CHAPTER III

COMPOSITION OF FARMED AND WILD YELLOW PERCH (*Perca flavescens*)[1]

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Abstract

Fillets from farmed yellow perch (*Perca flavescens*) fed a commercial diet were compared to wild yellow perch fillets. Proximate composition, mineral, fatty acid, and amino acid contents, texture, color, and sensory analyses were determined for both treatments. The data were subjected to one-way ANOVA using the Statistical Analysis System (SAS).

Fat content of farmed yellow perch was significantly higher, while protein content was significantly lower than wild yellow perch. A variety of fatty acids was significantly different between wild and farmed yellow perch; arachidonic acid (20:4 n-6) was significantly higher ($p \leq 0.05$) in wild yellow perch fillets, however no significant differences were found in the total amount of n-3 fatty acids, which was around 30 % of total fatty acids. Docosahexaenoic acid (22:6 n-3, DHA) was the predominant fatty acid in both treatments.

Shear force (total energy/g (J/g)) was higher ($p \leq 0.05$) in wild yellow perch fillets. Color (L*****, a* and b* values) also was significantly different between the two treatments. However, no significant differences were found in flavor between wild and farmed yellow perch.

The objective of this study was to determine if there were differences in sensorial and other properties between wild and farmed yellow perch.

Keywords: Wild; farmed; yellow perch; quality; fatty acid composition; amino-acid composition

1. Introduction

The aquaculture industry faces a significant challenge in attempting to present consumers with a final product resembling the wild fish counterpart and, ideally, a product having improved nutritional values. Wild and farmed fish vary in nutrients (Nettleton and Exler, 1992), sensorial, chemical and physical properties (Lindsay, 1980; Chanmugam et al., 1986; Haard, 1992; Orban et al., 1997; Cox and Karahadian, 1998; Grigorakis et al., 2003), with diet being one of the major factors that affects these properties (Lie, 2001; Kinsella, 1988; Cox and Karahadian, 1998; Rasmussen, 2001; Alsalvar et al., 2002). Fish "quality" has been assessed using various parameters: % yield, drip loss, gaping, texture, color, fat content, fatty acid composition, amino acid composition, mineral content, and among others, microbiological count (Haard, 1992; Rasmussen, 2001; Jankowska et al., 2003).

An important parameter that has attracted the attention of consumers and researchers is the content of n-3 (omega-3) fatty acids in different species of fish (Kinsella, 1988; Chen et al., 1995; George and Bhopal, 1995; Ackman et al., 2002). According to the American Heart Association, n-3 fatty acids have been proven to help in preventing heart disease, by decreasing risk of arrhytmia, thrombosis, lowering plasma triglyceride levels and blood pressure (American Heart Association, 2002). The consumption of fatty fish (200-400 g/day) also reduces asthma, atherosclerosis, arthritis, tumor growth and other diseases (Kinsella, 1988). The fatty acid composition of fish will differ depending on a variety of factors including species, age, freshwater or marine origin, (Ackman, 1989; Steffens, 1997; Tocher, 2002) due to diet, whether they are farmed or wild. Because diet represents the major determining factor influencing fatty acid composition, the aquaculture industry possesses a great tool to beneficially modify the fatty acid profile of fish.

Flavor and other quality aspects of farmed fish may reduce consumer appeal when compared to wild counterparts. This is especially true upon introduction of a new or little known species by the aquaculture industry. One of the most important justifications for improving farmed fish quality is the continuing decline of landings of the major commercial species.

Yellow perch *(Perca flavescens*), a low fat and small sized fish, is a high priority species in the US, most specifically in the Great Lakes area, where demand is high. According to Malison (1999) 70% of yellow perch sales occur in this area. The decline of yellow perch populations

around the 1970 and 1980's in this area stimulated the aquaculture industry to increase yellow perch production to satisfy regional demands. An important issue however, is to determine whether differences exist between wild and farmed fish with respect to their sensorial differences. It is upon this issue that the following research centered attention.

