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Jacques Rinchard
The College at Brockport, jrinchar@brockport.edu

Renaud Becheret
Ohio State University

Konrad Dabrowski
Ohio State University

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[Communication]

Growth, Survival, and Body Composition of Yellow Perch Juveniles Fed Commercial and Experimental Diets

JACQUES RINCHARD,[1] RENAUD BECHERET, AND KONRAD DABROWSKI*

School of Environment and Natural Resources, Ohio State University, 2021 Coffey Road, Columbus, Ohio 43210, USA

Abstract.—Two experiments were carried out to evaluate the efficacy of commercial and experimental diets on the survival, growth, and body composition of juvenile yellow perch *Perca flavescens*. In both experiments, fish were fed by hand four to five times a day at a restricted ration of up to 90% satiation for 51 d. In experiment 1, fish (initial weight, 87 ± 24 mg) were fed three experimental diets (F1, F2, and a casein–gelatin-based diet) and one commercial diet (Kyowa 400B). In experiment 2, fish (initial weight, 174 ± 56 mg) were fed four experimental diets (Kyowa 400B, INVE-NRD, a starter diet from BioOregon, and a starter diet from Purina). In both experiments, the growth performance of yellow perch juveniles was significantly affected by dietary treatments. In experiment 1, fish fed Kyowa 400B and the casein–gelatin-based diet grew significantly faster than those fed the F1 and F2 diets. However, survival was significantly lower in fish fed the casein–gelatin-based diet than in those fed the other dietary treatments. In experiment 2, fish fed the INVE-NRD diet exhibited the best growth performance. Survival was not affected by dietary treatments. In both experiments, the proximate composition of fish among dietary treatments reflected the proximate composition of the diet. Our results indicate that satisfactory growth of yellow perch juveniles can be achieved using commercial and experimental diets.

The yellow perch *Perca flavescens* has been identified as a species with high potential for aquaculture in the Great Lakes region (Heidinger and Kayes 1986) because of its strong market demand. Moreover, with the decline of wild populations (e.g., in Lake Michigan, Wells 1977; Wilberg et al. 2005), commercial and recreational fisheries have been strictly regulated. The growth performance of yellow perch juveniles has been evaluated under different experimental conditions, such as water temperature, fish density and size, and lighting conditions (Malison and Held 1992; Tidwell et al. 1999; Saoud et al. 2004; Wallat et al. 2005). However, one of the major constraints associated with the culture of yellow perch is the need to wean them to a dry diet at the earliest possible stage.

Several attempts have been made to replace live food organisms with inert or artificial complete diets, but these efforts have resulted in low larval survival, delayed larval development, and larval mortality (Brown et al. 1996). Current aquaculture practices to produce yellow perch fingerlings include using live foods (e.g., algae, protozoans, rotifers, copepods, cladocerans, and brine shrimp *Artemia* spp.) until fish reach a total length [TL] of 15–20 mm and then gradually weaning them onto a dry diet (Malison 2000). Malison and Held (1992) reported that yellow perch harvested from ponds 34 d posthatch (TL, 16.9 mm) and transferred to intensive culture conditions successfully accepted a commercial diet.

The nutritional requirements of yellow perch have not been completely established (Brown and Barrows 2002), and no diet is available for juveniles of this species. However, the fastest practice to wean any species successfully is to use available commercial feeds. Although these diets may not be suitable to provide maximum survival and growth, they may be used to make recommendations. Thus, the objective of this study was to evaluate the efficacy of commercial and experimental diets with respect to the survival, growth performance, and body composition of yellow perch juveniles. These results will also provide baseline information on the nutritional requirements of yellow perch juveniles.

Methods

Six hundred yellow perch juveniles (age, 7–8 weeks) were obtained from Mill Creek Perch Farms LLC (Marysville, Ohio), where they were reared in a 0.4-ha outdoor pond. Juveniles fed on zooplankton (especially rotifers) were collected by seining and immediately transferred under oxygen to the aquaculture laboratory of the School of Natural Resources (Columbus, Ohio). Before experimentation, juveniles were held in a 400-L tank and starved for 2 d.

Two experiments were conducted simultaneously, experiment 1 with juveniles weighing 87 ± 24 mg (mean ± SD) and experiment 2 with juveniles weighing 174 ± 56 mg. In experiment 1, three experimental diets

* Corresponding author: dabrowski.1@osu.edu
[1] Present address: Department of Environmental Science and Biology, State University of New York College at Brockport, 350 New Campus Drive, Brockport, New York 14420, USA.

