Evaluation of Commercial Feeds for Rearing Advanced Fingerling Walleye[1]

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Abstract: An experiment was conducted to evaluate the suitability of 5 commercial feeds[3] for rearing juvenile walleye (*Stizostedion vitreum*). Two open-formula feeds (the coolwater W-16 formulation and the Abernathy salmon formula) and 3 closed-formula trout and salmon feeds (Glenco Mills trout feed, BioMoist, and BioDry) were evaluated. In the first phase, walleyes (age ~166 days posthatch, 161 ± 13.2 mm total length (TL), and 39.2 ± 10.4 g) were stocked at 4 densities from 6.7 to 14.6 g/liter (20 to 50 fish per tank) and reared separately on W-16 and the Glenco Mills trout feed for 70 days (from 166–236 days posthatch). In the second phase, walleyes (age ~313 days posthatch, 227.5 ± 17.2 mm TL, and 108.2 ± 28.3 g) were stocked at the same density (22.0 g/liter) in all tanks, and performance was compared over 98 days (313–411 days posthatch) separately on BioMoist, BioDry, and Abernathy feeds. Density had no effect on growth or condition with the W-16 and Glenco Mills feed. Feed type, however, significantly influenced growth and condition: growth rates were poor for fish fed the Glenco Mills and Abernathy diets, and in the second phase, fish fed BioMoist and BioDry grew faster and had a better condition than fish fed the Abernathy feed.

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State and federal agencies have undertaken research on various phases of walleye culture for many years (Nickum 1986 and Coolwater Fish Cult. Workshops in 1991 and 1992). The emphases of prior research have been on pond culture (Dobbie 1956, Richmond and Hynes 1986, Fox and Flowers 1990), training first-feeding larval walleyes to formulated feed (Krise and Meade 1986, Kindischi and MacCon-

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nell 1989, Loadman et al. 1989), and training pond-reared fingerlings (35–50 mm) to formulated feeds in intensive culture (Cheshire and Steele 1972, Beyerle 1975, Nagel 1976, Masterson and Garling 1986, Kuipers and Summerfelt 1992).

Once trained to formulated feed, walleyes can be reared to advanced fingerling size for stocking or to food size (≥0.68 kg). Larger fingerlings are desirable for maintenance stocking in lakes with an existing predator population and for introduction as a new predator for control of overpopulated forage fishes. Ellison and Franzin (1992), in an overview of several walleye stocking studies, found that success of fry and small fingerling stocking success averaged 32% but that success for stocking large fingerlings was 50%. Paragamian and Kingery (1992) report that stocking of fingerlings in 3 Iowa rivers had significant impact on existing walleye populations but that stocking of fry in the same rivers was inconsequential. In 2 southern Illinois reservoirs, Heidinger et al. (1985) observed stocked fingerlings to be more successful than stocked fry. Nickum (1978) claimed that many fisheries managers regard walleye ≥200 mm important as predatory control of forage fishes. Because of their high market value as food fish, walleyes are also attractive to private aquaculturists (Malison et al. 1990).

Although the potential for successful production of food-sized walleyes on formulated feeds seems promising, production has not been demonstrated (Nickum 1986). Malison et al. (1990) suggested several problems associated with rearing walleyes beyond the small fingerling size: aggressive behavior, sensitivity to disturbance, and a diminution in growth rate "well before" they reach marketable size. In addition, there is a lack of nutritional information on feeds for rearing advanced fingerlings to food-size. Aside from the studies by Reinitz and Austin (1980), Barrows (1987), and Barrows et al. (1988*a,b*), there has been little research on walleye diets. At the time of this research, the only feed developed specifically for walleyes was the W-16 formulation, which was designed for training pond-cultured fingerlings to formulated feed (Colesante et al. 1986, Westers 1986). Even for that purpose, the W-16 feed had a higher protein level than necessary (Barrows et al. 1988*b*).