2. **Materials and methods**

2.1 Animals

Fresh wild yellow perch (150 g) were obtained from the Great Lakes area and immediately shipped to the Department of Food Science and Technology at Virginia Polytechnic Institute and State University (Virginia Tech). Upon arrival, fillets were skinned and frozen immediately at -20° C. Farmed yellow perch were obtained from the Virginia Tech Aquaculture Center, where they were grown to 150 g on a commercial diet (Melick, Aquafeeds Inc, Catawassa, PA, USA). The diet provided 42% protein and 16% lipid. Fish were filleted, skinned and frozen pre-rigor at - 20° C.

2.2 Compositional analyses

Fish fillets (n = 3 per treatment) were freeze-dried and subsequently analyzed in triplicate for lipid (Soxhlet method; AOAC, 1990), Kjeldahl protein (AOAC, 1990) and moisture (AOAC, 1990).

2.3 Amino acids

Fish fillets (n = 3 per treatment) were freeze dried and analyzed by the Protein Nutrition Laboratory at Virginia Tech for amino-acid composition by the Waters Pico Tag method, using a free amino acid analysis column (Waters Corporation, Milford, MA, USA), which is a reverse phase silica-based chromatography column (3.9 mm x 300 mm) (Bidlingmeyer et al., 1984). Amino acids were subjected to precolumn derivatization using phenylisothiocyanate (PITC) as the tagging agent. Each sample was homogenized and weighed (0.02 g) in triplicate and placed into 5 mL ampules, adding 6 N HCl (3 mL). Ampules were sealed and autoclaved for 12 h (132º C). Samples were then placed into 5 mL volumetric flasks and brought to volume with 1 mL of internal standard and purified water. A 10 µL aliquot of the sample was derivatized and analyzed (Bidlingmeyer et al., 1984).

2.4 Minerals

Fish fillets were defrosted (n = 3 per treatment) and were digested by wet ashing for the flame emission method (AOAC, 1990). Approximately 4 g of each sample were dried for 2.5 h

at 110º C, digested in concentrated nitric acid and further diluted with hot water to 100 mL. Digestions of each sample and 1 L of the matrix solution were analyzed by the Soil Testing Laboratory at Virginia Tech for mineral composition (Al, Fe, Cu, Mn, Zn, Cr, Ni, As, Se, Cd, Pb, S, Co, Na, Mg, P, K, Ca, Sn, Mo, Ba) using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP) (Spectro Flame Modula Tabletop ICP with autosampler; Fitchburg, MA, USA). Samples were stored at 3º C prior to testing. Minerals were reported as ppm in solution.

2.5 Color

Color was measured in raw fish fillets from each treatment (n = 6 wild/cultured). Three different positions of the fillet (head, center and tail) were measured. Minced fish fillets were also analyzed. Three fillets per treatment were minced with a knife and homogenized; color was measured on minced and whole fillet samples using a Minolta (CR-2000, Japan) colorimeter to determine L***** (white), a* (green to red), and b* (blue to yellow) values.

2.6 Firmness

Shear force was measured using an Instron Universal Testing Machine (model 1101, Canton, MA). The data were reported as total energy (J), using a 500 kg load transducer. Crosshead speed was set as 100 mm/min and a 20% load range was used. Fish fillets from each treatment (n = 12) were defrosted and placed on ice prior to testing. Fish fillets were cut in rectangles to fit a 10-blade Lee-Kramer cell and the weight of each sample was recorded. Fish portions were similar in thickness. The total energy used to penetrate the sample was divided by the sample weight and firmness was reported as total energy per gram of sample.

