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The effects of dietary protein level on growth, feed efficiency and survival of juvenile Florida pompano (*Trachinotus carolinus*)

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Abstract

Florida pompano is considered a suitable candidate for mariculture due to its ready adaptation to culture systems, acceptance of formulated feeds, and rapid growth rates. Little information on the nutritional requirements or growth rates under controlled conditions have been reported. A seven week feeding experiment was conducted with juvenile fish (mean wt. 4.5 g) to evaluate the effect of dietary protein level on growth, feed intake, feed utilization and survival. Four practical diets were formulated to be isoenergetic and to contain increasing levels of protein (30, 35, 40 or 45% crude protein). Although total feed intake was not significantly different among treatments, feed intake expressed as amount consumed per unit of body weight was significantly different among treatments. Fish fed the highest protein diet had lower percentage daily feed consumption values than did fish fed the lowest protein diet. Growth and feed efficiency ratios increased with dietary protein level and were highest for fish fed the diet containing 45% protein. The results obtained in the present study indicate that juvenile Florida pompano required a minimum of 45% protein for maximum growth and feed efficiency ratio when fish meal and soybean meal are the primary sources of protein. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Florida pompano; Protein requirements; Fish nutrition; Fish culture

1. Introduction

Florida pompano (*Trachinotus carolinus*) is a popular jack fish, sought by both sport and commercial fishermen (Hoese and Moore, 1992). It is one of the most highly

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desired marine fish species and comprises a small but important fishery in the Gulf of Mexico, particularly in Florida (Berry and Iversen, 1966). The Atlantic and Gulf of Mexico commercial fishery reported an average catch of approximately 400 metric tons per year during 1950–1996 with an average commercial landing value of US\$1,400,000 per year (National Marine Fisheries Service, personal communication). Over the last ten years prices have increased to an average commercial value of US\$6.6/kg.

Because of its acceptance as an excellent food fish, high market price and adaptability to intensive culture systems, ready acceptance of formulated feeds and relatively rapid growth rate, the Florida pompano has been considered a suitable candidate species for commercial culture (Williams et al., 1985). Since the late 60s, there has been considerable interest in commercial culture of the Florida pompano, which has led to several studies on the biology and ecology of this species (Berry and Iversen, 1966; Bellinger and Avault, 1971; Armitage and Alevizon, 1980; Gomez and Larez, 1983). In nature, juvenile Florida pompano seem to be opportunistic feeders, preying mainly on invertebrates such as small clams, amphipods, polychaetes and shrimp as well as small fishes (Berry and Iversen, 1966; Bellinger and Avault, 1971). Juvenile pompano growth rates have been estimated at 1.2 to 3.2 cm per month, with a mean of about 2.5 cm per month (Berry and Iversen, 1966).

The success of a commercial aquaculture operation depends on a variety of factors within the fields of biology, engineering and economics. One key biological component is the availability of suitable diets that are efficiently digested and provide the required nutrients to support good growth and health. Most research in captivity has been conducted in cages or pond polyculture systems with little control of environmental parameters (Tatum, 1972; Gomez and Scelzo, 1982; Gomez and Larez, 1983). Little information on the nutritional requirements of Florida pompano under controlled conditions have been reported. Williams et al. (1985) reported that the optimum level of fish oil in a 42% protein fish and soybean meal diet for juvenile pompano was between 4 and 8% of the diet. More research is needed to optimize the level of inclusion of other nutrients in the diets such as protein and energy.

Protein is usually the most expensive component in the diet of fish species in culture, hence dietary protein levels directly affect production cost. Most marine fish diets contain a relatively high level of protein because carnivorous species have higher protein requirements than do non-carnivorous species (NRC, 1983; Wilson, 1989). Currently little is known about the optimum dietary protein level for juvenile Florida pompano. Consequently, the objective of this research was to evaluate the effect of different protein levels on growth, feed conversion efficiency and survival of wild caught juvenile Florida pompano under controlled experimental conditions.

2. Materials and methods

A seven-week feeding experiment was conducted to evaluate the effect of dietary protein levels on growth, feed utilization and survival of juvenile Florida pompano (*T. carolinus*). Four practical diets were formulated to contain increasing levels of protein

(30, 35, 40 or 45%) derived primarily from menhaden fish meal (Table 1). Feed ingredients were ground with a laboratory hammer-type mill with a # 40 mesh screen (1.02-mm diameter hole). Once the ingredients were ground, they were thoroughly blended with the oil using a food mixer (Hobart, Troy, OH) for 15 min. Hot water was subsequently added to the mash to attain the desired consistency for pelleting. Each diet was then extruded in a meat grinder using a 3 mm die and dried for 4 h below 45°C and subsequently air-dried overnight to a moisture content less than 10%.

