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Production Characteristics and Body Composition of Juvenile Cobia Fed Three Different Commercial Diets in Recirculating Aquaculture Systems

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Abstract.—The effect of feeding three commercial diets on production characteristics and body composition of juvenile cobia *Rachycentron canadum* reared using recirculating aquaculture systems (RASs) was assessed in a 56-d growth trial. Juvenile cobia (mean weight ± SE, 29.2 ± 0.7 g) were stocked into three 8-m^3 tanks in each of four RASs at an initial density of 1.2 kg/m^3. After stocking, fish were fed one of three commercial diets: Hybrid Striped Bass diet (HSB; 44% protein, 12% lipid), Finfish Gold diet (GOLD; 42% protein, 16% lipid), or Marine Grower diet (MG; 50% protein, 15% lipid), all at a targeted feed rate of 3–5% of body weight per day. At 2-week intervals, 10% of the population of each tank was collected to determine mean weight, weight gain, specific growth rate (SGR), feed conversion efficiency (FCE), and biomass. At the end of the rearing trial, the entire population of each tank was harvested to determine production characteristics and survival. In addition, fish were sampled to determine whole-body composition, hepatosomatic index, intraperitoneal fat ratio, energy retention (ER), protein efficiency ratio (PER), and protein productive value (PPV). Final weight (311.0 g), weight gain (281.8 g), SGR (4.23% per day), FCE (85.7%), biomass (11.20 kg/m^3), and ER (32.7%) of fish fed the MG diet were significantly greater than those of fish fed the HSB and GOLD diets. No differences in survival, gross energy, ash, or crude lipid content existed among fish fed the three diets. Lowest dry matter content, lowest PPV, and highest protein content were observed in fish fed the HSB diet. Highest PER was observed in fish fed the GOLD diet. Although the cost of production per kilogram for rearing juvenile cobia with the MG diet would be greater, this cost could be offset by the 15% reduction in rearing time required as compared with the HSB and GOLD diets.

Interest in culture of the cobia *Rachycentron canadum*, a migratory marine pelagic finfish and lone member of the family Rachycentridae (Smith 1986), has increased greatly in the United States over the course of the last decade. Cobia possess a number of attributes desirable for a commercially cultured fish. They can be spawned in captivity with or without hormonal induction (Dodd 2001; Franks et al. 2001; Arnold et al. 2002; Kilduff et al. 2002; Weirich et al. 2006), and protocols for larval rearing have been developed for the mass production of weaned juveniles to ensure a consistent and reliable supply of seed stock for on-growing operations (Liao et al. 2001; Holt et al. 2007; Benetti et al. 2008). Under suitable conditions,

cobia exhibit extremely rapid growth rates (Chou et al. 2001, 2004; Weirich et al. 2004; Lunger et al. 2006), attaining weights of 4–6 kg in less than 1 year (Chou et al. 2004; Liao et al. 2004); they adapt well to confinement and readily accept formulated feeds (Schwarz et al. 2004; Weirich et al. 2004), and they are of excellent food quality, with high consumer appeal (McClane 1974; Chen 2001; Oesterling 2001; Rickards 2001; Shiau 2007). These characteristics, coupled with the successful expansion and growth of cobia aquaculture in Taiwan, China, and southeast Asia (Liao et al. 2001, 2004; Liao 2003; De Silva and Phillips 2007), have served as stimulants for industry development elsewhere, including Central America and the Caribbean (Benetti et al. 2007, 2008).

Although the vast majority of farmed cobia are currently produced by net-pen rearing operations, establishment of land-based recirculating aquaculture

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system (RAS) technologies for cobia production could mitigate some of the issues associated with development of net-pen culture in U.S. waters, such as permitting, effluent discharge regulations, and restrictions on the use of coastal and offshore environments (Weirich et al. 2003). However, to be a feasible alternative, RASs must be both biologically and economically viable. Regarding the latter, because feed expense generally accounts for over 50% of annual operational costs for marine finfish aquaculture operations (Tucker 1998), development of cost-effective feeds and feeding strategies are of great importance to future development of cobia aquaculture, especially if practiced using RAS technologies.