2.7 Sensory Analysis

A triangle test (Meilgaard et al., 1999) was used to determine an overall difference in flavor between wild and farmed yellow perch fillets. Fillets were minced separately and baked in aluminum foil at (177° C) for 7 min. Approximately 28 g of fish were placed in 28 g cups with lids and served to panelists (n = 40). Test sensitivity parameters were set up to be: $\beta = 0.20$; $\alpha = 0.05$ and $P_d = 30$ % (proportion of distinguishers) (Meilgaard et al., 1999). Each panelist received one triangle test or 3 samples, identified by a three digit code that was randomly chosen and assigned to each sample. A balanced design was used to randomly present the samples to the

panelists. A red light was used to avoid bias and panelists were seated in individual booths. Panelists were chosen from students, faculty and staff from the Food Science and Technology Department at Virginia Tech.

2.8 Fatty Acid Profile

Lipids from three different frozen fillets from each treatment were extracted by the Folch procedure (Folch et al., 1957). Fatty acids were transesterified to methyl esters with 0.5 N NaOH in methanol and 14% boron trifluoride in methanol (Park and Goins, 1994). In addition 120 µg undecenoic acid (Nu-Check Prep) was added prior to methylation as an internal standard.

All samples were analyzed on a 6890N gas chromatograph with a 7683 autoinjector, split/splitless capillary injector and flame ionization detector (Agilent Technologies, Palo Alto, CA, USA). The carrier gas was ultrapure hydrogen, with a gas velocity of 29 cm/sec and flow at 1.4 mL/min. The injection volume was 0.5 µL**,** and a split ratio of 65:1 was used. A Chrompack CP-Sil 88 100 m x 0.25 mm id capillary column was used to separate fatty acid methyl esters (Chrompack, Middleburg, The Netherlands). The temperature program for separation began at 70º C, was held for 1 min, increased to 100º C at 5º C/min, held for 3 min, increased to 175º C at 10º C/min, held for 45 min, increased to 220º C at 5º C/min and held for 15 min. Total analysis time was 86.5 min. Temperatures for injector and detector were 250º C and 300º C, respectively. Data were integrated and quantified using a Chem DataStation (Agilent Technologies, Palo Alto, CA, USA). Fatty acids were reported as total percent of fatty acids.

2.9 Statistical Analysis

All data were subjected to One-way Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS Institute, Cary, NC). Sensory analysis was analyzed according to number of correct responses based on table T8 in Meilgaard et al. (1999).

3. Results and Discussion

Protein and fat content differed between farmed and wild yellow perch (Table 1). Fat content (2.78%) of farmed yellow perch was significantly higher ($p \leq 0.05$), while protein content (92.11%) was significantly lower ($p \leq 0.05$) when compared to wild yellow perch (1.39%, 94.32%, respectively). The results thereby corroborate the finding of others when comparing wild and farmed fish (George and Bophal, 1995; Nettleton and Exler, 1992; Rueda et al., 1997; Alasalvar et al., 2002; Grigorakis et al., 2002; Grigorakis et al., 2003; Orban et al., 2003). Higher lipid content in farmed fish is expected (Haard, 1992) when compared to their wild counterparts due to a variety of factors including availability and type of food, dietary ingredients (commercial diets are usually high in fat content and also include dietary carbohydrate), higher energy consumption in farmed fish when compared to wild fish (Grigorakis et al., 2002); and possible periods of starvation encountered by wild fish (Haard, 1992). In contrast to the present trial, however, Cox and Karahadian (1998) did not find significant differences in lipid contents when comparing wild and farmed yellow perch.

