

Original Article

# Composition of farmed and wild yellow perch (*Perca flavescens*)

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Received 11 October 2004; received in revised form 24 January 2006; accepted 24 January 2006

## Abstract

This study was carried out to determine if there were differences in the chemical, physical and sensorial properties between wild and farmed yellow perch. Fillets from farmed yellow perch (*Perca flavescens*) fed with a commercial diet were compared to wild yellow perch fillets from the Great Lakes of the United States. Mineral, fatty acid and amino acid contents, proximate composition, 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. For example, 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 (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.

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**Keywords:** Wild; Farmed; Yellow perch; *Perca flavescens*; 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 that resembles wild fish and which is ideally a product with 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; Delwiche and Liggett, 2004), with diet being one of the major factors that affects these properties (Lie, 2001; Kinsella, 1988; Cox and Karahadian, 1998; Rasmussen, 2001; Alasalvar 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, microbiological count and others (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 Bophal, 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 arrhythmia, 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, 2003) diet, and whether they are farmed or wild. Diet represents the major determining factor influencing fatty acid composition, and with this the aquaculture

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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 the farmed varieties are compared to their 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 small-sized, low-fat fish, is a high-priority species in the United States, more specifically in the Great Lakes area where demand is high. According to Malison (1999), 70% of yellow perch sales occur in this region. The decline of yellow perch populations during the 1970s and 1980s in this area stimulated the aquaculture industry to increase yellow perch production to satisfy regional demand. An important issue is to determine whether differences exist between wild and farmed fish with respect to their sensorial differences. It is upon this issue that the research in this article centered its attention.

## 2. Materials and methods

### 2.1. Animals

Fresh wild yellow perch (150 g each) were obtained from the Great Lakes area of the United States 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  $-20^{\circ}\text{C}$ . Farmed yellow perch were obtained from the Virginia Tech Aquaculture Center where they were grown to 150 g in a recirculating aquaculture system (RAS). Fish were fed a commercial diet that provided 42% protein and 16% lipid (Melick, Aquafeeds Inc, Catawassa, PA, USA). Fish were then filleted, skinned and frozen at  $-20^{\circ}\text{C}$ .

### 2.2. Compositional analyses

Fish fillets ( $n = 9$  per treatment) were freeze-dried and subsequently analyzed in triplicate for lipid (Soxhlet method; AOAC, 1990), moisture (AOAC, 1990) and Kjeldahl protein, which was calculated using the Kjeldahl nitrogen and conversion factor 6.25 ( $N \times 6.25$ ) (AOAC, 1990).

### 2.3. Amino acids

Fish fillets ( $n = 9$  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. This method uses a free amino acid analysis column (Waters Corporation, Milford, MA, USA), which is a reverse phase silica-based chromatography column (3.9 mm  $\times$  300 mm) (Bidlingmeyer et al., 1984). Amino

acids were subjected to precolumn derivatization using phenylisothiocyanate (PITC) as the tagging agent. Each sample was homogenized, weighed (0.02 g) in triplicate, placed into 5 mL ampules, and 6 N HCl (3 mL) was added. Ampules were sealed and autoclaved for 12 h at  $132^{\circ}\text{C}$ . Samples were then introduced into 5 mL volumetric flasks and brought to volume with 1 mL of internal standard and purified water. A 10  $\mu\text{L}$  aliquot of the sample was derivatized and analyzed (Bidlingmeyer et al., 1984).

### 2.4. Minerals

Fish fillets were defrosted ( $n = 9$  per treatment) and digested by wet ashing for the flame emission method (AOAC, 1990). Approximately 4 g of each sample were dried for 2.5 h at  $110^{\circ}\text{C}$ , 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 and Ba) using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP) (Spectro Flame Modula Tabletop ICP with auto-sampler; Fitchburg, MA, USA). Samples were stored at  $3^{\circ}\text{C}$  prior to testing and minerals were reported as ppm in solution.

### 2.5. Color

Color was measured using a Minolta colorimeter (CR-2000, Japan) to determine  $L^*$  (white),  $a^*$  (green to red), and  $b^*$  (blue to yellow) values in raw fish fillets from each treatment (wild/cultured). Color was measured on both whole and minced fillets. Three different positions were measured on whole fillets of each treatment ( $n = 9$ ) (head, center and tail). Fillets from each treatment were minced with a knife, homogenized and analyzed ( $n = 6$ ).