While not yet as comprehensive as that previously established for other cultured marine finfish species, the scientific literature available on cobia nutrition has grown considerably in recent years. To date, several studies have been conducted with cobia on topics including ingredient digestibility (Zhou et al. 2004), dietary methionine and lysine requirements (Zhou et al. 2006, 2007), dietary fish meal replacement (Chou et al. 2004; Zhou et al. 2005; Lunger et al. 2006, 2007a, 2007b), and optimal protein and lipid levels (Chou et al. 2001; Wang et al. 2005; Craig et al. 2006). Nonetheless, no commercial diets specifically for feeding cobia are currently available in the United States; therefore, producers must use diets developed for other finfish species. The present study was conducted to compare the effect of three available commercial diets with different protein and lipid contents on the production characteristics and body composition of juvenile cobia reared in RASs.

Methods

Experimental systems.—Studies were conducted in four replicate RASs located within the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS) Sustainable Tank Aquaculture Recirculating Research Facility on the campus of Harbor Branch Oceanographic Institute (HBOI) at Florida Atlantic University (FAU), Fort Pierce. Each 45-m³ RAS consisted of four 8-m³ round fiberglass culture tanks engineered with a Cornell dual-drain system (Timmons et al. 1998). Primary solids removal was accomplished by a 600-L Wave 36 vortex filter (W. Lim Corp., Mira Loma, California) attached to each tank and a centralized Hydrotech 801 drum filter equipped with a 40-μm screen (Water Management Technologies, Inc., Baton Rouge, Louisiana). Water was circulated by two 1.5-kW pumps through two 0.7-m³ propeller-washed bead filters (PWBF; Aquaculture Systems Technologies, New Orleans, Louisiana) for biofiltration and fine solids removal. Each RAS also

included a 2.2-m³ oxygen injection cone (Waterline Ltd., Charlottetown, Prince Edward Island), two degassing towers, and a 520-W multi-lamp ultraviolet sterilization unit (Emperor Aquatics, Inc., Pottstown, Pennsylvania). Plastic nets (0.95-cm mesh) were placed over each tank to prevent fish escape. A 12 h light : 12 h dark photoperiod (surface light level = 50–200 lx) was provided with overhead fluorescent lights. During the study, each of the two PWBF units servicing each RAS was backwashed every other day on a rotating schedule (Pfeiffer and Malone 2006). Settled sludge was removed from PWBF units, wave vortex filters, and tank-bottom drain lines daily. Daily water loss from systems was less than 4% of total system volume. Water used to supply the RASs was obtained from two sources located on the campus of HBOI–FAU. Saline water was pumped from a 7-m-deep well adjacent to the Indian River Lagoon, and brackish water was obtained from a 600-m-deep well. Both water sources were subjected to biological and mechanical filtration before entry into experimental units via float valves installed in system sumps. During the study, salinity of the saline- and brackish-water sources ranged from 28 to 33 g/L and from 1.0 to 1.5 g/L, respectively.

Experimental design, husbandry, and sampling protocol.—At the start of the 56-d rearing trial, juvenile cobia reared from recently metamorphosed postlarvae obtained from the Rosenstiel School of Marine and Atmospheric Science, University of Miami, were stocked into three tanks in each of the four RASs at an initial nominal density of 1.2 kg/m³, equivalent to 324 fish/tank. Mean (±SE) weight of fish at stocking was 29.2 ± 0.7 g (n = 100). Dietary treatments were assigned using a randomized complete block design with four replicates per treatment. At initiation of the rearing trial, 15 fish were collected and preserved at −20°C for subsequent whole-body composition analysis. After stocking, fish were hand fed one of three commercial diets: Hybrid Striped Bass (HSB; 44% protein, 12% lipid; floating pellet), Finfish Gold (GOLD; 42% protein, 16% lipid; floating pellet), or Marine Grower (MG; 50% protein, 15% lipid; slow-sinking pellet) twice daily at 0900 and 1500 hours. All diets were manufactured by Zeigler Brothers, Inc., Gardners, Pennsylvania. Fish were allowed 30 min to consume allotted rations at each feeding period. Food particle size of each diet fed from day 1 through day 42 was 3.0 mm; thereafter, fish were fed 5.0-mm diets until the conclusion of the trial. The targeted feed rate throughout the study ranged from 3% to 5% of body weight per day, which was achieved by increasing feed distributed to each tank by a factor of 4% daily. At stocking and at 2-week intervals thereafter, 10% of the fish population of each tank was randomly collected