Essential amino acid concentrations did not vary between fish (Table 2), although some non-essential amino acids illustrated significantly higher concentrations ($p \leq 0.05$) in wild yellow perch (tyrosine, serine, arginine and alanine) when compared to farmed yellow perch. The only amino acid found in higher concentrations in farmed yellow perch was glycine. These results resemble those presented by Mai et al. (1980), where the amino acid profile of different freshwater species [white sucker (*Catostomus commersoni*), burbot (*Lota lota*), black crappie (*Pomoxis nigromaculatus*), rainbow trout (*Salmo gairdneri*), walleye pike (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*)] was compared. The primary amino acids detected in wild yellow perch were: glutamic acid, aspartic acid, arginine, lysine, leucine and valine, indicating that the amino acid composition of freshwater fish mimics that of marine fish (Mai et al., 1980). Tidwell et al. (1999) reported amino acid profiles of yellow perch raised at different temperatures and found, like the study herein, that arginine, leucine, and lysine were the major amino acids (glutamic and aspartic acid were not reported). The latter amino acids together with threonine varied with increasing rearing temperatures. While the amino acid profile appears to be unaffected by diet (Shearer, 1994), it has been suggested that free amino acids, may influence fish flavor (Haard, 1992). The influence of amino acid composition on flavor and variations in

amino acid profile caused for example by varying rearing temperatures upon final product quality clearly represents an area deserved of future research.

Mineral content of yellow perch was affected by growing conditions with most macrominerals differing between treatments (Table 3). Farmed yellow perch contained higher magnesium, phosphorus and potassium, while wild yellow perch had significantly higher concentrations of sodium and sulfur ($p \leq 0.05$). Significantly higher concentrations ($p \leq 0.05$) of manganese and lower concentrations of selenium were obtained in farmed yellow perch when compared to wild yellow perch (Table 3). No other differences in mineral content were observed. Mineral content of fish fillets can be influenced by diet. Specifically, in farmed fish, phosphorus is obtained from the protein source present in feed. According to Haard (1992), consumers are interested in mineral content of fish because of a concern for the presence of heavy metals in fish flesh. There is also interest in the delivery of essential minerals (P, Na, K, Mg, Ca, Fe, Zn, Se, Cr, Co, Cu, Mn, Zn). Minerals also might have an influence on fillet flavor, increasing the level of importance on mineral comparisons between wild and farmed fish. Levels of zinc and iron in wild or farmed yellow perch were not as high when compared to other studies (Gordon and Roberts, 1977; Tahvonen et al., 2000; Alasalvar et al., 2002) analyzing a variety of fish. However, lead levels were higher in wild and farmed yellow perch fillets (3.81, 4.15 ppm respectively) when compared to wild and farmed sea bass (0.84, 1.03 ppm in flesh). Cadmium levels were also very similar when compared to sea bass (Alasavar et al., 2002).

The color of wild and farmed yellow perch minced and whole fillets (Table 4) differed ($p \leq 0.05$). Farmed yellow perch were whiter as illustrated by the higher L* values of minced yellow perch. In wild yellow perch fillets a significant difference was observed in the a* value, indicating that wild yellow perch possessed more red hues than farmed fish. The results of the present study concur to the findings of others (Lindsay, 1980; Cox and Karahadian, 1998). The latter authors suggested that farmed yellow perch was whiter possibly due to the presence of a less pronounced vascular system and indeed, in the present study, the vasculature of wild yellow perch fillets was easily noticed. The darker or lower L* values and higher a* values in wild yellow perch could be due to a variety of reasons including but not limited by: lower fat content, blood vasculature, higher deposition of melanin due to dietary effects; or enzymatic reactions from tyrosine (Lindsay, 1980). Interestingly, tyrosine content in wild yellow perch was significantly higher than farmed yellow perch ($p \leq 0.05$; Table 2). Overall however, both wild

and farmed perch can be considered as light in color, which is typical of lean fish due to their high water content (Rahman et al., 1995).

The texture of wild yellow perch (0.53 J/g) was tougher ($p \leq 0.05$) than farmed yellow perch (0.41 J/g). According to Haard (1992), farmed fish are less firm than wild fish, possibly attributed to a higher fat content in farmed fish (Lie, 2001), as well as, higher levels of activity in wild fish, which may improve texture. Texture of fish, also, can be influenced by various factors such as: rigor mortis, postmortem pH, proteolysis, nutritional state of the fish, storage time, water holding capacity, size, and type of muscle protein (Haard, 1992; Lie, 2001; Rasmussen, 2001). Lindsay (1980) and Cox and Karahadian (1998) did not find significant differences between cooked wild and farmed yellow perch fillets during the sensorial evaluation of firmness. In the present study, firmness was not evaluated using sensory analyses.