### 2.6. Firmness

Shear force (model 1101, Instron, Canton, MA) was measured using a 10-blade Lee–Kramer cell and 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, where they were cut in rectangles to fit the Lee–Kramer cell and the weight of each sample was recorded. 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  $Pd = 30\%$  (proportion of distinguishers), according to table T-7 in Meilgaard et al. (1999). Each panelist received one triangle test or three samples, identified by a three-digit code that was randomly chosen and assigned to each sample. A balanced design was also 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 Technology.

### 2.8. Fatty acid profile

Lipids from three different frozen fillets from each treatment ( $n = 9$ ) were extracted by a modified 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  $\mu\text{g}$  of undecenoic acid (Nu-Check Prep) was added prior to methylation as an internal standard.

All samples were analyzed on a 6890 N gas chromatograph with a 7683 auto-injector, 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/s and flow at 1.4 mL/min. The injection volume was 0.5  $\mu\text{L}$ , and a split ratio of 65:1 was used. A Chrompack CP-Sil 88 100 m  $\times$  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 70 °C, was held for 1 min, increased to 100 °C at 5 °C/min, held for 3 min, increased to 175 °C at 10 °C/min, held for 45 min, increased to 220 °C at 5 °C/min and held for 15 min for a total analysis time of 86.5 min. Temperatures for injector and detector were 250 and 300 °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 ( $P \leq 0.05$ ), and

Table 1

Moisture, fat and protein percentages of wild and farmed freeze-dried yellow perch fillets

	Yellow perch fillets (% dry weight basis)	
	Wild	Farmed
Moisture (fresh sample)	81.3 $\pm$ 1.14 <sup>a</sup>	80.6 $\pm$ 0.28 <sup>a</sup>
Lipid (freeze-dried)	1.39 $\pm$ 0.20 <sup>a</sup>	2.78 $\pm$ 0.24 <sup>b</sup>
Protein (freeze-dried)*	94.3 $\pm$ 0.36 <sup>a</sup>	92.1 $\pm$ 1.13 <sup>b</sup>

<sup>a</sup>Means  $\pm$  s.d. ( $n = 9$ ) with different letters in the same row are significant different at  $P \leq 0.05$ .

\*Protein value was calculated as Kjeldahl nitrogen (wild = 15.2; farmed = 14.6 (dry weight basis))  $\times$  6.25 in freeze-dried yellow perch fillets.

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, 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 that arginine, leucine, and lysine were the major amino acids (glutamic and aspartic acid were not reported) in yellow perch raised at different temperatures, similar to the present study. The latter amino acids together with threonine varied with increasing rearing temperatures. While the amino acid profile appears to be unaffected by

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

Amino acids	Yellow Perch (g/100 g of freeze-dried fillet) dry weight basis	
	Wild	Farmed
Alanine	4.19 ± 0.05 <sup>a</sup>	4.07 ± 0.03 <sup>b</sup>
Arginine	5.46 ± 0.08 <sup>a</sup>	5.18 ± 0.13 <sup>b</sup>
Aspartic acid	7.48 ± 0.13 <sup>a</sup>	7.38 ± 0.20 <sup>a</sup>
Cysteine	0.26 ± 0.02 <sup>a</sup>	0.26 ± 0.01 <sup>a</sup>
Glutamic acid	11.6 ± 0.17 <sup>a</sup>	11.2 ± 0.26 <sup>a</sup>
Glycine	3.00 ± 0.07 <sup>a</sup>	3.16 ± 0.03 <sup>b</sup>
Histidine	1.77 ± 0.03 <sup>a</sup>	1.85 ± 0.05 <sup>a</sup>
Isoleucine	4.28 ± 0.25 <sup>a</sup>	4.06 ± 0.11 <sup>a</sup>
Leucine	6.59 ± 0.37 <sup>a</sup>	6.21 ± 0.16 <sup>a</sup>
Lysine	8.12 ± 0.99 <sup>a</sup>	7.63 ± 0.37 <sup>a</sup>
Methionine	2.58 ± 0.08 <sup>a</sup>	2.50 ± 0.05 <sup>a</sup>
Phenylalanine	3.57 ± 0.37 <sup>a</sup>	3.50 ± 0.08 <sup>a</sup>
Proline	2.41 ± 0.04 <sup>a</sup>	2.38 ± 0.01 <sup>a</sup>
Serine	1.92 ± 0.04 <sup>a</sup>	1.83 ± 0.04 <sup>b</sup>
Threonine	2.68 ± 0.06 <sup>a</sup>	2.65 ± 0.06 <sup>a</sup>
Tyrosine	2.72 ± 0.03 <sup>a</sup>	2.54 ± 0.08 <sup>b</sup>
Valine	4.10 ± 0.07 <sup>a</sup>	4.01 ± 0.09 <sup>a</sup>

