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Evaluation of Reduced Fish Meal Diets for Second Year Growout of the Largemouth Bass, *Micropterus salmoides*

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Abstract

Development of efficient cost-effective diets is a critical component in the refinement of production technologies for the largemouth bass, *Micropterus salmoides* (LMB). One of the first steps in reducing feed costs can be to decrease the amount of fish meal in the diet. The objective of this study was to evaluate reduced levels of fish meal, and a least-cost formulation diet, for second year growout of LMB under practical pond conditions. Twelve 0.04-ha ponds were stocked with juvenile LMB (210.1 ± 3.3 g) at a stocking density of 8650 fish/ha (350 fish/pond). Each pond was randomly assigned one of the four dietary treatments with three replicate ponds per treatment. The three experimental diets contained varying levels of fish meal. Diets FM-45, FM-24, and FM-8 contained 45, 23.5, and 8% fish meal, respectively. In diets FM-24 and FM-8, fish meal was replaced by varying levels of poultry by-product meal, soybean meal, and blood meal. The fourth diet was a commercial salmonid diet widely used as a LMB growout feed (Nelson and Sons, Inc., Silvercup™, Steelhead, Murray, UT, USA). This diet served as a commercial control (CC) and contained 46% crude protein. The experimental diets were formulated to be isonitrogenous and isocaloric with the CC diet and were fed once daily to apparent satiation for 180 d. At harvest, there were no significant differences between treatments ($P > 0.05$) in terms of survival, which averaged 95% overall. Mean weights of fish fed the three experimental diets FM-45, FM-24 and FM-8 were not significantly different ($P > 0.05$) and averaged 518, 546, and 529 g, respectively, but were all significantly greater ($P \leq 0.05$) than those fed the CC (488 g). Feed conversion ratio (FCR) of fish fed the FM-45 and FM-8 diets (1.43 and 1.46, respectively) was significantly greater ($P \leq 0.05$) than those fed the FM-24 diet (1.34). The FCR of fish fed the CC diet (1.39) was not significantly different ($P > 0.05$) from fish fed other diets. Feed cost per unit of weight gain ($US/kg) was significantly lower ($P \leq 0.05$) in fish fed the FM-24 and FM-8 diets ($0.73 and $0.72/kg, respectively) than in fish fed other diets. Feed cost per unit gain of fish fed the FM-45 diet ($0.83/kg) was significantly lower ($P \leq 0.05$) than those fed the CC diet ($1.04/kg). There were no significant differences ($P > 0.05$) in dress-out percentages or proximate composition among fish fed the four diets. This study indicates that fish meal levels in feeds used for the second year growout of LMB can be reduced to ≥8% of the formulation without reducing survival or growth and without negatively impacting body composition.

The largemouth bass, *Micropterus salmoides* (LMB) is a large North American freshwater predator that shows promise as an aquaculture species. Although feed costs account for an extremely high proportion of production costs (Woods 1999), the numbers of studies conducted on LMB nutrition to date are limited. Development of efficient cost-effective diets is considered a critical component in the refinement of production technologies for LMB (JSA 1983). One of the first steps in reducing feed costs, and improving the environmental sustainability of production, can be to decrease the amount of fish meal in the diet. Fish meal is the most valuable non-edible commodity produced from wild harvest fisheries with annual production ranging between 5.5 and 7.7 million megatons (Hardy and Tacon 2002). According to Tidwell and Allan (2001), the amount of pelagic fish harvested to produce fish meal has remained relatively constant for the past 25 yr; however, demand on this limited resource

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continues to increase (FAO 2007). In other species, replacing fish meal in diet formulations has resulted in decreases in production costs, without adversely effecting growth rate and body composition (Gomes et al. 1995; Adeliza et al. 1998).

Most LMB producers currently feed high protein (>40%) and high fat (>15%) salmonid diets for both juvenile and growout production of LMB (Tidwell et al. 2005). The use of salmonid diets is primarily based on ready availability rather than known nutritional suitability for LMB. Salmonid diets contain relatively high levels of fish meal (>25%) and costs can exceed $700/ton. In addition, most of these diets are currently manufactured in the western USA and shipping can add an additional $100/ton or more for producers in other areas of the country.