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TABLE 1.—Formulation of experimental diets F1 and F2 fed to yellow perch juveniles for 51 days in experiment 1 to determine effects on survival, growth, and body composition.

Ingredient	F1 (%)	F2 (%)
Fish meal (79% protein, 9.9% lipid)	57.3	64.0
Fish protein concentrate[a]	12.0	12.0
Soy lecithin	11.0	11.0
Cod liver oil	6.7	0.0
Vitamin mixture[b]	8.0	8.0
Mineral mixture[c]	4.0	4.0
Betaine	1.0	1.0

[a] Concentrate of fish-soluble protein (CPSP 90: crude protein 82–84% by weight; crude lipid, 9–13% by weight), Soprepêche S.A., Boulogne-sur-Mer, France.
[b] Composition (g/100 g): retinyl acetate, 0.034; cholecalciferol, 0.00025; all-racemic α-tocopherol acetate, 0.4; menadione, 0.01; thiamine, 0.1; riboflavin, 0.25; D-calcium pantothenate, 0.5; pyridoxine HCl, 0.1; cyanocobalamin, 0.00006; niacin, 0.001; folic acid, 0.05; biotin, 0.01; and meso-inositol, 10.
[c] Composition (g/100 g): potassium chloride, 0; potassium iodide, 0.004; calcium phosphate dibasic, 50; sodium chloride, 4; cupric citrate, 0.3; zinc sulfate, 0.4; copper sulfate pentahydrate, 0.002; ferrous sulfate, 2; manganese sulfate, 0.3; calcium carbonate, 21.5; magnesium sulfate, 12.4; and sodium fluoride, 0.1.

TABLE 2.—Formulation of the casein–gelatin-based diet fed to yellow perch juveniles for 51 days in experiment 1 to determine effects on survival, growth, and body composition.

Ingredient	%
Casein (vitamin free)	40.00
Gelatin	8.00
Dextrin (80% water soluble)	6.25
Wheat meal	15.00
Fish protein concentrate[a]	5.00
Soy-refined lecithin	14.00
Vitamin mixture[b]	4.00
Mineral mixture[c]	3.00
Ascorbic acid[d]	0.05
Carboxymethylcellulose sodium salt	2.00
L-arginine	0.50
L-methionine	0.40
L-lysine	0.80
Choline chloride (99%)	1.00

[a] Concentrate of fish-soluble protein (CPSP 90: crude protein, 82–84% by weight; crude lipid, 9–13% by weight), Soprepêche S.A., Boulogne-sur-Mer, France.
[b] Roche Performance Premix (Hoffman-La Roche, Inc., Nutley, New Jersey): composition per gram: vitamin A, 2,645.50 IU; vitamin D_3, 220.46 IU; vitamin E, 44.09 IU; vitamin B_{12}, 13 μg; riboflavin, 13.23 mg; niacin, 61.73 mg; D-pantothenic acid, 22.05 mg; menadione, 1.32 mg; folic acid, 1.76 mg; pyridoxine, 4.42 mg; thiamin, 7.95 mg; and D-biotin, 0.31 mg.
[c] Bernhart Tomarelli salt mixture (ICN Pharmaceuticals, Costa Mesa, California), composition (g/100 g): calcium carbonate, 2.1; calcium phosphate dibasic, 73.5; citric acid, 0.227; cupric citrate, 0.046; ferric citrate (16–17% Fe), 0.558; magnesium oxide, 2.5; manganese citrate, 0.835; potassium iodide, 0.001; potassium phosphate dibasic, 8.1; potassium oxide, 6.8; sodium chloride, 3.06; sodium phosphate, 2.14; and zinc citrate, 0.133. Five milligrams of Se in the form of sodium selenite was added per kilogram of the salt mixture.
[d] Phosphitan C (Mg-L-ascorbyl-2-phospahte), Showa Denko K.K., Tokyo, Japan.

and one commercial diet were tested. Two of the experimental diets (F1 and F2) were provided by J. L. Zambonino-Infante (IFREMER, Brest, France) and differed only by their lipid and protein concentrations (Table 1). Both diets were sieved, and particles ranging from 400 to 600 μm were used. The third experimental diet (particle size, 500–710 μm) was a casein–gelatin-based diet in which soy lecithin was used as the only source of lipids (Table 2). Kyowa 400B (BioKyowa Inc., Chesterfield, Missouri) was used as the commercial diet (particle size, 400 μm). In experiment 2, four commercial diets were tested: Kyowa 400B (particle size, 400 μm); an NRD diet from INVE Inc., Salt Lake City, Utah (particle size, 400–600 μm); and two starter diets, one from BioOregon, Inc., Warrenton, Oregon (particle size, 600–850 μm), and one from Purina Mills LLC, St. Louis, Missouri (Aqua Max fry starter: particle size, 600–850 μm). The results of the proximate analysis of each diet are reported in Table 3.