Until a species-specified diet formulation is developed for all life stages of walleye, feeds developed for other species will have to suffice. We describe the growth rates of walleye fed the W-16 feed and 4 salmonid feeds for rearing fingerling walleyes from 161 mm total length (TL) and 39.2 g (an initial age ~166 days posthatch) to an average 258 mm TL and 166 g by age 411 days posthatch. There are no previously published reports on rearing of walleyes beyond 120 days posthatch or 150 mm. Because feed costs can constitute 50% to 60% of annual production costs in aquaculture (Sedgewick 1985), an evaluation using available commercial feeds is a logical first step toward successful production of large juvenile walleyes.

Methods

Fish Origin

The walleyes used in this phase were obtained as pond-reared fingerlings on 19 June 1987 from the Iowa Department of Natural Resources Spirit Lake Hatchery, Welch Lake production site. Fingerlings were seined from Welch Lake at 50–60 days posthatch (19 Jun) and transported to the aquaculture facility at Iowa State University where they were trained (habituated) to W-16 formulated feed (Kuipers and Summerfelt 1992). The median age of the fish was 166 days posthatch at the beginning of the first phase of the present study and 313 days posthatch at the beginning of the second phase.

Facilities

Fish were reared in 120-liter (52 x 55 cm with 38 cm water depth), rectangular, fiberglass tanks. The rearing facility was supplied with tap water that had been dechlorinated in high-pressure tanks with activated carbon. The water was heated to 19.8° C, degassed in a packed column, and supplied at a rate of 2 liter/minute (1 exchange/hour) from 8 October 1987 until 10 May 1988 (fish age 383 days), at which time flow was increased to 4 liter/minute (2 exchanges/hour) to maintain water quality for the increasing biomass.

The culture room was maintained at low light intensity (31.6 ± 7.3 lx) for 18 hours daily and without light for 6 hours daily. Tanks were covered with 0.64-cm plastic-mesh screen; the screen reduced the light intensity at the water surface to about 50% of room light.

Water Quality

Dissolved oxygen was measured once every 2 weeks for each tank in the first phase and once every 25 days from 3 tanks in the second phase. During the second phase, total ammonia nitrogen (TAN) and pH were measured on 4 occasions. TAN was measured by using the salicylate-hypochlorite method (Verdouw et al. 1978, Bower and Holm-Hansen 1980). TAN was converted to un-ionized ammonia (UIA) by using tables given by Thurston et al. (1979). An Orion Research 407A ion analyzer was used to measure pH.

In the first phase, average dissolved oxygen values were 6.27 ± 0.67 mg/liter, and the minimum value was 4.03 mg/liter; in the second phase, average values were 6.23 ± 0.23 mg/liter, and the lowest was 3.92 mg/liter. In the second phase, pH ranged from 7.2 to 8.6, with a mean of 7.7 ± 0.32; total ammonia nitrogen (TAN) ranged from 0.08 to 0.41 mg/liter, with a mean of 0.19 ± 0.10 mg/liter, and un-ionized ammonia (UIA) ranged from 0.002 to 0.006 mg/liter, with a mean of 0.004 ± 0.0015 mg/liter. The UIA concentrations never exceeded the 0.050 to 0.200 mg/liter concentrations reported to affect growth (Colt and Armstrong 1981).

Temperature was measured on 32 days during the first phase and on 40 days during the second. Average water temperatures during both phases were 19.8° and 19.6° C, respectively. Maximum and minimum temperatures were 23.0° and 17.2° C in the first phase and 21.1° and 18.0° C in the second.

Feeding

Feed was dispensed with automatic raceway feeders (North Star Co., Gaston, Ore.) at 5-minute intervals during the 18-hour lighted portion of the day. Feed sizes and feeding rates were adjusted according to fish size. During the first phase, fish were fed 5.0% of their body weight from age 166 to 194 days, 4% from age 195 to 209 days, 3.5% from age 210 to 223 days, and 3.0% from age 224 to 236 days. In the second phase, fish were fed 3.0% of their body weight from age 313 to 369 days, 2.8% from age 370 to 383 days, 2.5% for age 384 to 397 days, and 2.0% from age 398 to 411 days. Excess feed and feces were removed by daily siphoning and weekly scrubbing of tank walls.