and individual weights were recorded to the nearest 1.0 g to determine production characteristics: mean weight, weight gain, specific growth rate (SGR), feed conversion efficiency (FCE), and biomass. Specific growth rate was calculated by using the formula: $[\log_{10}(W_t) - \log_{10}(W_i)]/t \times 100$ (where W_t = weight at the end of a sampling period, W_i = initial weight, and t = length of time of the sampling period in days). Feed conversion efficiency was calculated by using the formula: [(wet weight gain, g)/(dry weight of feed fed, g)] $\times$ 100. Mean weight of fish from each treatment was used to recalculate appropriate feed rations. Mortalities were removed and recorded daily as necessary to estimate percent survival at each sampling period. At the termination of the rearing trial, the entire population of each tank was harvested and group weights of 20–30 fish each were obtained to determine production characteristics and survival. In addition, five fish were obtained from each tank to determine the hepatosomatic index (HSI = [liver weight/body weight] $\times$ 100) and intraperitoneal fat ratio (IPF = [intraperitoneal fat weight/body weight] $\times$ 100), and 15 fish were collected and preserved at $-20°C$ for subsequent whole-body composition analysis. Total length (TL) of individually weighed fish from each tank at stocking and at termination was measured to determine condition factor (K) using the formula: $K = 100 \times (W/L^3)$, where W is weight (g) and L is TL (cm).

Whole-body composition and nutritional indices.— Standard procedures were used for determining proximate components of fish and the diet fed during the rearing trial (AOAC 2003). Pooled whole-body samples were minced in a meat grinder and further homogenized using mortar and pestle. Two samples from each homogenized pool were taken for moisture analysis and dried at $105°C$ for 24 h. Tissues remaining in the pooled samples were analyzed for crude protein (CP), crude lipid (CL), ash, and gross energy (GE). Nitrogen was determined by combustion (TruSpec N-elemental analyzer; Leco Corp., St. Joseph, Michigan), and CP was calculated as N $\times$ 6.25. Ash was determined after incineration at $600°C$ for 2 h. Crude lipid was determined gravimetrically after chloroform–methanol extraction (Bligh and Dyer 1959) in a Soxhlet apparatus. Gross energy was determined by adiabatic bomb calorimetry (Parr Model 1266; Parr Instruments Co., Moline, Illinois). In addition to proximate components, energy retention (ER), protein efficiency ratio (PER), and protein productive value (PPV) were determined. Energy retention was calculated using the formula: $(W_t \times E_t - W_i \times E_i)/\text{FI} \times E$ (where W_t = weight at the end of a sampling period; W_i = initial weight; FI = feed intake; and E, E_t, and E_i = energy content of the diet, fish at termination, and fish

at initiation of the rearing trial, respectively). The PER was calculated using the formula: (wet weight gain, g)/(protein intake, g). The PPV was calculated using the formula: $(W_t \times P_t - W_i \times P_i)/\text{FI} \times P$ (where P, P_t, and P_i = protein content of the diet, fish at termination, and fish at initiation of the rearing trial, respectively).

