±56.59	1009.8^{ab}±40.62	877.7^b±50.37
Condition coefficient	0.91^a±0.04	0.96^a±0.03	0.88^a±0.04

Values in a row denoted with different letters are significantly ($p<0.01$) different.

Analyses performed during the preliminary processing of the fish to obtain skinned fillets showed the individual weight to average 607.00 g and 410.18-485.66 g in the wild and cultured zander, respectively. In addition to fillets, the head (157.80-221.26 g), viscera (97.33-132.00 g), and the vertebral column (80.56-100.87 g) were found to have substantially contributed to the total body weight (Table 3).

Analysis of the basic components the fillets showed the wild zander meat to have the highest (79.96%) water content and the lowest (0.96%) fat content. The lowest water contents and the highest fat contents, 77.17 and 2.87%, respectively, were shown by meat of the cultured fish fed artificial feeds. Differences in water content were significant ($p<0.01$) between the three groups of fish, while significant ($p<0.01$) differences in fat content were detected between the zander fed artificial feed and the remaining groups. The raw protein and mineral compounds contents were similar in all the fish groups (Table 4).

Table 3. Contribution of various body parts to the zander body weight a (g) (mean ± SEM)

Body part	Wild zander	Cultured zander	
		fed artificial feed	fed natural food
Viscera	97.33 ±11.12	132.00 ±10.26	100.85 ±16.96
Gonads	44.22 ±13.15	31.40 ±8.50	32.65 ±12.33
Head	221.26 ±12.21	177.24 ±8.40	157.80 ±12.07
Fins	43.38 ±1.54	34.98 ±0.71	38.48 ±1.36
Vertebral column	100.87 ±5.50	87.28 ±3.34	80.56 ±6.70
Skin	66.45 ±1.64	55.16 ±2.06	52.36 ±3.10
Skinned fillets	607.00 ±26.60	485.66 ±22.20	410.18 ±32.21
Loss	4.59 ±0.71	6.08 ±0.88	4.79 ±1.38

Table 4. Contents of basic components in the zander muscle tissue (%) (mean ± SEM)

Component	Wild zander	Cultured zander	
		fed artificial feed	fed natural food
Water	79.96^{a} ±0.28	77.17^{b} ±0.20	78.67^{c} ±0.20
Protein	18.01^{a} ±0.25	18.81^{a} ±0.20	18.80^{a} ±0.15
Fat	0.96^{a} ±0.07	2.87^{b} ±0.15	1.46^{a} ±0.17
Mineral compounds	1.03^{a} ±0.01	1.05^{a} ±0.01	1.04^{a} ±0.12

Values in a row denoted with different letters are significantly ($p<0.01$) different.

Table 5 shows profiles of fatty acids, isolated from the zander muscle tissue, arranged by retention time, number of carbon atoms, and unsaturation level. Fatty acids with carbon chain length from C 14 to C 22 were identified; the highest contents were typical of docosahexaenoic (DHA, 22:6n-3), palmitic (16:0), and oleic (18:1) acids that jointly accounted for 55.77, 57.46, and 57.46% of the total fatty acid content in the wild, artificial feed-fed cultured, and natural food-fed cultured zander, respectively. In addition, it was in the cultured zander meat that the presence of 22 :1n-11 and erucic (22:1n-9) acids, identified also in the feed offered, was detected (Tables 1 and 5).

Table 5. Fatty acid profiles (% total fatty acids) of zander muscle tissue lipids (mean ± SEM)

Fatty acid	Wild zander	Cultured zander	
		fed artificial feed	fed natural food
C 14:0	2.07^{a} ±0.19	4.05^{b} ±0.14	3.06^{c} ±0.23
C 14:1	0.47^{a} ±0.04	0.15^{b} ±0.01	0.17^{b} ±0.02
C 15:0	0.45^{a} ±0.04	0.42^{a} ±0.01	0.41^{a} ±0.02
C 16:0	19.91^{a} ±0.38	20.24^{a} ±0.34	20.33^{a} ±0.35
C 16:1	5.11^{a} ±0.34	8.33^{a} ±0.57	7.17^{a} ±0.83
C 17:1	0.78^{a} ±0.02	0.71^{a} ±0.01	0.72^{a} ±0.05
C 18:0	5.25^{a} ±0.16	2.68^{b} ±0.15	2.96^{b} ±0.18
C 18:1 cis 9	11.36^{a} ±0.38	16.30^{b} ±0.89	14.48^{ab} ±1.17
C 18:1 cis 11	3.25^{a} ±0.08	2.62^{b} ±0.02	3.26^{a} ±0.18
C 18:2 n-6	3.16^{a} ±0.11	6.09^{a} ±0.80	5.95^{a} ±1.47
C 18:3 n-3	2.78^{a} ±0.20	1.02^{b} ±0.09	1.54^{c} ±0.05
C 18:4 n-3	0.82^{a} ±0.13	1.11^{a} ±0.03	0.72^{a} ±0.10
C 20:0	0.16^{a} ±0.01	0.13^{a} ±0.01	0.12^{a} ±0.01
C 20:1 n-9	0.39^{a} ±0.01	2.03^{b} ±0.05	0.89^{c} ±0.08

Table 5 cont.