Previous studies have provided some of the information required to begin to formulate economical species-specific diets for LMB, including examination of protein levels (Tidwell et al. 1996), protein/energy ratios (Bright et al. 2005), effectiveness of amino acid supplementation (Coyle et al. 2000), alternative lipid sources (Subhadra et al. 2006a; Tidwell et al. 2007), alternative protein sources (Tidwell et al. 2005; Subhadra et al. 2006b), and digestibility of ingredients (Portz and Cyrino 2004). However, with the exception of Tidwell et al. (1996), all of these experiments were conducted in aquaria with juvenile fish. Before recommendations are made to producers and/or feed manufacturers, results need to be verified under pond culture conditions.

The objective of this study was to evaluate reduced levels of fish meal and a least-cost formulation diet for LMB under practical pond conditions. The growout stage or second year of production was chosen based on the greater total feed costs incurred during this phase of production.

Materials and Methods

Test diets were formulated to be approximately isonitrogenous (45% protein) and isocaloric (4.0 kcal/g diet), based on gross energy values of 5.64 kcal/g protein, 4.11 kcal/g carbohydrate, and 9.44 kcal/g fat (NRC 1993). The three experimental diets were custom mixed and extruded into 5.5 mm pellets by a commercial feed mill (502 Feed Mill, Benton, KY, USA) and contained varying levels of fish meal (Table 1). The high fish meal diet was based on previous studies and estimates of closed commercial formulations. It contained 45% fish meal and was designated diet FM-45. In the second experimental diet, fish meal was reduced to 23.5% (designated diet FM-24). The third experimental diet was formulated using a linear programming model to be a least-cost formulation (using ingredient costs published in Feedstuffs 2006) and contained 8% fish meal (designated FM-8). In diets FM-24 and FM-8, fish meal was replaced by varying levels of poultry by-product meal, soybean meal, and blood meal (which was maintained ≤7% of total formulation in all experimental diets to maintain palatability). The three experimental diets were formulated to contain ≤20% carbohydrates to prevent liver vacuolization (Amoah et al. 2008). The reduced carbohydrate levels of the experimental diets produced "slow sinking" pellets. The fourth diet was a 5.5 mm floating commercial salmonid diet widely used as a LMB growout feed (Nelson and Sons, Silvercup, Steelhead, Murray, UT, USA). This diet served as a commercial control (CC) and contained 46% crude protein and 17.5% lipid. All diets were analyzed to determine moisture, protein, lipid, fiber, and ash by a commercial analytical laboratory (Eurofins Scientific Inc., Des Moines, IA, USA; Table 1). Diets were also analyzed for amino acid composition (Table 2) and fatty acid composition (Table 3) by a commercial analytical laboratory (Eurofins Scientific Inc.). All diets tested were found to have exceeded recommended levels of amino acids methionine and lysine reported by Coyle et al. (2000).

One-year-old pellet-trained LMB were stocked on May 4, 2006, into 12 0.04-ha ponds at a rate of 8650 fish/ha (350 fish/pond) at an initial size (mean ± SD) of 210.1 ± 3.3 g. At stocking, 50 randomly sampled fish were

Table 1. *The formulation, analyzed composition, and relative feed cost (includes bagging and shipping) of a proprietary formulation CC diet*[a] *and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal.*

	Diet			
Ingredient	CC	FM-45	FM-24	FM-8
Menhaden fish meal (62% P)	[b]	45	23.5	8
Soybean meal (48% P)	[b]	16	30.5	44.5
Blood meal	[b]	7	6	5
Poultry by-product meal	[b]	0	16	23
Corn	[b]	23	13	8.5
Menhaden fish oil	[b]	7	9	9
Ethoxyquin	[b]	0.06	0.06	0.06
Choline	[b]	0.3	0.3	0.3
Mineral mix	[b]	0.5	0.5	0.5
Vitamin mix	[b]	0.5	0.5	0.5
Di-calcium phosphate	[b]	0.7	0.7	0.7
Relative feed cost	1	0.78	0.73	0.66
Analyzed composition (as fed)				
Moisture (%)	8.1	7.0	7.6	9.3
Protein (%)	45.9	46.3	47.5	44.7
Ash (%)	6.9	9.8	9.9	8.8
Lipid (%)	17.5	13.3	14.9	14.5
Fiber (%)	1.2	1.5	1.6	2.2
NFE (%)	20.3	22.2	18.7	20.7
Energy (kcal/g diet)	42.2	39.4	39.9	39.2
E:P (kcal/g protein)	9.2	8.5	8.4	8.8

