CHAPTER IV

CHEMICAL, PHYSICAL AND SENSORIAL DIFFERENCES BETWEEN FARMED YELLOW PERCH (*Perca flavescens*) FED DIETS VARYING IN PROTEIN CONCENTRATION[1]

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ABSTRACT

Groups of yellow perch (*Perca flavescens*) were fed isocaloric diets varying in protein concentrations (38, 45, 55% crude protein; N=2 per dietary treatment) at the Aquaculture Center at Virginia Tech. The lipid content was maintained constant for all diets (10%). Each tank of fish was group weighed at the midpoint and end of the trial. Fish were fed the experimental diets to apparent satiation for a period of four months, at which point they were of market size (> 150 g) and group weighed for the determination of weight gain as a percent gain from initial weight, feed efficiency (grams gained/grams fed) and sampled for biological indices.

There were no significant differences in weight gain (percent increase from initial weight), but feed efficiency ratio values were significantly affected by dietary protein levels ($p < 0.0001$) in fish fed the three experimental diets. Yellow perch minced fillets from fish fed the highest protein concentration possessed more yellow hues than the other treatments ($p \leq 0.05$). Flavor differences were observed between yellow perch fed 45 and 55% crude protein.

KEYWORDS. Yellow perch, dietary protein, sensory, water quality

INTRODUCTION

Yellow perch *(Perca flavescens*), a low fat and small size fish, is a high priority species in the US, most specifically in the Great Lakes area, where the demand is high. The aquaculture industry, with the support of research institutions, is helping with the development of culture methods. Commercial production of yellow perch is based on the pond method, however production with intensive-tank rearing systems also exists (Burden 2004). Research to improve production, commercialization and nutrition of yellow perch are of great interest to the industry and researchers due to the high consumer demand coupled with low natural supply.

One of the most important research areas in aquaculture and fish nutrition is the quantitative determination of the protein requirement in different species and protein requirements of omnivorous fish have been recommended to be around 35-42% (Tacon 1987). Research on the effect of dietary protein on maximum growth in percids, such as yellow perch (Ramseyer and Garling 1998), silver perch (Yang et al. 2002) and Eurasian perch (Fiogbé et al. 1996; Mathis et al. 2003), has shown that the optimal protein concentration ranges between 21-27% (Ramseyer and Garling 1998) and 42-43% (Yang et al. 2002; Fiogbé et al. 1996). Differences in the apparent protein requirement of similar species may be due to differences in experimental design, fish size, available dietary energy and the composition of the specific dietary protein (Wilson 1984). Species-specific protein requirements are extremely important not only to maximize growth, optimize health and formulate cost-effective feeds, but also to reduce the amounts of protein utilized as energy that is subsequently released into the environment in the form of nitrogen.

Protein is the most expensive ingredient of aquafeeds, particularly when fish meal is utilized as the sole, intact protein source (Bassompierre et al. 1997; Watanabe 2002). The type (animal or vegetable) and amount of dietary protein delivered in aquafeeds can influence not only the growth and health of fish, but also metabolites such as ammonia and phosphorus levels in the effluents from the culture system (Yang et al., 2002; Jahan et al., 2003). Therefore, recent research has focused upon identifying alternate protein sources that can be utilized to optimize growth, reduce feed cost, and stabilize ammonia and phosphorus content in water (Cho and Bureau 2001; Rasmussen 2001; Yang et al. 2002; Cheng et al. 2003; Jahan et al. 2003; Francesco et al. 2004; Kaushik et al. 2004). While plant protein sources are typically less expensive than

animal protein sources, they are also generally of lower quality, often lacking essential amino acids such as methionine and lysine. In fact, lysine is often the most limiting amino acid in a majority of vegetable protein sources (Bai and Gatlin 1994). Supplemental dietary lysine has been shown to spare protein in carp feeds as well as lower nitrogen and phosphorus excretion (Viola and Lahav 1991).