Sensory analysis between farmed and yellow perch was undertaken in the present study to determine overall difference in flavor. No overall differences ($p > 0.05$) in flavor were found between fish. These results are similar to those found in Lindsay (1980) when comparing deep fried wild and farmed yellow perch. Cox and Karahadian (1998) observed some differences in sweetness and oxidized flavor between butter broiled farmed and wild yellow perch fillets at some stages of storage. Usually, wild and farmed fish can diverge in flavor due to differences in fatty acid profile, oxidation processes, dietary ingredients, mineral and amino acid content (Haard, 1992). Farmed fish are known to express off-flavors. However in this study both treatments had similar flavor, suggesting that the system of rearing (e.g. recirculation versus pond) may be an important determinant with respect to off-flavors development.

Differences in concentration were observed in some of the most important fatty acids of wild and farmed yellow perch (Table 5). Overall, the major fatty acids in both treatments were docosahexaenoic acid (DHA, 22:6n-3), arachidonic acid (20:4n-6), palmitic acid (16:0), stearic acid (18:0), lignoceric acid (24:0), oleic acid (18:1n-9) and linoleic acid (18:2n-6), docosapentaenoic acid (22:5n-3) and palmitoleic acid (16:1n-7). Cox and Karahadian (1998) reported similar major fatty acids in farmed and wild yellow perch fillets. In the present study, a higher concentration of arachidonic, docosapentaenoic acid and DHA was found in both wild and farmed yellow perch when compared to those reported by Cox and Karahadian (1998). Nevertheless, both studies illustrate that wild yellow perch possess higher concentrations of

arachidonic acid ($p \leq 0.05$). According to a variety of authors, freshwater fish contain higher concentrations of arachidonic and linoleic acid when compared to marine fish, possibly due to a dietary effect and saturation and/or elongation mechanisms (Ackman et al., 2002; Tocher, 2003; Steffens, 1997; Jankowska et al., 2003; Orban et al., 2003; Rahman et al., 1995). The higher concentration of arachidonic acid in wild yellow perch could be attributed to the type of diet, yellow perch are exposed in the wild: insect larvae, freshwater algae, crustacean that are rich in linoleic and linolenic acid (Steffens, 1997). The ability of freshwater fish to produce arachidonic acid and DHA through enzymatic desaturation and elongation of linoleic and linolenic acid respectively increases the final concentration of arachadonic acid and DHA (Ackman, 1989, Tocher, 2003). Other studies have shown higher concentrations of arachidonic acid in the wild fish when compared to its farmed counterpart [Carp (Suzuki et al., 1986); pikeperch (Jankowska et al., 2003); seabass (Orban et al., 2003; Alasalvar et al., 2002); gilthead sea bream (Orban et al., 2003; Grigorakis et al., 2002); some Malaysian fresh water fish (Rahman et al., 1995); red porgy (Rueda et al., 1997) and yellow perch (Cox and Karahadian, 1998)]. The high concentration of DHA in the muscle of farmed yellow perch could have been influenced by the content of fish meal (percentage unknown due to commercial formulation; 42% protein) and fish oil (16%) in the commercial diet. Even though levels of n-3 fatty acids were not significantly different ($p > 0.05$) between farmed and wild yellow perch, a difference was observed in the n-3:n-6 ratio ($p \leq 0.05$) with the ratio being lower in wild when compared to farmed yellow perch (Table 5), due to the high content of omega-6 fatty acids in wild yellow perch. It is common for wild freshwater fish to have a low n-3:n-6 ratio (Steffens, 1997). The fact that farmed yellow perch contained a significantly higher ($p \leq 0.05$) n-3:n-6 ratio demonstrated that with appropriate dietary ingredients fatty acid profiles can be beneficially altered in farmed yellow perch. The fatty acid profile of both wild and farmed yellow perch could be considered nutritionally attractive for consumers, but limited research analyzing the beneficial effects of freshwater fish on human health has been undertaken (Steffens, 1997).