Both experiments were carried out in a semiclosed recirculating-water system composed of twelve 30-L glass aquaria, an Aquanetics Deluxe System Paks (Model 166; Aquanetic Systems, San Diego, California), and a sedimentation tank. Each aquarium was equipped with continuous aeration, and water was supplied at a rate of 1 L/min. Throughout the experiments, water temperature ranged within 19–22°C, whereas photoperiod was held constant (12 h light : 12 h dark). The aquaria were cleaned and mortality monitored daily. For each experiment, fish were randomly distributed among 12 aquaria ($n = 40$ and 17 in experiments 1 and 2, respectively) and assigned to one of the diets with three aquaria per dietary treatment. Fish were fed by hand four to five times a day at a rate of 5% of their body weights for 51 d.

Every 2 weeks, fish from each aquarium were weighed and counted, and the feeding rate was readjusted. At the end of the feeding experiment, survival, weight gain (WG; WG = [{final weight − initial weight} × 100]/initial weight) and specific growth rate (SGR; SGR = [{$\log_e$ final weight − $\log_e$ initial weight} × 100]/d) were calculated. Fish from each aquarium were sacrificed by overdose of tricaine methanesulfonate (>200 mg of tricaine methanesulfonate/L of water) and stored at −80°C for subsequent analysis. Analyses of crude protein, ash, and moisture in the diets and whole-body fish were performed according to standard procedures (AOAC 1995). Dietary and whole-body lipids were extracted and quantified according to the procedure of Folch et al. (1957). Mineral composition of whole-body fish was determined by the inductively coupled plasma emission spectrometry method (ARI-3560 Spectrometer; Ap-

TABLE 3.—Proximate analysis (% of dry matter basis) of the commercial and experimental diets (see text and Tables 1, 2) fed to yellow perch juveniles for 51 days in experiments 1 and 2 to determine effects on survival, growth, and body composition.

Diet	Diet type	Experiment	Crude protein	Crude lipid	Ash	Moisture
Kyowa 400B	Commercial	1, 2	61.9	20.7	13.1	3.3
F1	Experimental	1	57.4	23.8	15.8	5.7
F2	Experimental	1	60.6	18.0	15.7	6.8
Casein–gelatin	Experimental	1	65.0	13.8	15.4	5.7
INVE-NRD	Commercial	2	64.7	18.4	16.0	4.0
BioOregon starter	Commercial	2	59.5	16.7	15.9	16.4
Purina starter	Commercial	2	57.3	20.0	12.4	9.0

plied Research Laboratories, Valencie, California) according to Watson and Isaac (1990).

Results are expressed as means ± SDs ($n = 3$). Homogeneity of variance was verified for all data using Hartley's test (Dagnelie 1975). Data were subjected to analysis of variance (ANOVA) and subsequent comparison of means by the Fisher least-significant-difference test. Percentage data were arcsine transformed before statistical analysis. Differences were accepted as statistically significant when $P < 0.05$.

Results

Experiment 1

The growth of yellow perch juveniles was significantly affected by dietary treatments (Table 4; Figure 1). The first significant difference was observed after 6 weeks of feeding. At the completion of the feeding experiment, specific growth rates of fish fed Kyowa 400B and the casein–gelatin-based diet were significantly higher than those of fish fed the F1 and F2 diets. As a result, the weight gains and final body weights in yellow perch fed Kyowa 400B and the casein–gelatin-based diet were significantly greater than those in fish fed the F1 and F2 diets. Survival was also significantly different among dietary treatments; the highest was observed in yellow perch fed the F2 diet and the lowest in fish fed the casein–gelatin diet.