Another important, but often overlooked, aspect of dietary protein sources and levels in aquafeeds is their potential impact on final product quality. Fillet quality is affected by the type and amount of nutrients in the feed. It has been shown that high lipid diets impact final product quality (Haard 1992; Rasmussen 2001), however little research has been conducted analyzing the influence of dietary protein on proximate composition of the fillet (Huang et al. 1991; Robinson and Li 1999; Ramseyer and Garling 1998; Al Hafedh 1999; Alvarez-Gonzalez et al. 2001; Kikuchi et al. 1992). As aquafeeds continue to rely upon alternate protein sources for cost effective feed formulations, the impact of these alternate protein sources upon final product quality must be investigated.

The ability to lower dietary protein levels and reduce nitrogen and phosphorus excretion while maintaining optimal weight gain and final product quality would be of tremendous benefit to producers of yellow perch, especially those utilizing recirculating aquaculture systems (RAS). Therefore, the primary objective of this research was to analyze the effects of dietary protein levels not only upon water quality, weight gain, feed efficiency ratio values and biological indices, but also to investigate the impact of these levels upon final product quality of yellow perch fillets.

MATERIALS AND METHODS

Animals and husbandry

The systems used in this study were composed of 4 one cubic meter tanks, connected together as a recirculation aquaculture system (RAS). Each system employed a sump containing Kaldnes media as a biofilter, a bead filter, UV system for sterilization and a protein skimmer. Two systems were randomly assigned to each diet at a stocking rate of 75 fish per tank (300 fish per system). Average initial weight of the yellow perch selected for this study was 60g. Water temperature was maintained at 24 ± 1º C and photoperiod was established to be 12L:12D.

Water temperature and dissolved oxygen (DO) were monitored daily using an YSI-85 Series dissolved oxygen meter (YSI Inc., Yellow Springs, OH, USA). Nitrite and nitrate levels (Hach Inc., Loveland, CO, USA) and total ammonia nitrogen (TAN) were monitored daily by spectrophotometric analysis.

Fish were filleted, skinned and frozen pre-rigor at - 15° C.

Diets and feeding

Three diets providing varying protein concentration (38, 45, and 55%) (Table 1) were formulated and processed at the Aquaculture Center at Virginia Tech. The lipid content was held at 10% for all diets and dextrin was added as needed to maintain diets isocaloric, providing 314 kcals available energy/100 g dry diet. The protein source was menhaden fish meal, however in Diet 1 (38%) a mixture of fish meal and defatted soybean meal (1:1) was used as the protein source to investigate the impact of plant protein inclusion on weight gain, feed efficiency ratio and water quality parameters. Additionally, supplemental lysine (3% of dry diet) was included in Diet 1 with the soybean meal to investigate potential protein sparing in combination with reduction of metabolites due to lower protein levels and alternate protein sources. Fish were fed to apparent satiation twice daily during 4 months by observing feeding behavior and weighing the feed container before and after feeding to calculate daily feed intake. At the end of the feeding trial, fish were group-weighed for determination of weight gain, feed efficiency ratio values and biological indices. Additional samples were obtained for analytical procedures described below.

Compositional Analyses

Fillets from three fish (n = 3 per treatment) were lyophilized and subsequently analyzed on triplicate for lipid % (Soxhlet method), kjeldahl protein % and fiber % (AOAC, 1990).

Firmness

Firmness was measured using a 10-blade Lee-Kramer cell and an Instron Universal Testing Machine (model 1101, Canton, MA), with 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 thawed and placed on ice prior to testing. Fish fillets were cut in rectangles to fit the Lee-Kramer cell and the weight of each sample was recorded. Fish samples were similar in thickness .The total energy used to penetrate the sample was divided by the sample weight and firmness (hardness) was reported as total energy per gram of sample (J/g).

Color

Color was measured in raw minced fish fillets of each treatment (n = 3) before sensory testing. Each fish fillet was minced with a knife until a homogenous sample was obtained. The minced fillet was placed in a Petri plate and measurements were taken in three different parts of the minced fillet. Color was measured using a Minolta (CR-2000, Japan) colorimeter to determine a* (green to red), b* (blue to yellow), and L* (white) values.

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 (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, the gas velocity was 29 cm/sec and the flow at 1.4 ml/min, the injection volume was 0.5µl**,** and a split ratio of 65:1 was used. A Chrompack CP-Sil 88 capillary column (100 m x 0.25mm id) was used to separate fatty acid methyl esters (Chrompack, Middleburg, The Netherlands). Temperature program for separation began at 70º C, held for 1 min, increased to 100 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 minutes. 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 percent of total fatty acids.