CC = commercial control; LMB = largemouth bass.
[a]Feed was a steelhead diet (Nelson and Sons, Silvercup Feeds, Murray, UT, USA).
[b]Commercial diet. Proprietary formulation not known.

individually weighed (g) and measured (total length). Fish were fed once daily to apparent satiation. Each of four treatments (diets) was replicated in three ponds. Ponds used in this study were approximately 1.5 m deep and were supplied with water from a reservoir filled by rain runoff. Water levels in the ponds were maintained by periodic additions from the reservoir. A monthly sample of 30–50 fish were captured by seine, group weighed, counted, and returned to the pond for the determination of average individual weights (Fig. 1).

Water temperature and dissolved oxygen (DO) were monitored in each pond twice daily (0800 and 1600 h) at a depth of 0.5 m using a YSI Model 556 oxygen meter (YSI, Yellow Springs, OH, USA). Mechanical aeration was supplied if DO was predicted (by graph) to fall below 5 mg/L during the night. Ammonia, nitrite, and pH were determined weekly (1600 h) using a HACH DR/2500 spectrophotometer (HACH, Loveland, CO, USA).

Final harvest took place on October 31, 2006, 180 d after stocking. At harvest, total number and weight of fish in each pond were determined. Fifty fish were randomly chosen from each pond and individually weighed (g) and measured for total length (cm). Five fish from each pond were removed, sexed, and sacrificed to determine dress-out weight, head weight, fillet weight, and gut weight. Fillets from five fish per pond were pooled and analyzed by a commercial analytical laboratory (Eurofins Scientific Inc.) for proximate composition of moisture, protein, lipid, and ash.

Feed conversion ratio (FCR) was calculated as weight of feed fed (kg)/live weight gain (kg). Specific growth rate (SGR, % body weight per day) was calculated as $[(\ln W_f - \ln W_i)/t]$

TABLE 2. *Concentration of essential amino acids and cystine (% of protein) of a proprietary formulation CC diet*[a] *and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal.*

	Diet			
Amino acid (% of protein)	CC	FM-45	FM-24	FM-8
Arginine	2.88	2.98	3.39	3.22
Histidine	1.43	1.34	1.50	0.85
Isoleucine	1.77	1.96	1.94	1.82
Leucine	4.02	3.89	3.90	3.56
Lysine	3.34	3.52	3.54	3.04
Methionine + cystine	1.63	1.55	1.45	1.28
Phenylalanine	2.48	2.32	2.40	2.18
Threonine	2.17	2.16	2.13	1.96
Tryptophan	0.63	0.61	0.62	0.58
Valine	2.74	2.48	2.82	2.26

CC = commercial control; LMB = largemouth bass.
[a]Feed was a steelhead diet (Nelson and Sons, Silvercup Feeds, Murray, UT, USA).

$\times 100$, where W_f is the final weight; W_i the initial weight; and t the time in days (Ricker 1975). Condition factor (K) was calculated as $100 \times W/L^3$, where W is the weight (g) and L the total length (cm) (Weatherly and Gill 1987). Protein efficiency ratio (PER) was calculated as (final body weight−initial body weight)/protein fed. Hepatosomatic index (HSI) was calculated as (weight of liver (g)/weight of whole body (g)) × 100. Feed cost per unit of gain ($US/kg gain) was calculated as $US feed/kg (includes cost of ingredients based on prices published in Feedstuffs [April 24, 2006], manufacturing, bagging, and shipping of experimental diets) × weight of feed required to produce 1 kg of fish weight gain.