The proximate composition of fish among dietary treatments reflected the proximate composition of the diet (Table 5). Significantly lower levels of lipids and higher levels of proteins were found in fish fed the F2 diet and the casein–gelatin-based diet. The opposite trend was found in fish fed Kyowa 400B and the F1 diet. The mineral composition of the whole-body fish among dietary treatments is summarized in Table 6. Regardless of the dietary treatment, the whole-body concentrations of potassium and aluminum in yellow perch juveniles were not significantly different. In contrast, the whole-body concentrations of the other minerals were generally significantly lower in fish fed the commercial diet (Kyowa 400B) than in those fed experimental diets (F1, F2, and the casein–gelatin diet).

Experiment 2

The initial weight of yellow perch juveniles was significantly higher in experiment 2 than in experiment 1 (174 ± 56 mg versus 87 ± 24 mg). Each diet promoted growth; however, by week 4 yellow perch fed the INVE-NRD diet were already outperforming those fed the other commercial diets (Figure 1). At the end of the feeding trial, yellow perch juveniles fed the

TABLE 4.—Growth and survival of yellow perch juveniles fed different diets for 51 d in experiments 1 and 2 to determine effects on survival, growth, and body composition. For each experiment, means with different letters in a column are significantly different ($P < 0.05$).

Diet	Final body weight (mg/fish)	Weight gain[a] (%)	Specific growth rate[b] (%/d)	Survival (%)
		Experiment 1		
Kyowa 400B	543 ± 90 z	524 ± 103 z	3.6 ± 0.3 z	60.8 ± 6.3 y
F1	306 ± 16 y	252 ± 19 y	2.5 ± 0.1 y	73.3 ± 6.3 y
F2	270 ± 25 y	211 ± 28 y	2.2 ± 0.2 y	87.5 ± 4.3 z
Casein–gelatin	482 ± 78 z	454 ± 89 z	3.3 ± 0.3 z	35.0 ± 17.5 x
		Experiment 2		
Kyowa 400B	828 ± 189 y	376 ± 109 y	3.0 ± 0.5 y	86.3 ± 3.4 z
INVE-NRD	1,428 ± 243 z	721 ± 139 z	4.1 ± 0.4 z	64.7 ± 17.7 z
BioOregon starter	472 ± 35 x	171 ± 20 x	2.0 ± 0.1 x	84.3 ± 6.8 z
Purina starter	1,084 ± 129 y	523 ± 74 y	3.6 ± 0.2 zy	78.4 ± 9.0 z

[a] Weight gain = [(final weight – initial weight) × 100]/initial weight.
[b] Specific growth rate = [($\log_e$ final weight – $\log_e$ initial weight) × 100]/duration of the experiment in days.

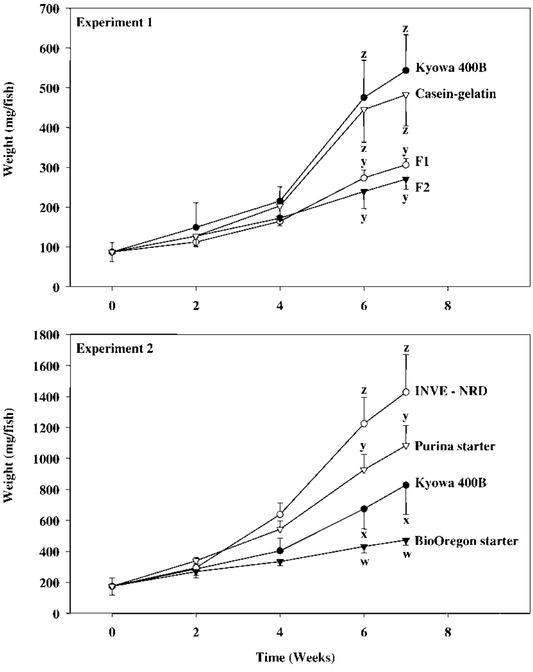

FIGURE 1.—Effect of dietary treatments (see text) on the growth of yellow perch juveniles in experiments 1 and 2. For each experiment, means with different letters at given sampling times are significantly different ($P < 0.05$).

BioOregon starter diet were significantly smaller than those fed the other diets (Table 4). Growth was similar in fish fed Kyowa 400B and the Purina starter diet. Survival was not affected by dietary treatments.

As reported in experiment 1, the whole-body composition of yellow perch juveniles reflected the differences observed in the dietary treatments (Table 5). The whole-body composition of fish fed Kyowa 400B, the INVE-NRD diet, and the Purina starter diet did not differ significantly but was significantly different from that of fish fed the BioOregon starter diet. The yellow perch fed the BioOregon starter diet exhibited the lowest concentration of lipids and the highest concentrations of protein, ash, and moisture. The average concentrations of each mineral in yellow perch fed Kyowa 400B, the INVE-NRD diet, and the Purina starter diet were similar, whereas, except for manganese, they were significantly higher in fish fed the BioOregon starter diet (Table 6).