Water quality.—Temperature, salinity, and pH of each RAS sump and dissolved oxygen of each culture tank were measured twice daily at 0900 and 1700 hours during the rearing trial. Total ammonia nitrogen (TAN), nitrite-nitrogen (NO_2-N), and alkalinity of each RAS were measured daily between 1000 and 1200 hours. Temperature and dissolved oxygen were measured using a Hach LDO HQ10 meter (Hach Co., Loveland, Colorado), and salinity and pH were measured using a YSI 556 meter (YSI, Inc., Yellow Springs, Ohio). Concentrations of TAN and NO_2-N were determined via Hach colorimetric assays (methods 8155 and 8153, respectively) using a Hach D/R 2500 spectrophotometer. Alkalinity was determined using the Hach digital titration method 8203. Water temperature and salinity ranged from $27.0°C$ to $30.5°C$ and from 25.0 to 30.4 g/L, respectively. Postfeeding dissolved oxygen levels were maintained at above 80% saturation. Levels of TAN and NO_2-N were each maintained at levels below 0.4 mg/L. Alkalinity was maintained at approximately 300 mg/L as $CaCO_3$. The pH ranged from 7.1 to 8.2. Sodium bicarbonate was added daily to systems to maintain alkalinity levels. To reduce the potential for parasitic infections, copper sulfate was added daily to experimental systems to maintain a level of 0.25 mg/L (as Cu^{2+}). Concentrations were verified daily with a copper test kit (Red Sea, Ellat, Israel).

Statistical analyses.—Statistical analyses were performed using SigmaStat version 3.0 (SPSS, Inc., Chicago, Illinois). Percentage data were arcsine, square-root transformed before analysis. All data were subjected to analysis of variance, and means separation was achieved using Tukey's studentized range test at a significance level α of 0.05.

Results

With the exception of feed fed at day 14 and survival throughout the rearing trial, significant differences in measured production variables were evident at each sampling date and at the termination of the trial (Table 1). Final mean weight of juvenile cobia fed the MG diet (311.0 g) was significantly greater than that of fish fed the HSB (212.0 g) and GOLD (216.6 g) diets. Final weight gain of fish fed the MG diet (281.8 g) was greater ($P < 0.001$) that that of fish fed the HSB (182.8 g) and GOLD (187.4 g) diets. The SGR of juvenile cobia fed each diet decreased only slightly on a

TABLE 1.—Weight, weight gain, specific growth rate (SGR), feed conversion efficiency (FCE), feed fed, and survival of juvenile cobia (initial weight = 29.2 g) fed three different commercial diets for 56 d in recirculating aquaculture systems (see text for description of HSB, GOLD, and MG diets). Values (mean ± SE) within columns for each sample day that share the same letter are not significantly different ($P > 0.05$).

Day	Diet	Weight (g)	Weight gain (g)	SGR (%/d)	FCE (%)	Feed fed (g/fish)	Survival (%)
14	HSB	52.4 ± 0.8 y	23.3 ± 0.5 y	4.19 ± 0.06 y	70.8 ± 1.4 y	32.9 ± 0.1 z	99.6 ± 0.2 z
	GOLD	54.5 ± 0.8 y	25.3 ± 0.7 y	4.46 ± 0.09 y	76.6 ± 2.2 y	33.1 ± 0.1 z	99.0 ± 0.3 z
	MG	58.7 ± 0.9 z	29.5 ± 0.5 z	4.99 ± 0.06 z	89.8 ± 1.6 z	33.0 ± 0.1 z	99.4 ± 0.2 z
28	HSB	84.5 ± 1.2 x	55.3 ± 0.7 x	3.80 ± 0.03 x	67.9 ± 0.9 y	81.4 ± 0.2 x	99.3 ± 0.3 z
	GOLD	92.5 ± 1.3 y	63.3 ± 2.2 y	4.12 ± 0.08 y	75.0 ± 2.4 y	84.4 ± 0.3 y	98.9 ± 0.4 z
	MG	110.3 ± 1.5 z	81.1 ± 1.9 z	4.75 ± 0.06 z	91.5 ± 2.3 z	88.7 ± 0.3 z	99.1 ± 0.3 z
42	HSB	135.5 ± 2.2 x	106.4 ± 3.8 x	3.66 ± 0.07 x	69.5 ± 2.5 y	153.0 ± 0.4 y	99.3 ± 0.3 z
	GOLD	151.9 ± 2.6 y	122.7 ± 3.6 y	3.93 ± 0.06 y	75.6 ± 1.7 y	156.3 ± 1.6 y	98.9 ± 0.4 z
	MG	194.6 ± 3.3 z	165.4 ± 3.9 z	4.51 ± 0.05 z	89.5 ± 1.9 z	184.9 ± 0.6 z	99.1 ± 0.3 z
56	HSB	212.0 ± 3.2 y	182.8 ± 3.2 y	3.54 ± 0.03 y	69.9 ± 0.8 y	261.5 ± 1.6 y	98.9 ± 0.5 z
	GOLD	216.6 ± 3.7 y	187.4 ± 3.7 y	3.58 ± 0.03 y	70.8 ± 0.4 y	264.6 ± 4.0 y	98.8 ± 0.8 z
	MG	311.0 ± 3.3 z	281.8 ± 3.3 z	4.23 ± 0.02 z	85.7 ± 0.5 z	329.1 ± 5.4 z	97.9 ± 1.2 z