<sup>a</sup>Means ± s.d. ( $n = 9$ ) with different letters in the same row are significant different at  $P \leq 0.05$ .

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 where 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 and Zn). Minerals also might have an influence on fillet flavor thus 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; Tahvonon 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,

Table 3  
Mineral concentration in wild and farmed yellow perch fillets

Minerals	Yellow Perch	
	Wild	Farmed
<i>Micro-minerals (ppm dry weight basis)</i>		
Aluminum (Al)	2.44 ± 0.75 <sup>a</sup>	3.57 ± 3.33 <sup>a</sup>
Iron (Fe)	4.65 ± 2.07 <sup>a</sup>	4.90 ± 1.22 <sup>a</sup>
Copper (Cu)	0.38 ± 0.12 <sup>a</sup>	0.45 ± 0.18 <sup>a</sup>
Manganese (Mn)	0.16 ± 0.01 <sup>a</sup>	0.29 ± 0.07 <sup>b</sup>
Zinc (Zn)	7.24 ± 0.53 <sup>a</sup>	5.91 ± 1.02 <sup>a</sup>
Chromium (Cr)	0.44 ± 0.12 <sup>a</sup>	0.39 ± 0.16 <sup>a</sup>
Nickel (Ni)	< 0.31 <sup>a</sup>	< 0.31 <sup>a</sup>
Arsenic (As)	0.99 ± 0.11 <sup>a</sup>	1.42 ± 0.38 <sup>a</sup>
Selenium (Se)	1.61 ± 0.15 <sup>a</sup>	1.20 ± 0.13 <sup>b</sup>
Lead (Pb)	3.81 ± 0.46 <sup>a</sup>	4.15 ± 0.76 <sup>a</sup>
Cadmium (Cd)	0.42 ± 0.30 <sup>a</sup>	0.24 ± 0.27 <sup>a</sup>
Cobalt (Co)	0.12 ± 0.03 <sup>a</sup>	< 0.10 <sup>a</sup>
Tin (Sn)	0.74 ± 0.03 <sup>a</sup>	1.00 ± 0.18 <sup>a</sup>
Molybdenum (Mo)	0.08 ± 0.03 <sup>a</sup>	0.01 ± 0.10 <sup>a</sup>
Barium (Ba)	0.26 ± 0.03 <sup>a</sup>	0.26 ± 0.01 <sup>a</sup>
<i>Macro-minerals (mg/g) dry weight basis</i>		
Sulfur (S)	2.61 ± 0.06 <sup>a</sup>	2.41 ± 0.01 <sup>b</sup>
Sodium (Na)	0.50 ± 0.03 <sup>a</sup>	0.32 ± 0.02 <sup>b</sup>
Magnesium (Mg)	0.22 ± 0.01 <sup>a</sup>	0.29 ± 0.01 <sup>b</sup>
Phosphorus (P)	1.64 ± 0.04 <sup>a</sup>	2.08 ± 0.04 <sup>b</sup>
Potassium (K)	2.63 ± 0.06 <sup>a</sup>	3.72 ± 0.04 <sup>b</sup>
Calcium (Ca)	0.16 ± 0.02 <sup>a</sup>	0.28 ± 0.05 <sup>b</sup>

<sup>a</sup>Means ± s.d. ( $n = 9$ ) with different letters in the same row are significant different at  $P \leq 0.05$ .