Experimental Design

Fish Age 166–236 Days Posthatch.—In the first phase, fish were stocked at 20, 30, 40, and 50 fish/tank (6.7, 9.6, 12.4, and 14.6 g/liter) in 8 120-liter tanks and reared 70 days (8 Oct–17 Dec 1987, fish age 166–236 days). The initial sizes (mean ± standard deviation) were 161 ± 13.2 mm TL and 39.2 ± 10.4 g. In this phase, dead fish were replaced immediately with fish of nearly the same length and weight to maintain density relationships. The feeds were the U.S. Fish and Wildlife Service coolwater diet W-16 (Colesante et al. 1986, Westers 1986) and a commercial trout feed, manufactured by Glenco Mills (Table 1). Tanks were stystematically assigned a feed, and fish were randomly placed in tanks. Because of the systematic, rather than random assignment, and the lack of replication for each density, this feeding study provides only descriptive data, and the 2 feeds cannot be statistically compared. Each feed was used 4 times, once at each of 4 density levels.

Fish Age 313–411 Days Posthatch.—The second phase used a completely randomized design, which allowed for a statistical evaluation of the effects of food types on growth. Nine tanks were randomly assigned 1 of 3 diets, and fish were randomly placed in the tanks. Each of the diets was replicated 3 times. The feeds were BioMoist grower and BioDry 3500 (BioProducts Inc., Warrenton, Ore.) and Abernathy S8-2 (Glenco Mills, Glenco, Minn.) (Table 1). The initial size of the fish

Table 1. Proximate composition of the feeds used for walleyes: protein, fat, fiber, moisture, and ash given as percentage and energy in kcal/g.

Composition	W-16[a]	Trout[b] feed	BioMoist™[c] grower	BioDry™[c]	Abernathy[a] S8-2
Crude protein	61.1	41.0	41.0	41.0	48.0
fish protein	NA	(17.0)	(35.0)	(24.0)	(40.5)
Crude fat	16.0	10.0	16.5	19.5	17.0
Moisture	8.0[d]	12.6	26.5	14.5	10.0
Ash	9.0[d]	—	10.5	9.5	10.0
Other	5.9	—	5.5	15.5	15.0
Metabolizable energy (kcal/g)	4.176	2.469	3.055	3.370	3.868
% Protein/ME	14.6	16.6	13.4	12.3	12.4

[a] Westers 1986.
[b] Analysis provided by Glenco Mills.
[c] BioMoist™ grower and BioDry™ 3500 are products of BioProducts Inc., Warrenton, OR.
[d] Personal communication, H. George Ketola (Tunison Laboratory of Fish Nutrition, Cortland, NY).

in this phase was 227.5 ± 17.2 mm TL, and 108.2 ± 28.3 g. Fish were stocked at a mean density of 22.0 ± 1.5 g/liter. The phase was completed at 98 days (4 Mar–10 Jun 1988, fish age 313–411 days).

Collection and Analysis of Data

The total number of fish in each tank was counted every 14 days at which time the lengths and weights of a random subsample of 10 fish (20% to 50% of the population) were recorded from a population of 20 to 50 fish in each tank. The fish population was enumerated in this manner on 6 and 8 sampling dates during the first and second phases, respectively. A condition factor (K) was calculated as a measure of robustness or well-being: $K = \text{weight} \times 10^5/\text{total length}^3$. To reduce stress induced by removing fish from the tanks to determine their size, tricaine methanesulfonate (TMS) was added to the tank (20 mg/liter) before sampling. After removal from the tanks, fish were placed into a solution of 1% salt (sodium chloride) and 55 mg/liter TMS for total anesthesia before weight was measured.

Data from the second phase were analyzed by using the Statistical Analysis System (SAS 1982). Analysis of variance, *t*-tests, and Duncan's new multiple range test were used to compare means. In addition to direct comparisons of performance on each feed type, orthogonal comparisons were made to test for effects on growth rates beteeen fish reared on Abernathy and the average of fish reared on the 2 BioProducts, Inc., feeds, BioDry and BioMoist. These tests were used because the similar compositions of BioDry and BioMoist feeds suggested that fish reared on BioProducts, Inc., feeds would produce similar growth, but perhaps different from the growth of fish reared on Abernathy. The 0.05 alpha value was used to determine significance for all statistical comparisons. Growth rates were obtained from the slopes of regressions of time on lengths and weights.