Treatment effects were statistically compared by ANOVA using Statistix version 8.0 (Statistix Analytical Software, Tallahassee, FL, USA). The differences were regarded significant if $P \leq 0.05$. If significant treatment differences were indicated by ANOVA, means were

TABLE 3. *Concentration of fatty acids (% relative) of a proprietary formulation CC diet*[a] *and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal.*

	Diet			
Fatty acid (%)	CC	FM-45	FM-24	FM-8
14:0	4.60	6.02	5.23	5.11
16:0	20.59	19.54	19.40	18.87
16:1	7.26	8.43	8.48	8.55
18:0	5.42	4.40	4.74	4.63
18:1 (Oleic)	22.28	14.85	18.66	19.51
18:2 $n-6$ (Linoleic)	9.56	9.85	11.41	12.99
18:3 $n-3$ (Linolenic)	1.52	1.97	2.15	2.37
20:4 $n-6$ (Arachidonic)	1.64	1.68	1.73	1.77
20:5 $n-3$ (EPA)	10.42	11.27	8.85	7.74
22:5 $n-3$	1.74	2.32	1.87	1.64
22:6 $n-3$ (DHA)	5.86	8.05	7.14	6.89
Miscellaneous	9.11	11.62	10.24	9.93

CC = commercial control; LMB = largemouth bass.
[a]Feed was a steelhead diet (Nelson and Sons, Silvercup Feeds, Murray, UT, USA).

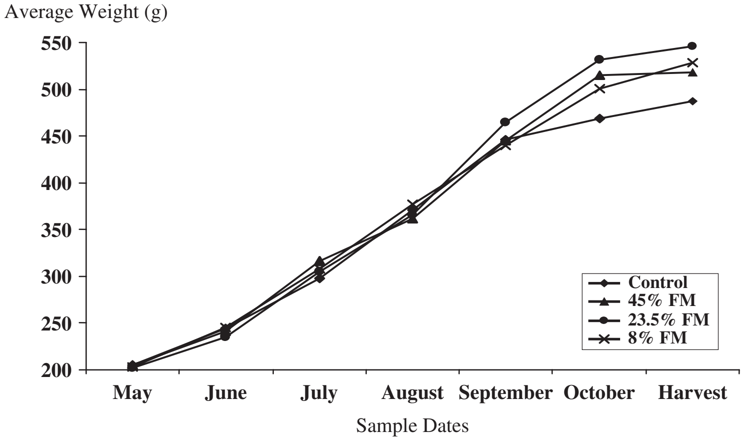

FIGURE 1. *Sample mean weights of largemouth bass (LMB) fed a proprietary formulation commercial control diet (CC) and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal. Ponds were sampled monthly. Values are means for three replicate ponds per diet.*

separated using Fisher's least significant difference test (Steele and Torrie 1980).

Results

There were no significant differences ($P > 0.05$) between treatments in terms of overall means for measured water quality variables (Table 4). Overall means (±SE) were: water temperature, 22.5 ± 0.2 C; DO, 10.6 ± 1.3 mg/L; total ammonia-N, 0.27 ± 0.04 mg/L; un-ionized ammonia-N, 0.09 ± 0.01 mg/L; nitrite-N, 0.01 ± 0.00 mg/L; total alkalinity, 101.2 ± 5.8 mg/L; total hardness, 158.0 ± 5.6 mg/L; and afternoon pH, 9.0 ± 0.1. All variables fell within the range considered acceptable for LMB growth and health (Tidwell et al. 2000).

At harvest, there were no significant differences ($P > 0.05$) in survival among fish fed the four diets, which averaged 95.2%, overall. Average harvest weights and total production did not differ ($P \leq 0.05$) among fish

TABLE 4. *Water quality results from ponds reared with LMB fed a proprietary formulation CC diet*[1] *and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal. Values are means (±SE) of three replicate ponds per diet. There are no significant differences (*$P < 0.05$*) among treatments for any parameter.*