Oxidation study

After filleting, fish fillets were shattered packed in plastic (Blue Poly sheet liners (linear low density polyethylene), Frontier Packaging, Inc, Seattle, WA, USA) and stored (-10° C) in waxed cardboard boxes. Thiobarbituric acid reactive substances (TBARS) were measured using a modified method from Spanier and Traylor (1991). TBARS were calculated by the following equation:

Sample TBARS (mg/kg) = Ks x A x 5.0/ sample weight (where A= absorbance of sample.

TBARS were measured every two weeks after day 0 (filleting day) during 12 weeks.

Sensory Analysis

A triangle test (n= 23 α= 0.05, β= 0.20, Pd = 40% (proportion of distinguishers)) (Meeilgaard et al. 1999) was used to determine an overall difference in flavor between fillets of yellow perch fed diets varying protein concentration. Fish fillets of each treatment were minced with a knife separately and baked in aluminum foil at 177° C for 10 min. Approximately 28 g of fish from each treatment were placed in individual plastic (28 g) cups with lids and served to the panelists at room temperature. Each cup represented an individual sample and each panelist received three triangle tests (9 samples). All treatments were compared to each other (fish fed 38 vs. fish fed 45 % dietary protein (triangle test 1); fish fed 38 vs. 55% dietary protein (triangle test 2) and fish fed 45 vs. 55% dietary protein (triangle test 3). Each treatment was assigned with three different and randomly chosen three-digit codes. A balanced design was used to randomly present the samples to the panelists. Red light and individual booths were used to avoid bias. Panelists were chosen from students, faculty and staff from the Food Science and Technology Department at Virginia Polytechnic Institute and State University, Blacksburg, VA.

Statistical Analysis

The data were subjected to One-Way Analysis of Variance (ANOVA) using Jump (JMP®, SAS Institute, Cary, NC). Sensory analysis was analyzed according to number of correct responses based on table T8 in Meilgaard et al (1999).

RESULTS AND DISCUSSION

Variations in dietary protein with a fixed lipid content influenced different biological and quality parameters in yellow perch. Fish fed the three experimental diets showed no significant differences in weight gain, although feed conversion efficiency values were significantly lower in fish fed the 45% CP diet (Table 2). The weight gain data indicate that soybean meal inclusion had no detrimental impact on production when combined with supplemental lysine. Research with other species has shown a positive impact when supplemental lysine has been included in aquafeeds, primarily with carp which have one of the highest lysine requirements of cultured fish (Viola and LaHav 1991). Little research has been conducted determining yellow perch protein requirement, however Fiogbé et al. (1996) determined that Eurasian perch (*Perca fluviatilis*) showed maximum growth at dietary protein levels between 36.8 and 43.6%. Similar results were found by Mathis et al. (2003), who found highest gain weight in Eurasian perch when fed a diet containing 46.6% crude protein. Silver perch (*Bidyanus bidyanus*), when fed different protein concentrations (13-55%), showed maximum growth at 42.15% (Yang et al. 2002). However, Ramseyer and Garling (1998) determined that yellow perch could achieve optimal weight gain with diets providing 21-27% crude protein, as long as those diets supplied a minimum of 22 MJ ME/kg of diet and when the amino acids and carbohydrates were delivered at appropriate amounts in the diets. Diets in the present study were isocaloric, providing 13.1 MJ available energy/kg diet, much lower than those utilized by Ramseyer and Garling (1998). High energy diets are known to yield fatty fillets in a variety of species (Haard 1992; Rasmussen 2001), which in lean fish, such as the yellow perch, might be considered detrimental to final product quality. Impacts of dietary manipulations upon final product quality must be investigated further, not only in yellow perch, but in other popularly cultured aquatic animals as well, as these data are severely lacking.