temporal basis. Fish fed the MG diet exhibited significantly higher SGR values than fish fed the HSB and GOLD diets at each sampling period and at the termination of the trial. Final SGRs of fish fed the HSB, GOLD, and MG diets were 3.54, 3.58, and 4.23% per day, respectively. The FCE of fish fed each diet also remained constant during the trial. Juvenile cobia fed the MG diet had greater FCE values at each sampling period and at the conclusion of the trial than fish fed the HSB and GOLD diets ($P < 0.001$). Final FCE values of fish fed the HSB, GOLD, and MG diets were 69.9, 70.8, and 85.7%, respectively. The amount of feed fed to fish of each treatment was significantly different at days 28, 42, and 56. The total amount of feed fed to fish receiving the MG diet during the trial (329.1 g) was greater than the amount fed to fish receiving the HSB (261.5 g) or GOLD (264.6 g) diet ($P < 0.001$). Tank biomass of fish fed the MG diet was significantly greater than that of fish fed the HSB and GOLD diets at each sampling period and also at the end of the trial. Final tank biomasses of fish fed the HSB, GOLD, and MG diets were 7.35, 7.53, and 11.20 kg/m^3, respectively. Final survival rates of fish fed the

HSB, GOLD, and MG diets were 98.9, 98.8, and 97.9%, respectively.

Initial K of fish measured at stocking was 0.491 ± 0.03. Final K was 0.729 ± 0.01 for fish fed the HSB diet, 0.732 ± 0.07 for fish fed the GOLD diet, and 0.716 ± 0.06 for fish fed the MG diet. No significant differences in K existed between dietary treatments.

Proximate composition of the commercial diets fed to fish during the rearing trial is shown in Table 2. The HSB diet contained significantly lower GE (5,063 cal/g) and dry matter (89.3%) content than did the GOLD and MG diets. Ash and CP content of each diet was significantly different, and both variables were lowest in the GOLD diet (7.2% and 43.2%, respectively). Crude protein level of the HSB and MG diets was 46.9% and 54.7%, respectively. Crude lipid content of the MG diet (9.9%) was lower than that of the HSB (16.4%) and GOLD (13.8%) diets ($P = 0.01$).

Whole-body composition of juvenile cobia sampled from each dietary treatment at the conclusion of the rearing trial is presented in Table 3. No differences in GE, ash, or CL content existed among fish fed the three diets assessed. The CL content of fish fed HSB,

TABLE 2.—Proximate composition of commercial diets fed to juvenile cobia during the experimental rearing trial (see text for description of diets). Values (mean ± SE; expressed on a dry-weight basis) within a row sharing the same letter are not significantly different ($P > 0.05$).