Results

W-16 and Trout Feed

The maximum and minimum growth rates in length and weight of fish fed W-16 were 0.58 mm/day, 0.45 mm/day, 0.56 g/day, and 0.39 g/day, respectively (Table 2). The maximum and minimum growth rates of fish fed Glenco Mills trout feed were 0.38 mm/day, 0.33 mm/day, 0.19 g/day, and 0.13 g/day, respectively (Table 2). The only mortality (1.8% total) encountered for fish fed either feed (5 fish of 280) occurred during handling. The regressions of growth rates on density, however, were nonsignificant.

BioMoist, BioDry, and Abernathy

On the final day of the second phase, when the walleyes were 411 days posthatch, treatment means for length, weight, and condition were significantly different ($P \leq 0.05$) among the 3 groups (Table 3). A multiple-comparison test (Duncan's

Table 2. Initial and final length, weight, and condition measurements (± standard deviation) for fish reared on W-16 and Glenco Mills trout feed.

Feed	Parameter	Density (*N* per tank)	Fish age (days) 166	236	Growth per day
W-16	Length (mm)	20	159.2 ± 12.9	200.4 ± 17.8	0.58
		30	155.6 ± 9.9	189.2 ± 17.8	0.45
		40	153.9 ± 10.1	185.3 ± 8.4	0.48
		50	154.0 ± 14.9	195.1 ± 15.7	0.58
	Weight (g)	20	39.2 ± 10.5	80.4 ± 22.5	0.46
		30	35.4 ± 8.2	64.0 ± 20.0	0.40
		40	33.7 ± 7.9	59.5 ± 0.1	0.39
		50	33.5 ± 11.9	69.2 ± 19.4	0.56
	Condition	20	0.94 ± 0.07	0.97 ± 0.07	
		30	0.92 ± 0.06	0.92 ± 0.05	
		40	0.91 ± 0.05	0.93 ± 0.05	
		50	0.88 ± 0.08	0.91 ± 0.07	
Trout feed	Length (mm)	20	163.4 ± 10.9	187.2 ± 13.9	0.34
		30	164.7 ± 15.3	191.6 ± 15.8	0.38
		40	167.2 ± 10.5	190.0 ± 14.8	0.33
		50	169.5 ± 13.7	192.4 ± 17.8	0.33
	Weight (g)	20	41.8 ± 9.5	53.7 ± 15.5	0.15
		30	41.5 ± 11.1	53.7 ± 14.7	0.13
		40	44.2 ± 8.5	54.8 ± 15.0	0.19
		50	44.7 ± 11.6	59.5 ± 18.2	0.16
	Condition	20	0.94 ± 0.11	0.80 ± 0.10	
		30	0.91 ± 0.09	0.75 ± 0.07	
		40	0.94 ± 0.11	0.78 ± 0.04	
		50	0.90 ± 0.09	0.81 ± 0.09	

new multiple range test) indicated that the final length, weight, and condition for fish fed both the BioDry and BioMoist feeds differed significantly ($P \leq 0.05$) from fish fed the Abernathy feed. The final mean weights for fish reared on BioDry (160 g) and BioMoist (166 g) were substantially greater than the mean weight of fish reared on Abernathy (125 g). Mean final lengths were 259 mm, 258 mm, and 245 mm, for BioDry, BioMoist, and Abernathy, respectively. Condition increased over the 98-day interval for fish fed the BioDry and BioMoist feeds but decreased for fish fed the Abernathy feed (Table 3). Fish fed BioDry and BioMoist also had faster growth rate (mm/day and g/day) than fish fed the Abernathy feed (Table 3).

Comparisons among the 3 levels of performance (length, weight and condition) from the first day to the end (98th day) indicate that condition factor was a sensitive measure of differences in diet. Significant differences in condition factor occurred as soon as the 14th day (Fig. 1). Divergence in length between the groups could be seen by the 42nd day (the 4th sampling date), but they were not significant until the last date. Weight differences were significant on the 70th day and last sampling date.