	Diet			
Water quality analysis	CC	FM-45	FM-24	FM-8
Temperature	22.4 ± 0.1	22.6 ± 0.2	22.5 ± 0.1	22.5 ± 0.0
Dissolved oxygen	11.7 ± 1.5	10.0 ± 0.1	10.3 ± 0.1	10.3 ± 0.0
pH	9.0 ± 0.1	9.0 ± 0.0	9.0 ± 0.1	9.0 ± 0.1
Total ammonia	0.27 ± 0.00	0.26 ± 0.01	0.27 ± 0.03	0.27 ± 0.04
Un-ionized ammonia	0.09 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	0.09 ± 0.01
Nitrite	0.006 ± 0.002	0.007 ± 0.001	0.005 ± 0.003	0.006 ± 0.002
Alkalinity	98.3 ± 2.4	100.9 ± 3.7	99.6 ± 4.4	105.9 ± 2.5
Hardness	156.7 ± 2.9	159.4 ± 3.3	157.5 ± 2.7	158.6 ± 5.4

CC = commercial control; LMB = largemouth bass.
[1]Feed was a steelhead diet (Nelson and Sons, Silvercup Feeds, Murray, UT, USA).

TABLE 5. *Means (±SE) of AHW, survival, SGR, FCR, condition factor (K), PER, production, consumption, and feed cost per unit of gain*[1] *of LMB fed a proprietary formulation CC diet*[2] *and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal. Values are means of three replications per diet. Significant differences (* $P \leq 0.05$*) are indicated by different superscript letters within rows.*

	Diet			
Processing yields (%)	CC	FM-45	FM-24	FM-8
AHW (g)	487.5 ± 6.9^{b}	518.2 ± 1.2^{a}	545.6 ± 6.9^{a}	516.3 ± 16.6^{a}
Survival (%)	94.5 ± 1.2^{a}	95.5 ± 1.5^{a}	95.8 ± 1.5^{a}	95.0 ± 0.4^{a}
SGR (%/d)	1.37 ± 0.02^{c}	1.47 ± 0.04^{b}	1.57 ± 0.01^{a}	1.51 ± 0.02^{ab}
FCR	1.39 ± 0.02^{ab}	1.43 ± 0.03^{a}	1.34 ± 0.01^{b}	1.46 ± 0.02^{a}
K factor	1.69 ± 0.01^{b}	1.76 ± 0.01^{a}	1.78 ± 0.02^{a}	1.71 ± 0.01^{b}
PER	1.57 ± 0.03^{a}	1.52 ± 0.03^{a}	1.58 ± 0.01^{a}	1.51 ± 0.02^{a}
Production (kg/ha)	2410 ± 64^{b}	2756 ± 138^{a}	3020 ± 101^{a}	2786 ± 49^{a}
Consumption (kg/ha/d)	21.8 ± 0.4^{b}	24.7 ± 0.5^{a}	25.5 ± 0.4^{a}	26.2 ± 0.7^{a}
Feed cost of gain ($US/kg gain)[1]	1.04 ± 0.02^{a}	0.83 ± 0.02^{b}	0.73 ± 0.00^{c}	0.72 ± 0.01^{c}

AHW = average harvest weight; SGR = specific growth rate; FCR = feed conversion ratio; PER = protein efficiency ratio; CC = commercial control; LMB = largemouth bass.

[1]Feed cost per unit of gain ($US/kg gain) was calculated as $US feed/kg (includes cost of ingredients based on prices published in Feedstuffs [April 24, 2006], manufacturing, bagging and shipping of experimental diets) × weight of feed required to produce 1 kg of fish weight gain.

[2]Feed was a steelhead diet (Nelson and Sons, Silvercup Feeds, Murray, UT, USA).

fed the experimental diets FM-45, FM-24, and FM-8 (518, 546, and 529 g; 2756, 3020, and 2786 kg/ha, respectively), but were all significantly greater ($P \leq 0.05$) than those fed the CC (488g; 2410 kg/ha) (Table 5). SGR (%/d) was significantly higher ($P \leq 0.05$) in fish fed the FM-24 diet (1.57%/d) than for fish fed the FM-45 (1.47%/d). SGR of fish fed the FM-8 diet (1.51%/d) was not significantly different ($P > 0.05$) from fish fed the other experimental diets. The SGR of fish fed the CC diet (1.37%) was significantly lower ($P \leq 0.05$) than for fish fed any of the experimental diets. Condition factors (K) of fish fed the FM-45