4. Conclusions

Environmental conditions and diet influenced different quality properties in both wild and farmed yellow perch. From a sensorial perspective, both fish tasted similarly, overcoming in this way, the farmers challenge of delivering a product with altered flavor. From a nutritional perspective, wild and farmed yellow perch are both low fat fish. However the higher fat content of farmed fish and the higher content of n-3:n-6 ratio could be attractive to consumers interested in low-fat food choices that add potential health benefits. Aquaculturists posses an advantage over fishermen, since farmers can control and manipulate different stages of the rearing, feeding and processing steps to deliver a designer yellow perch to consumers having preferred quality and nutritional compositions.

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TABLES

Table 1. Moisture, fat and protein percentages of wild and farmed freeze dried yellow perch fillets

	Yellow perch fillets	
	% dry weight basis	
Percentage (%)	Wild	Farmed
Moisture (fresh sample)	81.33 ± 1.14[a]	80.60 ± 0.28[a]
Lipid (freeze dried)	1.39 ± 0.20[a]	2.78 ± 0.24[b]
Protein (freeze dried)	94.32 ± 0.36[a]	92.11 ± 1.13[b]

[ab]Means ± standard deviation (n=3) with different letters in the same row are significant different at $p \leq 0.05$

Table 2. Amino acid content of wild and farmed yellow perch fillets

	Wild	Farmed
Amino acids	(g/100g of freeze dried fillet) dry weight basis	
Alanine	4.19 ± 0.05[a]	4.07 ± 0.03[b]
Arginine	5.46 ± 0.08[a]	5.18 ± 0.13[b]
Aspartic acid	7.48 ± 0.13	7.38 ± 0.20
Cysteine	0.26 ± 0.02	0.26 ± 0.01
Glutamic acid	11.60 ± 0.17	11.15 ± 0.26
Glycine	3.00 ± 0.07[a]	3.16 ± 0.03[b]
Histidine	1.77 ± 0.03	1.85 ± 0.05
Isoleucine	4.28 ± 0.25	4.06 ± 0.11
Leucine	6.59 ± 0.37	6.21 ± 0.16
Lysine	8.12 ± 0.99	7.63 ± 0.37
Methionine	2.58 ± 0.08	2.50 ± 0.05
Phenilalanine	3.57 ± 0.37	3.50 ± 0.08
Proline	2.41 ± 0.04	2.38 ± 0.01
Serirne	1.92 ± 0.04[a]	1.83 ± 0.04 [b]
Threonine	2.68 ± 0.06	2.65 ± 0.06
Tyrosine	2.72 ± 0.03[a]	2.54 ± 0.08[b]
Valine	4.10 ± 0.07	4.01 ± 0.09

[ab]Means ± standard deviation with different letters in the same row are significant different at $p \leq 0.05$