1	2	3	4
C 20:2 n-6	0.30[a] ±0.01	0.20[b] ±0.01	0.26[c] ±0.01
C 20:4 n-6	6.85[a] ±0.50	0.93[b] ±0.05	3.29[c] ±0.42
C 20:4 n-3	0.85[a] ±0.09	0.52[a] ±0.02	0.57[a] ±0.06
C 20:5 n-3	7.49[a] ±0.14	8.08[a] ±0.37	7.86[a] ±0.49
C 22:1 n-11	*	1.03[a] ±0.08	0.42[b] ±0.09
C 22:1 n-9	*	0.25[a] ±0.02	0.12[a] ±0.03
C 22:5 n-6	1.65[a] ±0.12	0.38[b] ±0.01	0.80[c] ±0.09
C 22:5 n-3	2.40[a] ±0.16	1.81[a] ±0.11	2.25[a] ±0.11
C 22:6 n-3	24.50[a] ±0.67	20.92[a] ±1.29	22.65[a] ±1.03
Σ SFA	27.84[a] ±0.42	27.52[a] ±0.36	26.88[a] ±0.46
Σ MUFA	21.36[a] ±0.70	31.42[b] ±1.36	27.23[b] ±1.24
Σ PUFA	50.80[a] ±0.79	41.06[b] ±1.27	45.89[a] ±1.05
Σ n-3	38.84[a] ±0.58	33.46[a] ±1.60	35.59[a] ±1.39
Σ n-6	11.96[a] ±0.40	7.60[a] ±0.78	10.30[a] ±1.19
Σ n-3 / Σ n-6	3.25[a] ±0.10	4.40[a] ±0.57	3.46[a] ±0.42

* Not found; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.
Values in a row denoted with different letters are significantly ($p<0.01$) different.

The total content of saturated fatty acids and the total content of unsaturated fatty acids were very similar in the wild and cultured zander, the ratio between the two fatty acid types ranging within 0.37-0.39. Such similarity was absent when the total contents of mono- and polyunsaturated fatty acids (MUFA and PUFA, respectively) were compared. Muscle tissue lipids of the wild zander showed the significantly ($p<0.01$) lower MUFA content (21.36%), the corresponding contents in the cultured zander fed natural and artificial diets being similar and amounting to 27.23 and 31.42%, respectively. The significantly ($p<0.01$) lower PUFA content (41.06%) was typical of the fish kept on the artificial feed, compared to 45.89% in the fish fed natural food and 50.80% in the wild zander.

A comparison of the zander groups in terms of their contents of individual saturated fatty acids showed the palmitic acid contents to be similar in the three groups, while the wild zander lipids contained almost twice as much stearic (18:0) ($p<0.01$) and significantly ($p<0.01$) less miristic (14:0) acids than found in the cultured fish fed natural food. Similar differences were revealed by a comparison between the wild and the cultured zander kept on the artificial feed. On the other hand, the two cultured zander groups differed only in the content of the 14:0 acid, significantly lower ($p<0.01$) as a result of the natural diet.

Relationships between the MUFA contents were as follows. A significantly higher content of miristoleic (14:1) and a significantly lower content of gadoleic (20:1n-9) acids were found in the wild zander meat, compared to the two cultured groups ($p<0.01$). In addition, the wild zander muscles contained less oleic (18:1cis9) and more 18:1cis11 acid, compared to the cultured fish fed artificial feed. The significant ($p<0.01$) difference between the two groups of cultured zander resulted from a higher content of the 18:1cis11 acid and lower contents of the 22:1n-11 and 20:1n-9 acids in the natural food-kept fish. No significant differences were shown in contents of palmitoleic (16:1) and margaroleic (17:1) acids.