TABLE 6. *Dress-out percentages and proximate analysis of LMB fillet flesh from fish fed a proprietary formulation CC diet*[1] *and three experimental diets containing varying levels of fish meal fed to LMB. FM-45 was formulated to contain 45% fish meal, FM-24 was formulated to contain 23.5% fish meal, and FM-8 was formulated to contain 8% fish meal. Values are means of three replications per diet. Significant differences (*$P \leq 0.05$*) are indicated by different superscript letters within rows.*

	Diet			
Processing yields (%)	CC	FM-45	FM-24	FM-8
Whole dressed	63.9 ± 0.7^{a}	64.7 ± 0.3^{a}	64.1 ± 0.9^{a}	63.8 ± 0.5^{a}
Head	26.0 ± 0.2^{a}	25.7 ± 0.0^{a}	25.6 ± 0.4^{a}	26.4 ± 0.4^{a}
Fillets	40.1 ± 0.4^{a}	41.2 ± 0.4^{a}	40.1 ± 0.8^{a}	40.8 ± 0.3^{a}
Gut	5.9 ± 0.2^{a}	8.8 ± 3.1^{a}	6.5 ± 0.5^{a}	6.6 ± 0.3^{a}
HSI	3.6 ± 0.1^{a}	3.2 ± 0.3^{ab}	2.8 ± 0.1^{b}	2.1 ± 0.1^{c}
Analyzed composition flesh				
Moisture (%)	73.1 ± 0.8^{a}	74.3 ± 0.8^{a}	73.5 ± 0.3^{a}	73.9 ± 0.2^{a}
Protein (%)	18.0 ± 0.2^{a}	18.2 ± 0.3^{a}	17.9 ± 0.2^{a}	18.2 ± 0.1^{a}
Lipid (%)	7.0 ± 0.5^{a}	7.3 ± 0.3^{a}	7.0 ± 1.3^{a}	7.4 ± 0.8^{a}
Ash (%)	1.0 ± 0.0^{a}	1.0 ± 0.0^{a}	1.0 ± 0.0^{a}	1.0 ± 0.0^{a}

HSI = hepatosomatic index; CC = commercial control; LMB = largemouth bass.

[1]Feed was a steelhead diet (Nelson and Sons, Silvercup Feeds, Murray, UT, USA).

(1.76) and FM-24 (1.78) diets were significantly higher ($P < 0.05$) than those of fish fed the FM-8 (1.71) and CC (1.69) diets.

The average daily feed consumption was not significantly different ($P > 0.05$) among fish fed the experimental diets FM-45, FM-24, and FM-8 (24.7, 25.5, and 26.2 kg/ha/d, respectively) which were all significantly higher ($P \leq 0.05$) than in fish fed the CC diet (21.8 kg/ha/d). The FCR of fish fed the FM-24 diet (1.34) was significantly lower ($P \leq 0.05$) than for fish fed the FM-45 diet (1.43) and FM-8 diet (1.46). The FCR of fish fed the CC diet (1.39) was not significantly different ($P > 0.05$) from fish fed any of the experimental diets. PERs did not differ significantly ($P > 0.05$) among fish fed any of the four diets and averaged 1.55, overall. Feed cost per unit of gain ($U.S./kg gain) was not significantly different ($P > 0.05$) in fish fed the FM-24 ($0.73/kg) and FM-8 diets ($0.72/kg), which were both significantly lower ($P \leq 0.05$) than those fed the FM-45 diet ($0.83/kg). The feed cost per unit gain of fish fed the CC diet ($1.04/kg) was significantly higher ($P \leq 0.05$) than for fish fed any of the experimental diets. It should be noted that these differences include higher shipping costs in the CC diet.

Hepatosomatic index of fish fed the FM-8 diet (2.09) was significantly lower ($P \leq 0.05$) than for fish fed all other diets (Table 6). Fish fed the FM-24 diet (2.84) had a significantly lower ($P \leq 0.05$) HSI than in fish fed the CC diet (3.62). The HSI in fish fed the FM-45 diet (3.19) was not significantly different ($P > 0.05$) from fish fed either FM-24 or the CC diet. Dress-out percentages (as a percentage of body weight) did not differ significantly ($P > 0.05$) among fish fed the four diets and averaged: whole dressed, 64.1%; fillet, 40.5%; head, 25.9%; and gut, 6.9%. Proximate composition of fillets did not differ significantly ($P > 0.05$) among fish fed the four diets and averaged: moisture, 73.7%; protein, 18.1%; lipid, 7.2%; and ash, 1.0%, overall (Table 6).