Biomass density of fish at the beginning of the second phase did not differ among feed treatment groups ($P > F = 0.53$); however, final biomass density did

Table 3. Analysis (ANOVA) of differences in length (mm), weight (g), and condition factor for fish fed Abernathy, BioDry, and BioMoist feed for 98 days. When significant, differences between means were evaluated with Ducan's new multiple range test. Values connected by an underline are not significantly different.

Fish age (days)	Parameter	Feed: Abernathy	BioDry	BioMoist	F	$P > F$
Initial						
313	Length	230 ± 17	224 ± 17	229 ± 17	1.27	0.28
	Weight	112 ± 30	100 ± 27	112 ± 27	1.60	0.21
	Condition	0.90 ± .085	0.88 ± 0.07	0.92 ± 0.07	1.77	0.18
	Biomass	21.2 ± .68	22.4 ± 1.89	22.5 ± 1.73	0.70	0.53
Final						
411	Length	245 ± 21	259 ± 21	258 ± 27	3.96	0.02
	Weight	125 ± 36	160 ± 45	166 ± 53	7.57	< 0.01
	Condition	0.84 ± .13	0.90 ± 0.06	0.94 ± 0.10	7.57	< 0.01
	Biomass	25.0 ± 0.74	29.4 ± 0.21	27.0 ± 1.80	12.04	< 0.01
	Survival	0.96 ± 0.04	0.92 ± 0.10	0.95 ± 0.02	0.28	0.77
	Growth[a]					
313	length	0.153	0.321	0.284	23.93	< 0.01
to						
411	weight	0.222	0.588	0.532	11.78	< 0.01

[a]length, mm/day, weight, g/day.

differ ($P > F < 0.01$). Because fish fed the Abernathy feed grew more slowly, they had the least final biomass (25.0 g/liter) ($t = 4.17$). Biomass densities of fish reared on BioMoist and BioDry feeds (27.0 and 29.4 g/liter) did not differ. The difference in survival was not significant ($P \leq 0.05$).

Discussion

The present experiment demonstrates that pond-reared walleyes trained to W-16 can be converted to a variety of other commercial salmonid feeds and reared from 156-mm fingerling to 258-mm size in 245 days at ~20° C. Walleyes did not grow equally well on all trout and salmon diets tested, but good growth was obtained on some open feed formulations. Although W-16 contains about 10% more protein than necessary (Barrows et al. 1988*b*), it yielded adequate growth. Our comparisons indicate the W-16 feed is more effective than Glenco Mills trout feed for juvenile walleyes. The Glenco Mills trout feed had similar protein levels to both of the BioProducts feeds, but it had much lower fat and energy density (Table 1). BioProducts, Inc., feeds produce better growth than Abernathy and would be suitable for growing walleyes to food size until a better formula is available (BioProducts, Inc., now recommends BioDry 1500 for walleye and yellow perch culture). In an experiment using BioMoist and W-16 feeds, Kuipers (1990) found that fingerling walleye consistently grew faster in length and weight when fed BioMoist than when