Table 3. Mineral concentration in wild and farmed yellow perch fillets

Minerals (ppm dry weight basis)	Yellow Perch	
Micro minerals	Wild	Farmed
Aluminum (Al)	2.44 ± 0.75	3.57 ± 3.33
Iron (Fe)	4.65 ±2.07	4.90 ± 1.22
Copper (Cu)	0.38 ± 0.12	0.45 ± 0.18
Manganese (Mn)	0.16 ± 0.01[a]	0.29 ± 0.07[b]
Zinc (Zn)	7.24 ± 0.53	5.91 ± 1.02
Chromium (Cr)	0.44 ± 0.12	0.39 ± 0.16
Nickel (Ni)	< 0.31	< 0.31
Arsenic (As)	0.99 ± 0.11	1.42 ± 0.38
Selenium (Se)	1.61 ± 0.15[a]	1.20 ± 0.13[b]
Lead (Pb)	3.81 ± 0.46	4.15 ± 0.76
Cadmium (Cd)	0.42 ± 0.30	0.24± 0.27
Cobalt (Co)	0.12 ±0.03	< 0.10
Tin (Sn)	0.74 ± 0.03	1.00 ± 0.18
Molybdenum (Mo)	0.08 ± 0.03	0.01 ± 0.10
Barium (Ba)	0.26 ± 0.03	0.26 ± 0.01
Macro minerals		
Sulfur (S)	2613.51 ± 56.34[a]	2414.87 ± 11.57[b]
Sodium (Na)	501.05 ± 24.04[a]	321.90 ± 16.19[b]
Magnesium (Mg)	219.10 ± 4.98[a]	287.36 ± 9.81[b]
Phosphorus (P)	1645.00 ± 42.09[a]	2078.29 ± 42.40[b]
Potassium (K)	2629.27 ± 56.22[a]	3718.69 ± 39.58[b]
Calcium (Ca)	164.11 ± 22.05[a]	278.88 ± 49.51[b]

[ab]Means ± standard deviation with different letters in the same row are significant different at $p \leq 0.05$

Table 4. Color of minced and whole yellow perch fillets

Color	Yellow Perch minced		Yellow perch fillets	
	Wild	Farmed	Wild	Farmed
L*	40.25 ± 1.69[a]	46.25 ± 4.76[b]	45.74 ± 3.55[a]	46.18 ± 3.19[a]
a*	1.13 ± 1.00[a]	-1.51 ± 0.31[b]	0.75 ± 1.67[b]	-0.78 ± 0.55[a]
b*	5.34 ± 1.14[a]	2.05 ± 1.03[b]	3.13 ± 3.12[a]	2.32 ± 2.52[a]

[ab]Means ± standard deviation (n = 6 per treatment) with different letters in the same row are significant different at $p \leq 0.05$

Table 5. Important fatty acid concentrations of wild and farmed yellow perch fillets

Fatty acid	Yellow Perch fillets	
	Wild	Farmed
	g/100g fatty acids dry weight basis*	
14:0	0.78 ± 0.17	0.85 ± 0.06
16:0	17.5 ± 0.75[a]	20.9 ± 0.79[b]
18:0	4.09 ± 0.19[a]	5.23 ± 0.42[b]
24:0	10.4 ± 1.07	8.91 ± 1.46
16:1n-7	3.41 ± 0.58[a]	2.19 ± 0.13[b]
18:1n-9	7.27 ± 0.81	7.51 ± 1.11
18:2n-6	4.61 ± 1.11	4.43 ± 1.03
18:3n-6	0.29 ± 0.13	0.15 ± 0.03
20:4n-6	7.37 ± 0.74[a]	2.61 ± 0.22[b]
22:4n-6	0.51 ± 0.12[a]	0.18 ± 0.01[b]
18:3n-3	0.29 ± 0.24[a]	0.15 ± 0.05[b]
20:5n-3	0.22 ± 0.05	0.26 ± 0.17
22:5n-3	3.17 ± 0.40[a]	1.41 ± 0.12[b]
22:6n-3	32.3 ± 3.67	39.4 ± 3.86
Saturated fatty acids	33.5 ± 1.42	36.5 ± 1.90
Unsaturated fatty acids	66.5 ± 1.42	63.5 ± 1.90
n-3 fatty acids	36.4 ± 3.67	41.3 ± 3.77
n-6 fatty acids	13.6 ± 1.60[a]	8.26 ± 1.11[b]
n-3:n-6 ratio	2.72 ± 0.55[a]	5.10 ± 1.03[b]

[ab]Means ± standard deviation (n = 3 per treatment) with different letters in the same row are significant different at $p \leq 0.05$

*One or more of the fatty acid concentrations reported in this table might be erroneous (provided by service laboratory). Please refer to published manuscript for correct information.