Comparisons between the three groups of zander in terms of their PUFA contents showed significant ($p<0.01$) differences in the contents of alpha-linolenic (ALA;18:3n-3), 20:2n-6, arachidonic (AA; 20:4n-6), and 22:5n-6 acids which were higher in the cultured fish, both the artificial feed- and natural food-kept, compared to the wild zander. The cultured fish differed in contents of the following three acids: 20:2n-6, 20:4n-6, and 22:5n-6. Contents of the remaining PUFA, i.e., 18:4n-3, linolic (LA;18:2n-6), eicosapentaenoic (EPA; 20:5n-3), docosapentaenoic (DPA;22:5n-3), and DHA were not significantly different. Similarly, no significant differences were found in the total contents of n-3 and n-6 PUFA and in the n-3/n-6 ratio.

DISCUSSION

The fish body water and fat contents are interrelated, while the protein content remains relatively stable [11]. The food types used in the experiment, i.e., the natural food, similar to the wild zander diet, and the pelleted trout feed, differed in their fat content. The fat content of the artificial feed, almost three times higher than that of the

natural food, contributed to the fat content of the cultured zander fed the commercial feed being twice that of that found in the other fish groups. A tendency towards higher fat contents in meat of fish fed artificial feeds, compared to wild fish, is presumably a result of differing conditions of life, e.g., differences in food availability and quality, mobility, and energy demand.

The results presented show the content of DHA, the most abundant and nutritionally very important fatty acid, was – in the cultured zander lipids - twice as high as that in the artificial feed and four times that in the natural food offered. Native forms of polyunsaturated acids taken up by the fish from the food are subjected to desaturation, a process involving introduction of double bonds into a molecule by desaturases Δ6, Δ5, Δ4, and to chain elongation, mediated by elongases. Freshwater fish are known to be more efficient in terms of desaturation and elongation, compared to marine fish [8, 9, 10, 19, 23]. The results obtained in this study show shorter (C:18) chain n-3 acids in the food to be elongated and desaturated in the zander body, whereby longer-chain polyunsaturated acids, mainly DHA, are formed. The results demonstrate that zander is highly capable of transforming native forms of 18n-3 into long-chain acids, as a result of which the meat has a high DHA content. Similar results were obtained by Xu *et al*. [24] who analysed dietary effects on fatty acid composition in muscles and liver of European perch; they found high DHA contents, compared to the feed used. In addition, in spite of the differences in DHA contents in the foods used, the DHA contents in muscle lipids were similar in all the zander groups examined. It may be presumed that the effect observed was a result of a higher content of the 18:3n-3 acid and n-3 acid precursors in the natural food, and might have also been brought about by the high DHA content in the artificial feed, restricting metabolic conversion of shorter-chain acids to long-chain forms. Similarly, Ahlgren *et al*. [1] reported that, despite a low DHA content in the natural food of grayling (*Thymallus thymallus* L.), its meat DHA level was relatively high, comparable to that obtained with a DHA-rich diet. Such a tendency is confirmed by findings reported by Bp-Young Jeong *et al*. [3] who, when comparing fatty acid composition of the freshwater fish *Plecoglossus altivelis* in individuals living under natural conditions and those fed DHA- and EPA-rich as well as DHA- and EPA-poor commercial diets, found no differences in muscle tissue DHA contents. Buzzi *et al*. [5] demonstrated that the trout liver hepatocyte ability to synthesise 22:6n-3 acids from both 18:3n-3 and 20:5n-3 may be considerably enhanced by elimination of long-chain n-3 PUFA from the fish diet.

A comparison between contents of long-chain n-6 PUFA in foods and in the muscle tissue showed the contents of 22:4n-6 to be unchanged or lower. As demonstrated by *in vitro* studies, n-3 and n-6 PUFA compete for desaturation enzymes, desaturases Δ6 and Δ4 using n-3 PUFA more readily than n-6 PUFA [2, 20, 21].

Regardless of the differences between the three zander groups tested, it should be pointed out that the PUFA contents in the fish studied in this work were higher than those reported by Kołakowska *et al*. [14] from zander inhabiting rivers of north-western Poland. The discrepancy was primarily caused by a higher DHA content. On the other hand, the n-3 PUFA to n-6 PUFA ratio found in this work were lower than those reported by Kołakowska *et al*. [14], but higher than those given by Henderson and Tocher [9] for freshwater fish lipids.

CONCLUSIONS

1. The zander studied showed the muscle tissue water and fat contents to differ; a significantly higher fat contents being typical of the fish fed commercial pelleted feed.
2. The total polyunsaturated fatty acid contents in the meat of wild and cultured zander were similar, the differences involving the total contents of MUFA and PUFA.
3. The zander meat content of DHA, a fatty acid originating in the fish, was high and independent of the food DHA contents; this shows a potential of (18n-3) PUFA to be transformed into more unsaturated long-chain PUFA.

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