Variable	Diet		
	HSB	GOLD	MG
Gross energy (cal/g)	5,063 ± 29 y	5,338 ± 21 z	5,237 ± 20 z
Dry matter (%)	89.3 ± 0.1 y	89.9 ± 0.1 z	90.1 ± 0.1 z
Ash (%)	8.3 ± 0.2 y	7.2 ± 0.2 x	10.9 ± 0.0 z
Crude protein (%)	46.9 ± 0.1 y	43.2 ± 0.1 x	54.7 ± 0.3 z
Crude lipid (%)	16.4 ± 0.1 z	13.8 ± 0.6 z	9.9 ± 0.8 y

TABLE 3.—Whole-body composition of juvenile cobia fed three different commercial diets for 56 d in recirculating aquaculture systems (see text for description of diets). Values (mean ± SE; expressed on a dry-weight basis) within a row sharing the same letter are not significantly different ($P > 0.05$).

Variable	Diet		
	HSB	GOLD	MG
Gross energy (cal/g)	6,034 ± 47 z	6,019 ± 42 z	6,071 ± 57 z
Dry matter (%)	29.1 ± 0.2 y	31.6 ± 0.3 z	32.2 ± 0.2 z
Ash (%)	10.0 ± 0.3 z	9.8 ± 0.6 z	9.2 ± 0.4 z
Crude protein (%)	55.5 ± 0.3 z	50.7 ± 0.4 y	51.9 ± 0.2 y
Crude lipid (%)	23.6 ± 2.9 z	28.4 ± 3.2 z	26.6 ± 1.1 z

GOLD, and MG diets was 23.6, 28.4, and 26.6%, respectively. Dry matter content of fish fed the HSB diet (29.1%) was significantly lower than that of fish fed the GOLD (31.6%) and MG (32.2%) diets. The CP content of fish fed the HSB diet (55.5%) was greater ($P < 0.001$) than that of fish fed the GOLD (50.7%) and MG (51.9%) diets.

Significant differences existed among dietary treatments in ER, PER, PPV, HSI, and IPF (Table 4). The ER of fish fed the MG diet (32.7%) was significantly greater than that of fish fed the HSB (24.8%) and GOLD (26.1%) diets. The PER of fish fed each diet was different ($P < 0.001$) and was highest for fish fed the GOLD diet (1.64). The PER was 1.49 for fish fed the HSB diet and 1.57 for fish fed the MG diet. Fish fed the HSB diet had a significantly lower PPV (30.2%) than did fish fed the GOLD (32.9%) and MG (32.8%) diets. Fish fed the MG diet had a lower ($P < 0.001$) HSI (4.29%) than fish fed the HSB (4.95%) and GOLD (5.33%) diets. Fish fed the MG diet had a significantly higher IPF (0.18%) than fish fed either the HSB (0.05%) or GOLD (0.08%) diet.

Discussion

The aim of this study was to compare three different diets that were commercially available in North America, that had different protein and lipid levels, and that were specifically formulated for carnivorous fishes cultured in commercial-scale tanks. Diets from a single feed producer were selected for comparison to control for variability that could be encountered between different manufacturers in terms of sources of dietary components used for formulations (e.g., protein quality). All three diets provided growth rates, FCEs, and survival rates that were comparable with those in other studies that have assessed production of juvenile cobia in RASs (Resley et al. 2006; Faulk et al. 2007; Webb et al. 2007). However, it is clear that the MG diet out-performed both of the other diets.

These results are not surprising considering the higher protein levels present in the MG diet as compared with the GOLD and HSB diets. They are surprising, however, when compared with the results of Craig et al. (2006), which indicated no significant difference in most production metrics of juvenile cobia fed six diets with varying protein and fat levels (levels that were similar to those used in the present study). The only difference those authors noted was a significantly lower feed efficiency in juveniles (initial weight = 7.4 g) fed a diet with 50% protein compared with a 40% protein diet. This effect was not seen in their larger fish (mean initial weight = 49.3 g), and we did not see this effect in our results with intermediate-sized fish (mean initial weight = 29.2 g). In fact, we

TABLE 4.—Selected dietary efficiency variables, hepatosomatic index (HSI), and intraperitoneal fat ratio (IPF) of juvenile cobia fed three different commercial diets for 56 d in recirculating aquaculture systems (see text for description of diets). Values (mean ± SE) within a row sharing the same letter are not significantly different ($P > 0.05$).