Discussion

This study demonstrates that yellow perch juveniles can be successfully weaned with commercial and experimental diets at weights of 87 and 174 mg. Although we only weighed yellow perch juveniles before our feeding experiments, their initial lengths were estimated by the length : weight relationship established by Dabrowski et al. (1993) to be approximately 14–18 mm and 18–25 mm in experiments 1 and 2, respectively. Therefore, our data indicate that the yellow perch used in experiment 1 were weaned at a stage (16.9 mm) similar to that proposed by Malison and Held (1992). These authors, who weaned yellow perch to a formulated diet at different sizes (16.9, 32.5, and 42.6 mm), reported that survival was not affected by initial size but that smaller fish were weaned faster than larger ones.

In both experiments, yellow perch juveniles accepted immediately and consumed all of the experimental and commercial diets except for the casein–gelatin-based diet. We did not include in our feeding trials any transition phase in which both live and dry food were offered simultaneously to yellow perch juveniles, as reported for the Eurasian perch *Perca fluviatilis* (Awaiss et al. 1992; Kestemont et al. 1996; Ljunggren et al. 2003). In the first feeding trial, only a few fish accepted the casein–gelatin-based diet, and at the completion of the experiment the mortality rate was high (65%) in this group, mainly because fish were dying of starvation. Although the particle size (500–710 μm) of the casein–

TABLE 5.—Proximate composition of whole-body yellow perch fed different diets for 51 d (percent of dry matter except for moisture, which is percent of wet weight) in experiments 1 and 2 to determine effects on survival, growth, and body composition. For each experiment, means with different letters in a column are significantly different ($P < 0.05$).

Diet	Crude protein	Crude lipid	Ash	Moisture
Experiment 1				
Kyowa 400B	63.3 ± 1.1 y	21.5 ± 2.0 z	15.6 ± 0.3 y	80.6 ± 0.7 x
F1	65.3 ± 0.3 y	20.7 ± 1.0 z	16.7 ± 0.5 y	83.4 ± 0.6 y
F2	71.5 ± 0.9 z	15.3 ± 0.3 y	18.4 ± 0.9 z	85.5 ± 0.9 z
Casein–gelatin	74.0 ± 3.8 z	15.9 ± 1.8 y	15.8 ± 0.7 y	84.8 ± 1.5 zy
Experiment 2				
Kyowa 400B	62.3 ± 1.5 y	22.5 ± 3.1 z	15.7 ± 0.7 z	79.9 ± 1.3 y
INVE-NRD	61.6 ± 0.8 y	22.7 ± 1.7 z	15.2 ± 0.7 z	78.5 ± 1.5 y
BioOregon starter	67.3 ± 2.3 z	17.6 ± 5.7 y	16.5 ± 0.8 z	85.2 ± 1.2 z
Purina starter	61.5 ± 1.0 y	23.9 ± 0.7 z	15.2 ± 0.3 z	78.5 ± 1.3 y

TABLE 6.—Mineral composition (dry-matter basis) of whole-body yellow perch fed different diets for 51 d in experiments 1 and 2 to determine effects on survival, growth, and body composition. For each experiment, means with different letters in a column are significantly different ($P < 0.05$).

Diet	P (mg/g)	K (mg/g)	Ca (mg/g)	Mg (mg/g)	Na (mg/g)	Fe (μg/g)
			Experiment 1			
Kyowa 400B	21.8 ± 0.8 y	12.9 ± 0.5 z	30.8 ± 0.9 y	1.2 ± 0.1 yx	3.7 ± 0.2 w	33.5 ± 1.3 xy
F1	22.7 ± 0.6 y	13.1 ± 0.4 z	32.4 ± 0.9 y	1.3 ± 0.1 y	3.9 ± 0.1 x	36.4 ± 0.7 y
F2	24.3 ± 0.8 z	13.8 ± 0.6 z	34.7 ± 0.9 z	1.4 ± 0.1 z	4.2 ± 0.1 y	40.0 ± 2.5 z
Casein–gelatin	22.5 ± 0.6 y	13.7 ± 0.5 z	32.8 ± 1.6 zy	1.2 ± 0.1 x	4.4 ± 0.1 z	31.7 ± 2.3 x
			Experiment 2			
Kyowa 400B	22.4 ± 0.7 zy	12.6 ± 0.2 zy	31.8 ± 1.2 y	1.2 ± 0.1 y	3.8 ± 0.2 y	34.6 ± 4.9 y
INVE-NRD	20.8 ± 0.5 y	11.9 ± 0.1 y	29.6 ± 0.8 y	1.1 ± 0.1 x	3.5 ± 0.4 y	34.0 ± 6.4 y
BioOregon starter	24.2 ± 1.5 z	13.4 ± 0.8 z	35.6 ± 2.8 z	1.3 ± 0.1 z	4.3 ± 0.2 z	50.6 ± 12.6 z
Purina starter	21.0 ± 0.9 y	11.9 ± 0.8 y	30.0 ± 1.3 y	1.1 ± 0.1 x	3.6 ± 0.1 y	32.3 ± 2.5 y