Data from the present study also indicate that production of yellow perch was not detrimentally affected when the protein level was lowered to 38% crude protein (dry weight basis) in combination with supplemental lysine at 3.0% of dry diet. Increasing the protein level up to 55% CP did not result in significant increases in weight gain, but significantly increased feed conversion efficiency. These higher feed conversion efficiency values must be taken into account when justifying a lower protein diet, such as that utilized in the present study, for yellow

perch production. Clearly, these data indicate the use of aquafeeds containing 50% CP or more are not necessary for optimal production of yellow perch. Additionally, the higher protein diets utilized in the present study produced higher numeric values for total ammonia nitrogen and nitrites, key water quality parameters, especially in RAS. The ability to maintain production characteristics while lowering the levels of dietary animal protein could have dramatic impacts upon feed costs as well. These results could have dramatic impacts upon feed costs, as protein is typically the most expensive dietary component in aquafeeds and must be considered in terms of overall economic viability of yellow perch production.

Water quality (nitrogenous compounds) is affected by excessive amounts of dietary protein and subsequent catabolism of amino acids resulting in high excretion of ammonia (Cho and Bureau 2001). In the present study ammonia nitrites and nitrates levels showed numerically higher concentrations with increasing dietary protein (Table 3; $p > 0.05$), however no significant differences were found. Other studies, however, have concluded that increasing dietary protein significantly increases nitrogenous waste compounds in the culture system and no protein sparing effect has been observed by either increasing carbohydrate or lipid levels (Yang et al. 2002; Mathis et al. 2003). It has been hypothesized that a protein sparing effect by other nutrients (lipid, carbohydrate) could decrease nitrogenous compound production and detrimentally impact water quality (Cho and Bureau 2001; Watanabe 2002; Yang et al. 2002). In the present study, the presence of soybean meal in Diet 1 (38% CP; Table 1) did not significantly influence the amount of nitrogenous compounds produced. Fish fed this diet produced the lowest amount of nitrogenous compounds, but this is attributed to the total amount of protein in the diet and not the type of protein used in the formulation.

Fillet yields ranged between 44-46% but did not vary significantly between dietary treatments ($p > 0.05$; Table 2), most likely due to the similarity of the lipid content in the fillets and textural properties of the fillets. Hardness or firmness of the fillets were very similar for fish fed 38, 45 and 55 % CP (0.37, 0.39, 0.37 J/g respectively; $p > 0.05$). Yield percentages, though, were considered to be high for this species, considering the size of the fish and the fact that other perch species, like American pikeperch, show fillet yields around 40% (Jankowska et al. 2003). Similar results were described by Mathis et al. (2003), who reported fillet yields of 42% for Eurasian perch.

The effect of dietary protein in weight gain is well documented for a variety of species (Yang et al. 2002; Lee et al. 2000; Alvarez-González et al. 2002; Kikuchi et al. 1992); however information on the influence of dietary protein on proximate composition of the muscle or other quality properties is scarce. Varying dietary protein did not affect lipid and protein content ($p > 0.05$; Table 4) in yellow perch fillets. Lipid content of muscle is most affected by amount of dietary lipid or carbohydrates while protein content in muscle is not determined by diet but most likely by the genetic characteristics of each species (Shearer 1994; Rasmussen 2001; Morris 2001). According to Mathis et al. (2003), perch do not store fat in the muscle but in perivisceral tissues and some quality properties of the fillet could be attributed to other factors like size, sex or growth rate and not dietary effects. In the present study, proximate composition was not influenced by varying protein or carbohydrate concentrations but in previous studies by González et al. (2003), which compared wild and farmed yellow perch (commercial size), differences were observed in proximate composition, mineral content, texture, color and fatty acid profile. Quality of fish, (lean or fatty fish) is impacted by dietary ingredients, with lipid having the greatest effect and, second, the amount of carbohydrates.

Protein variations in the diet influenced fish fillet color. Overall, yellow perch fed the highest protein concentration showed higher L* and b* values (white-yellow) when compared to the other fish fillets ($p \leq 0.05$) (Table 5). The level of fish meal inclusion most likely influenced the variations in color. The amount and type of protein source has been observed in other studies to impact color of fish fillets (Oliveira et al. 2004; Francesco et al. 2004; Adelizi et al. 1998; Kaushik et al. 1995). In a previous study (González et al. 2003), wild yellow perch fillets were not as white as farmed yellow perch and a* (1.13) and b*(5.34) values were significantly higher. In the present study, yellow perch fed the highest protein concentration showed even higher b* values (8.20) when compared to those reported for wild yellow perch. Yellowish fillets (high b* values) were obtained in cultured sturgeon (Oliveira et al. 2004) when fed a trout diet (53% CP; 13.5% lipid) which negatively influenced the overall sensory acceptability of the fillets.