Discussion

Fish meal levels, and thereby feed costs, could be substantially reduced for LMB without decreasing growth, survival, or feed conversion efficiency, and without negatively impacting body composition. Because feed costs currently represent a large percentage of variable costs (>35%) of LMB production (Woods 1999), these results could have a positive impact on profitability.

This study appears to be the first to evaluate reduced fish meal levels in growout diets for LMB raised in ponds. These data agree with results of a previous aquarium trial by Tidwell et al. (2005) who reported that juvenile largemouth could be fed diets in which fish meal was replaced with poultry by-product meal and soybean meal without sacrificing growth. However, other aquarium studies have shown reduced growth when fish meal was replaced by poultry by-product meal and blood meal (Subhadra et al. 2006b). However, in that study, blood meal was included at a relatively high concentration (12%), which the authors indicated may have negatively impacted palatability. Hertrampf and Piedad-Pascual (2000) recommended a maximum inclusion rate of 10% for blood meal. In the current pond study, blood meal was maintained at ≤7% in all three experimental diets.

These data also agree with studies on other freshwater, warm-water predators. Muzinic et al. (2006) reported that sunshine bass, *Morone chrysops* × *M. saxatilis*, showed similar growth when turkey meal replaced 100% of the fish meal in the diet. Weight gains of palmetto bass, *Morone saxatilis* × *M. chrysops*, raised in cages also resulted in similar growth when fed diets containing 15, 30, and 45% fish meal (Webster et al. 1997). Although these data may be helpful in evaluating candidates for fish meal replacement in LMB diets, it should not imply that diets formulated for hybrid striped bass are suitable for LMB culture. The higher carbohydrate levels and lower protein levels in hybrid striped bass diets may be concerns.

Body composition and proximate analysis of flesh was not impacted by the different diets and results agree with those reported by Tidwell et al. (1996) for second year LMB. HSI was significantly different between treatments; however, values were within levels considered to be within the range of normal and were similar to those reported by Amoah et al. (2008) and Goodwin et al. (2002).

Feed conversion ratios for LMB in this study were similar to those reported for second year growout of LMB raised in ponds by Kubitza and Lovshin (1997) and Tidwell et al. (1996). However, FCRs of LMB in this study were lower than FCR reported for juvenile largemouth raised in aquaria by Tidwell et al. (2005) and Subhadra et al. (2006b). These differences are likely due to different development stages, differences related to the culture systems, or availability of natural foods in ponds. In any case, this research confirms that FCRs of 1.3–1.5 are achievable during second year growth of LMB.

Total feed consumption in fish fed the experimental diets was higher than those fed the CC diet. Tidwell et al. (2000) recommended the use of floating extruded diets for LMB production. However, the (≥20%) carbohydrate level required for pellet expansion and buoyancy has been found to negatively impact liver structure in LMB (Goodwin et al. 2002; Amoah et al. 2008). For this reason, the experimental diets in this study were formulated to contain ≤20% carbohydrate which resulted in "slow sink" pellets. The bass were observed to more actively consume these diets as they dropped through the water column compared with the more buoyant CC, especially on bright sunny days. This may have affected consumption in this experiment as fish were routinely fed during the mid-morning hours of 0830–1000.

During second year growout, LMB can be fed diets with fish meal levels as low as 8% of the total formulation without sacrificing growth. The lower FCR of the FM-24 diet should be considered, but was not reflected in a decreased cost of gain in fish fed that diet. A conservative recommendation could be to recommend that commercial diets contain 10–20% fish meal. However, if fish meal prices increase, these data indicate that levels as low as 8% of the total formulation should perform well. These data may not be applicable to first year fish which tend to have more stringent nutritional requirements. Future research should evaluate the effect of sinking, floating, and slow sink pellets on growth and feed conversion efficiency of LMB.

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