1.03 ppm in flesh). Cadmium levels were also very similar when compared to sea bass (*Dicentrarchus labrax*) (Alasalvar 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. 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 higher ( $P \leq 0.05$ ) than farmed yellow perch (0.41 J/g). According to Haard (1992), farmed fish are less firm than wild fish

Table 4  
Color of minced and whole yellow perch fillets

Color	Yellow Perch minced		Yellow perch fillets	
	Wild	Farmed	Wild	Farmed
<i>L</i> *	40.3 ± 1.69 <sup>a</sup>	46.3 ± 4.76 <sup>b</sup>	45.7 ± 3.55 <sup>a</sup>	46.2 ± 3.19 <sup>a</sup>
<i>a</i> *	1.13 ± 1.00 <sup>a</sup>	−1.51 ± 0.31 <sup>b</sup>	0.75 ± 1.67 <sup>b</sup>	−0.78 ± 0.55 <sup>a</sup>
<i>b</i> *	5.34 ± 1.14 <sup>a</sup>	2.05 ± 1.03 <sup>b</sup>	3.13 ± 3.12 <sup>a</sup>	2.32 ± 2.52 <sup>a</sup>

<sup>a</sup>Means ± S.D. (*n* = 6 per treatment for minced fillets and *n* = 9 for fillets) with different letters in the same row are significant different at *P* ≤ 0.05.

which could possibly be 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 can also be influenced by various factors such as rigor mortis, post-mortem pH, proteolysis, nutritional state of the fish, storage time, water holding capacity, size, and type of muscle protein (Haard, 1992; Lie, 2001; Rasmussen, 2001). Other studies measured firmness through sensorial evaluations such as Lindsay (1980) and Cox and Karahadian (1998) who did not find significant differences between cooked wild and farmed yellow perch fillets.

Sensory analysis between farmed and yellow perch was undertaken in the present study to determine overall difference in flavor. Overall differences (*P* > 0.05) in flavor were not found between baked fish fillets. Some researchers, that have studied sensorial properties of wild and farmed yellow perch, have prepared them deep fried as eaten in the Great Lakes area (Lindsay, 1980; Delwiche and Liggett, 2004). Lindsay (1980) found no significant differences, when comparing deep fried wild and farmed yellow perch while Delwiche and Liggett (2004) found significant differences between skin on, battered and fried farmed and wild yellow perch fillets. 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.

In the present study, the fillets were baked without added ingredients with the intention of comparing the natural flavor of wild and farmed (RAS) yellow perch. The variations of each study are understandable, since the preparations of the sample for sensorial analysis, age, diet, season, storage conditions of the fillets and other factors might have influenced sensorial properties of the fish for each study differently. In the present study, the lack of significant difference in flavor between baked wild and farmed yellow perch could suggest 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), 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* ≤ 0.05). According to a variety of authors, freshwater fish contain higher concentrations of arachidonic and linoleic acid when compared to marine fish. This may be 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 such as 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 arachidonic acid and DHA (Ackman, 1989; Tocher, 2003). Other studies have shown higher concentrations of arachidonic acid in wild fish when compared to its farmed counterpart [Carp (Suzuki et al., 1986); pikeperch (Jankowska et al.,

Table 5  
Important fatty acids concentration of wild and farmed yellow perch fillets

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

<sup>a</sup>Means ± S.D. (*n* = 9 per treatment) with different letters in the same row are significant different at *P* ≤ 0.05.

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

Important differences were found in some of the quality properties of both wild and farmed yellow perch that could have been influenced by several factors. However, nutrition, feeding regimes and living conditions seem to have influenced the physicochemical properties the most. In the present study, an overall difference in flavor was not found between wild and farmed baked fillets while significant differences were found in texture and color of the raw fillets. Farmed yellow perch showed a significant increase in the fat content and a subsequent higher n-3:n-6 ratio. Despite the increase in fat content, both wild and farmed yellow perch fall under the category of a low fat fish making this fish more specifically the farmed one, an attractive healthy alternative. Aquaculturists possess an advantage over fishermen since farmers can control and manipulate different stages of the rearing, feeding and processing steps to deliver to consumers a designer yellow perch with preferred quality and nutritional compositions.

#### Acknowledgements

This project was partially supported by a grant of the United States Department of Agriculture, Cooperative State Research Education and Extension Service. This work is the result of research supported in part by the NOAA Office of Sea Grant, US Department of Commerce, under Grant no. NA56RG0141 to the Virginia Graduate Marine Science Consortium and the Virginia Sea Grant College Program.

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