The majority of the fatty acids were unaffected by variations in protein concentration (Table 6). The only fatty acids (saturated or unsaturated) that differed between treatments were: 24:0, 18:2n-6, 20:4n-6, 22:4n-6 and 22:5n-3. Yellow perch fed diets containing 55% CP had a higher content of saturated fatty acids ($p \leq 0.05$) when compared to yellow perch fed diets containing 45% CP, which showed a higher content of unsaturated fatty acids ($p \leq 0.05$). However, no

significant differences were found in n-3 or n-6 fatty acids or the ratio of n-3/n-6 fatty acids. These results were not surprising due to the fact that fatty acids are mainly affected by the type and amount of oil added to the diet rather than small variations in protein content and the lipid content of the experimental diets was held constant at 10% (dry weight) across dietary treatments.

Sensory analysis showed no significant differences in overall flavor between fish fed diets containing 38 and 45 % CP and those fed diets containing 38 and 55 % CP. Nevertheless, an overall significant difference in flavor ($p \leq 0.05$) was found between yellow perch fed diets containing 45 and 55 % CP. In an informal preference test, ten panelists were asked to determine which fish sample they preferred the most (yellow perch fed 45 or 55% CP) and 9 out of the 10 panelists preferred fillets of yellow perch fed diets containing 55% CP. The difference in flavor between fish fed 45 and 55% protein might have been influenced by the content of fish meal in the 55% CP diet, delivering not only pigments to the fillets (Table 3) but also flavor and aroma compounds. Another factor that might have influenced the difference in flavor between these two treatments is the significantly higher concentration of unsaturated fatty acids (Table 4) in yellow perch fed 45 % CP. Oxidation of lipids is accelerated when high concentrations of polyunsaturated fatty acids are present (Undeland 2001; Flick et al. 1992). The higher concentration of unsaturated fatty acids might have produced oxidation off-flavors that could have impacted flavor of the fillets from fish fed 45% CP. The sensory analysis was assessed after 6 weeks of storage and at this point the TBARS (Figure 1) between all samples were not significantly different ($p > 0.05$; Figure 1).

The TBARS measured in this study fluctuated between 1.33 and 4.6 (ppm) through out the whole study (12 weeks). Numerically, fillets fed the lowest protein level showed lower TBARS when compared to the other treatments (Figure 1), while fillets from fish fed 45 and 55% dietary protein had the highest TBARS during week 2 and 4 respectively ($p \leq 0.05$). Fish fed the 45% CP diet (highest unsaturated fatty acid content) showed higher TBARS at week 2 ($p \leq 0.05$) when compared to the other two treatments, showing significantly earlier production of malonaldehydes and other thiobarbituric reactive substances, which might have influenced flavor and aroma of fish fed this diet. Overall it was observed that oxidation of the fillets from each treatment behaved similarly during the oxidation study.

CONCLUSIONS

Yellow perch achieved similar weight gain when fed diets containing protein levels ranging from 38 to 55% CP and 10% lipid. The inclusion of soybean meal did not negatively impact production characteristics when combined with supplemental lysine at protein levels lower than normally fed to cultured yellow perch. This has potential to reduce the protein level in aquafeeds designed for yellow perch without negatively impacting performance. Additionally, key water quality parameters such as total ammonia nitrogen, nitrites and nitrates were numerically lower in RAS where the lower protein feeds were fed. This warrants further investigation as the impacts of these reductions on commercial facility production costs must be delineated in terms of economic viability of yellow perch culture.

Variation of dietary protein when lipid is fixed did not influence lipid and protein content of fish fillets, however the variation of dietary protein did impact color and flavor of fish, key parameters of final product quality. Further research needs to address the impact of amino acids in the muscle when fed different protein concentrations and the influence it might have on flavor and resulting final product quality.