gelatin diet was larger, it did not affect food utilization because the growth of fish fed the casein–gelatin diet was comparable to that of fish fed a diet of smaller particle size (Kyowa 400B; 400 μm). Poor survival due to lack of palatability has been associated with purified or semipurified diets in which casein is used as the only source of protein (Xiao et al. 1999). In experiment 2, the particle sizes of both the Purina starter diet and the BioOregon starter diet were similar (600–850 μm), but growth was significantly lower in yellow perch juveniles fed BioOregon starter, most likely indicating an effect of dietary composition.

The proximate compositions of the experimental and commercial diets were different and consequently affected the growth of yellow perch. In both feeding trials, the whole-body lipid composition of yellow perch was affected by dietary treatments, as reported in studies of other species, such as muskellunge *Esox masquinongy* (Brecka et al. 1995), striped bass *Morone saxatilis* (Klar and Parker 1989), largemouth bass *Micropterus salmoides* (Brecka et al. 1996), and rainbow trout *Oncorhynchus mykiss* (Rinchard et al. 2007). We found a significant inverse relationship between body moisture and lipid contents. Lipids were significantly lower in fish fed the F2 diet and the casein–gelatin diet in experiment 1 and the BioOregon starter diet in experiment 2. In experiment 1, the three experimental diets contained soy lecithin (phospholipids). In diets F1 and F2, soy lecithin was supplemented at 11% (Zambonino-Infante, personal communication), whereas in the casein–gelatin diet, soy lecithin was used as the only source of lipids (14%). Dietary lecithin supplementation has been used to enhance growth and survival of several fish species (Poston 1990; Kanazawa 1997; Salhi et al. 1999; Cahu et al. 2003). Lecithin has been proven to prevent lipid oxidation and to facilitate fat absorption. Salhi et al. (1999) reported that the increase in dietary phospholipids may improve lipid transport from the enterocytes to the blood by enhancing chylomicron synthesis. However, fish fed the F1 and F2 diets did not exhibit the best growth performance, whereas fish fed the casein–gelatin diet presented the highest mortality rate. In experiment 2, fish fed the low-lipid diet (BioOregon starter) grew poorly, whereas fish fed high-protein and intermediate lipid contents (INVE-NRD) grew faster.

In conclusion, our results indicate that yellow perch can be successfully weaned at sizes of 87 and 174 mg and that satisfactory growth can be achieved with commercial and experimental diets. However, additional studies are required to evaluate the dietary requirements for yellow perch juveniles.

Acknowledgments

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TABLE 6.—Extended.

Diet	Mn (μg/g)	Al (μg/g)	Zn (μg/g)
	Experiment 1		
Kyowa 400B	7.2 ± 0.4 x	4.6 ± 1.1 z	148.6 ± 7.5 y
F1	12.9 ± 1.3 y	5.7 ± 1.7 z	185.2 ± 3.7 z
F2	13.7 ± 0.8 y	7.4 ± 1.9 z	204.7 ± 13.9 z
Casein–gelatin	35.6 ± 3.5 z	5.6 ± 3.1 z	194.1 ± 17.9 z
	Experiment 2		
Kyowa 400B	6.1 ± 0.4 w	4.6 ± 0.3 y	140.3 ± 11.4 y
INVE-NRD	7.4 ± 0.3 x	4.2 ± 1.0 y	118.7 ± 4.3 x
BioOregon starter	8.7 ± 0.7 y	7.1 ± 1.4 z	185.8 ± 8.8 z
Purina starter	10.4 ± 0.4 z	3.6 ± 0.4 y	124.2 ± 4.2 x

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