Variable	Diet		
	HSB	GOLD	MG
Energy retention (%)	24.8 ± 0.6 y	26.1 ± 0.4 y	32.7 ± 0.3 z
Protein efficiency ratio	1.49 ± 0.02 x	1.64 ± 0.01 z	1.57 ± 0.01 y
Protein productive value (%)	30.2 ± 0.6 y	32.9 ± 0.5 z	32.8 ± 0.1 z
HSI (%)	4.95 ± 0.18 z	5.33 ± 0.15 z	4.29 ± 0.13 y
IPF (%)	0.05 ± 0.01 y	0.08 ± 0.01 y	0.18 ± 0.03 z

noted significantly higher FCE values for cobia fed the higher-protein MG diet. Our results are consistent with those of Chou et al. (2001), who demonstrated differences in growth and FCE with different levels of protein and lipid in the diet.

The present study, however, was not designed to directly assess the effect of protein or lipid levels on growth, since this has been well evaluated in cobia. Rather, the aim was to assess the effect of selected commercial diets administered in production-scale RASs on the production characteristics of juvenile cobia. It appears, though, that there is a lack of consistency between our production-scale (8,000-L tanks) results and the results of experimental studies by Craig et al. (2006), which were conducted in 110-L glass aquaria. Behaviorally, the cobia is a pelagic species and probably prefers a less-restrictive environment, such as the relatively large tanks used in our study. It is quite possible that, in studies conducted in small aquarium-sized tanks, even a small cobia would experience a greater degree of stress as a result of confinement. Alteration of production characteristics, such as growth rate, by chronic stress related to the restricted environment (Huntingford et al. 2006) could mask the dietary effects being measured in studies using aquarium-sized tanks. Environmental factors, such as shape of rearing environment and degree of confinement, have been shown to affect stress and production characteristics of fish (Barcellos et al. 2004; Barretto and Volpato 2004).

Based on the proximate composition of fish fed the three different diets, whole-body deposition of lipids was equivalent. However, there appeared to be a difference in the tissues where lipids were deposited. Fish fed the HSB and GOLD diets appeared to store energy in liver tissue based on their elevated HSI values, whereas the MG-fed fish were beginning to store lipid in the intraperitoneal tissues. Wang et al.

(2005) noted a direct correlation between liver lipid levels and HSI values of juvenile cobia. In addition, the higher whole-body protein and PPV values of cobia fed the HSB diet may indicate a protein-sparing effect due to the higher dietary lipids. Protein sparing in high-lipid diets has been well documented in fish nutrition (Halver and Hardy 2002). However, protein sparing in cobia has not been documented in previous studies that systematically compared the effects of protein and lipid levels on production characteristics (Chou et al. 2001; Wang et al. 2005; Craig et al. 2006).

Feed represents the largest variable cost component in the production of carnivorous fishes, and using an appropriately formulated ration is critical in keeping cost down and minimizing metabolic waste products (Craig et al. 2006). Although the high-protein MG diet in our study produced higher growth rates and FCE values, the actual cost of feed per kilogram of fish produced was US$1.23 for MG, $0.99 for HSB, and $0.99 for GOLD. Given the calculated growth rates for each diet, the HSB diet would require an additional 11 d for fish to reach 310 g and fish fed the GOLD diet would require an additional 10 d. The cost of cobia production based on use of MG would only be equivalent to the other diets if the faster growth rate compensated for the additional cost of operating the rearing system for 10–11 d (i.e., approximately a 15% reduction in rearing time).

Conclusions

The MG diet performed better than either the HSB or GOLD diet in terms of growth rate, weight gain, and FCE for the rearing of juvenile cobia from a 29.2-g starting weight to a final weight of over 200 g. All three diets, however, performed well for rearing juvenile cobia. The difference in cost for rearing juvenile cobia with the MG diet rather than the HSB or GOLD diet could be compensated for by a 15% shorter production period.

Acknowledgments

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