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TABLES

Table 1. Ingredients and composition of the three experimental diets fed to yellow perch

Ingredients	Diet 1 (38/10)	Diet 2 (45/10)	Diet 3 (55/10)
	Ingredients g/100g		
Fish meal	32.5	64.1	78.2
Soybean meal	31.6	0	0
Dextrin	18.1	11	1
Lipid	6.7	3.4	2
Mineral	4	4	4
Vitamin	3	3	3
CMC	1	1	1
Lysine HCl	3.1	0	0
Cellufil	0	13.5	10.8
Total	100	100	100

Table 2. Weight gain, feed efficiency and yield % in yellow perch fed diets varying protein concentration: 38 % 45%, and 55%.

	38%	45%	55%
Weight gain[1]	178.9 ± 10.4	200.2 ± 10.9	177.46 ± 25.9
Feed conversion efficiency[2]	2.26 ±0.01[a]	1.82 ± 0.04[b]	2.36 ± 0.01[c]
Yield[3]	44.4 ± 2.62	45.9 ± 1.94	44.8 ± 2.59

[1]Weight gain (% initial weight)

[2]Feed conversion efficiency (g fed/g gained)

[3] Yield % (Fillet wt x 100/total wt).

[abc]Means ± standard deviation (n = 2 per treatment) with different letters in the same row are significantly different at $p \leq 0.05$

Table 3. Water quality indexes of yellow perch fed diets varying protein concentration: 38 %, 45%, and 55%.

	38%	45%	555
Ammonia (mg/L)	0.21 ± 0.12	0.21 ± 0.12	0.24 ± 0.12
Nitrites (mg/L)	0.12 ± 0.06	0.15 ± 0.05	0.26 ± 0.20
Nitrates (mg/L)	30.4 ± 4.86	33.5 ± 7.92	42.7 ± 12.02
Dissolved oxygen (mg/L)	5.38 ± 0.36	5.48 ± 0.32	5.56 ± 0.37
pH	7.34 ± 0.11	7.37 ± 0.24	7.24 ± 0.28

Table 4. Proximate composition of yellow perch fed three diets varying protein concentration: 38 %, 45%, and 55%.

	38%	45%	55%
Crude protein*	92.89 ± 0.94	93.69 ± 0.48	93.05 ± 0.29
Lipid	1.90 ± 0.11	2.07 ± 0.54	1.95 ± 0.18
Fiber (acid)	2.30 ± 0.15[a]	1.49 ± 0.14[b]	2.50 ± 0.15[a]

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

*Values reported on a dry weight basis

Table 5. Color of minced yellow perch fillets fed diets varying protein concentration: 38 %, 45% and 55%.

	Yellow perch fillets		
Color	38%	45%	55%
L*	58.01 ± 3.40[a]	56.10 ± 9.70[a]	69.29 ± 5.40[b]
a*	-2.16 ± 0.70[a]	-2.18 ± 0.50[a]	-0.72 ± 1.30[b]
b*	1.69 ± 2.50[a]	0.22 ± 1.90[a]	8.20 ± 2.20[b]

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

* L = lightness extends from 0 (black) to 100 (white); a* = redness- greenness: extends from a* (green) to + a* (red); b* = yellow-blue: extends from – b* (blue) to + b* (yellow)

Table 6. Selected fatty acid concentrations of yellow perch fed three diets varying protein concentration: 38 %, 45%, and 55%.