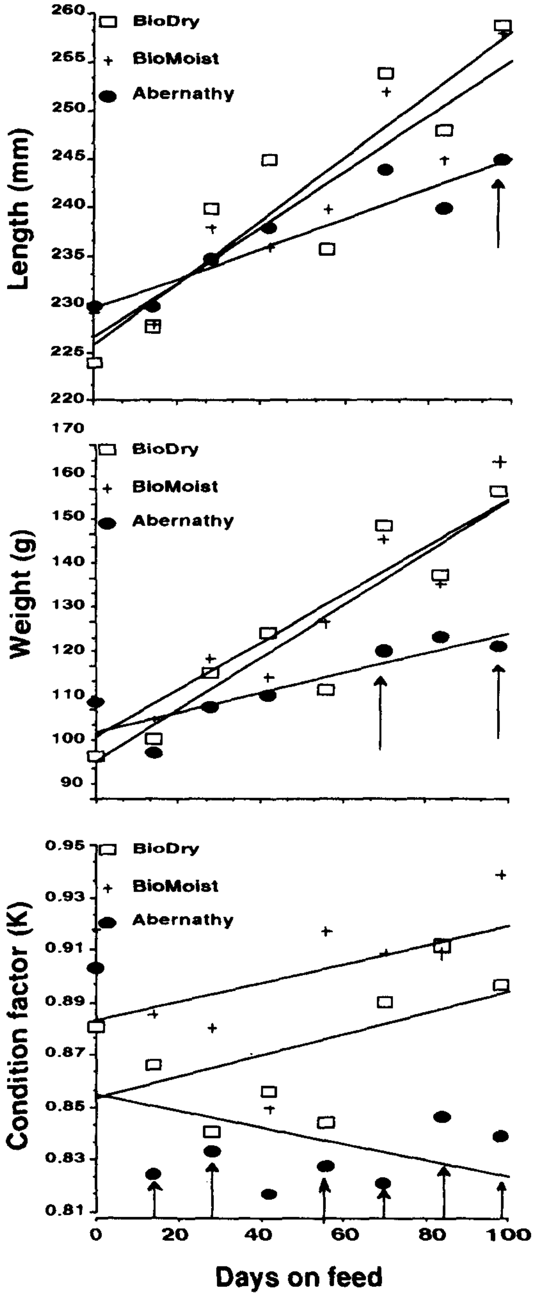

Figure 1. Regression of days on feed and length (mm), weight (g), and condition (g $\times$ 10^5 mm^{-3}) for fish reared on Abernathy, BioDry, and BioMoist feeds. Significantly different points are indicated with a "—>".

fed W-16 feed; however, the walleye fed the W-16 feed had a higher condition factor.

The poor performance of fish reared on the Abernathy feed was the most surprising finding given its protein, fat, and energy levels. Walleyes fed the Abernathy feed had poor growth, and the K value suggests that they had poor body condition. The proximate analysis for protein in the Abernathy feed was 48.0%, including 40.5% protein from herring meal which should have been adequate on the basis of protein requirements reported by Barrows (1987) and Barrows et al. (1988*b*). They reported that the optimal dietary protein and ME for walleyes were 51% and 3,530 kcal/kg, respectively, for 14-g walleyes, and 42.3% protein for 50-g walleyes. Barrows et al. (1988*a*) observed relatively rapid growth of larval walleye with a 50% protein, high-fat (high-energy) feed formulation and poor growth with a 54% protein, low-fat diet. Reinitz and Austin (1980) found that weight gain of walleyes reared from 0.4 to 8.9 g was positively correlated with the amount of fish (herring meal) protein (15% to 50%) in the feed.

In our study, the fastest growth rates were 0.58 mm/day from phase 1 (W-16) feed and 0.32 mm/day from phase 2 (BioDry). We calculated growth rates of 0.62 mm/day from data given by Malison et al. (1990) for fish from 117 to 170 mm at 21° C on W-16. Barrows et al. (1988*b*) reported a growth rate of 0.63 mm/day for fish from 124 to 168 mm at 21° C. Seigwarth and Summerfelt (1990) reported a growth rate of 0.12 and 0.45 mm/day for walleyes reared at 17° and 21° C, respectively, from 146 mm TL to 156 and 178 mm TL in 73 days on W-16. In another study, at 25° C, walleyes grew from 176 mm TL to 215 mm (0.55 mm/day), also on the W-16 feed (Seigwarth and Summerfelt 1992).

Considering these growth rates for walleyes growing from 144 to 258 mm, can walleyes be reared to a food size in an interval as short as is required to make commercial production practical? The appropriate size of a marketable fish has yet to be determined, but a 170–227 g (6–8 oz) fillet (skin on) is common. Using the 170-g (6-oz) size for a fillet and assuming a 40% yield on the live weight, an 849-g (1.87 lb) and 423-mm TL fish would provide 2 170-g (6-oz) fillets. If the average growth rate of 0.58 mm/day were to continue, walleyes could be grown from 156 mm to a food size in 15 months at a 20° C constant temperature.

Beyerle (1975) reported that H. E. Calbert et al. (1973) found that walleye growth was almost one-third less at 18° C than at 22° C. Seigwarth and Summerfelt (1990) reported a 3.8-fold increase in growth rates from 17° to 21° C. Since growth rates may be increased by as much as 30% at 23° C, the rates we observed at 20° C are probably less than maximum. Our study demonstrates that the feed formulation affects growth rate, but environmental variables, such as temperature, are important variables as well.

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