Fatty acid	Protein concentrations		
	38%	45%	55%
	% of total fatty acids*		
14:0	1.46 ± 0.21	1.49 ± 0.47	2.00 ± 0.48
16:0	23.5 ± 0.73	22.1 ± 0.76	22.7 ± 0.31
18:0	6.23 ± 0.14	5.49 ± 0.54	5.68 ± 0.59
24:0	10.5 ± 0.59[ab]	9.61 ± 0.86[a]	11.8 ± 1.08[b]
16:1n-7	3.41 ± 0.49	3.67 ± 1.50	4.70 ± 1.23
18:1n-9	6.22 ± 0.59	7.24 ± 1.97	6.74 ± 0.71
18:1n-7	1.51 ± 0.11	1.60 ± 0.25	1.62 ± 0.08
18:2n-6	0.87 ± 0.16[b]	2.84 ± 0.92[a]	1.04 ± 0.39[b]
18:3n-6	0.11 ± 0.02	0.10 ± 0.09	0.12 ± 0.02
20:4n-6	3.43 ± 0.26[ab]	2.44 ± 0.11[a]	3.62 ± 0.63[b]
22:4n-6	0.19 ± 0.03[a]	0.24 ± 0.05[ab]	0.36 ± 0.08[b]
20:5n-3	0.07 ± 0.01	0.06 ± 0.03	0.08 ±0.02
22:5n-3	1.83 ±0.04[b]	1.85 ± 0.17[b]	2.08 ± 0.05[a]
22:6n-3	37.2 ± 1.32	37.4 ± 3.44	33.5 ± 0.57
Saturated fatty acids	42.3 ± 0.41[ab]	39.3 ± 1.65[b]	43.0 ± 1.37[a]
Unsaturated fatty acids	57.5 ± 0.40[ab]	60.7 ± 1.67[b]	57.0 ± 1.35[a]
n-3 fatty acids	39.4 ± 1.27	39.8 ± 3.21	35.9 ± 0.49
n-6 fatty acids	5.28 ± 0.24	6.26 ± 1.07	5.72 ± 0.38
n-3/n-6 ratio	7.46 ± 0.40	6.55 ± 1.72	6.29 ± 0.34

[ab]Means ± standard deviation (n = 3 per treatment) with different letters in the same row are significantly 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.

FIGURES

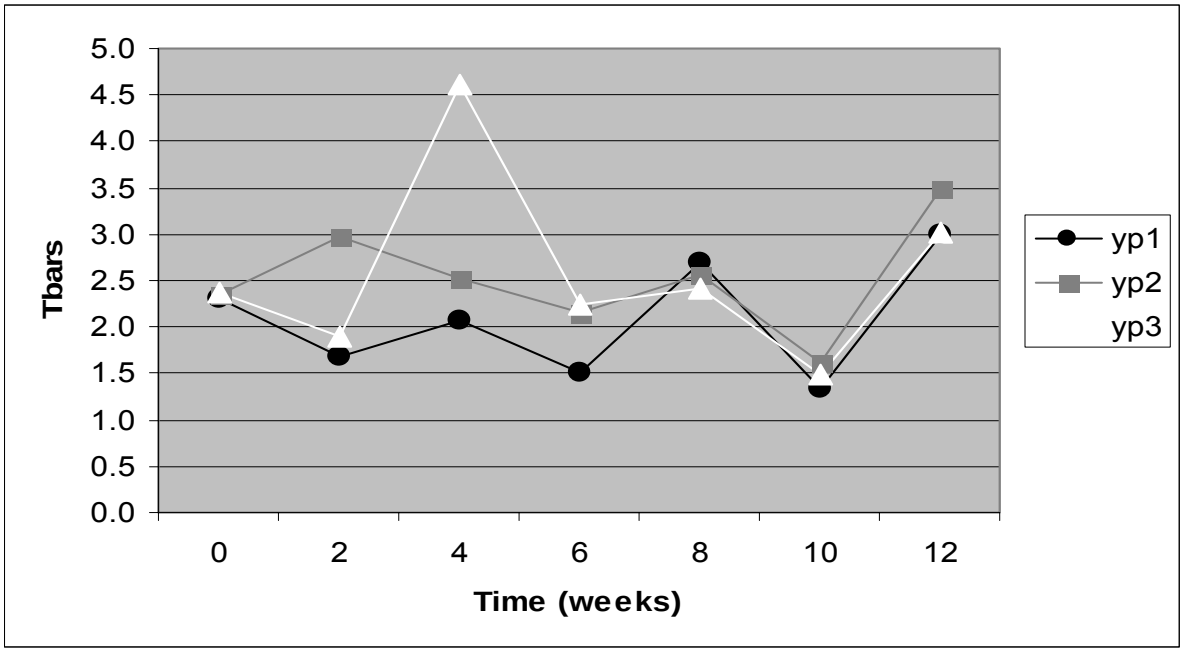

Figure 1. TBARS of yellow perch fillets (-10º C) measured every two weeks during 12 weeks.