Juvenile Florida pompano were caught with a seine at beaches of Mustang Island in the Gulf of Mexico, near Port Aransas, TX, during July 1997. Fish were transported to the Fisheries and Mariculture Laboratory of the University of Texas at Austin, Marine Science Institute and placed in a 1000-l raceway for acclimation. After one week the fish were hand-graded to a uniform size and stocked in groups of 12 at a similar biomass in

Table 1
Composition of test diets (g/100 g dry wt.)

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4
Menhaden fish meal ^a	20.70	23.30	26.70	30.00
Soybean meal ^b	34.00	39.70	45.00	51.00
Wheat starch ^c	35.59	27.54	19.09	10.04
Menhaden fish oil ^d	4.75	4.50	4.25	4.00
Fish solubles ^a	0.50	0.50	0.50	0.50
Soy lecithin ^e	0.50	0.50	0.50	0.50
Trace mineral premix ^f	0.50	0.50	0.50	0.50
Vitamin premix ^g	3.00	3.00	3.00	3.00
Vitamin C ^h	0.06	0.06	0.06	0.06
Sodium phosphate Monohydrate ⁱ	0.40	0.40	0.40	0.40
Formulated to contain				
Protein	30	35	40	45
(as analyzed)	(30.6)	(36.0)	(40.7)	(44.2)
Lipid	8.0	8.0	8.1	8.1
Energy (kcal/100 g) ^j	405	404	403	402
E:P	13.2	11.5	10.1	8.9

^aSpecial Select™, Zapata Haynie, Hammond, LA, USA.

^bSolvent extracted, Producers Cooperative, Bryan, TX, USA.

^cUnited States Biochemical, Cleveland, OH, USA.

^dZapata Protein, Reedville, VA, USA.

^eAqualipid 95, Central Soya Chemurgy Division, Fort Wayne, IN, USA.

^fg/100 g premix: cobalt chloride, 0.004; cupric sulfate pentahydrate, 0.250; ferrous sulfate, 4; magnesium sulfate heptahydrate, 28.398; manganous sulfate monohydrate, 0.650; potassium iodide, 0.067; sodium selenite, 0.010; zinc sulfate heptahydrate, 13.193; filler, 53.428.

^gg/kg premix: thiamin HCl, 0.5; riboflavin, 3; pyridoxine HCl, 1; DL Ca-pantothenate, 5; nicotinic acid, 5; biotin, 0.05; folic acid, 0.18; vitamin B-12, 0.002; choline chloride, 100; inositol, 5; menadione, 2; vitamin A acetate (20,000 IU/g), 5; vitamin D (400,000 IU/g), 0.002; DL-alpha-tocopherol acetate (250 IU/g), 8; alpha-cellulose, 856.26.

^hStay C, L-ascorbyl-2-polyphosphate, Hoffman-LaRoche, Nutley, NJ, USA.

ⁱSpectrum Chemical, Gardendale, CA, USA.

^jEnergy values are estimated based on 4 kcal/g for protein and carbohydrate sources and 9 kcal/g for lipid sources.

each of 12 round fiberglass tanks containing 240-l of seawater. The tanks were connected as a semi-closed recirculating system equipped with a biological filter, sand filter, circulating pump and supplemental aeration. Fish were acclimated to experimental conditions for one week and were fed to satiation with a commercial trout feed (Salmon and trout starter # 3 with 50% protein; Rangen, Bulh, ID). Photoperiod was set to a 12:12 light/dark cycle throughout the study.

Following the acclimation period, the fish were weighed (mean initial weight 4.5 g/fish) and stocked at a uniform biomass at a density of 10 fish per tank. The experimental diets were randomly assigned to each of the 12 tanks for a total of three replicate tanks per treatment. Eight fish from the initial population were collected and frozen at -60°C for analysis of body composition. Based on visual observations, fish were fed to apparent satiation twice per day (morning and afternoon) during a 45-min period. The amount of feed consumed by the fish in each tank was recorded daily.

Fish were counted and weighed weekly and the tanks were scrubbed and siphoned as needed. Water quality parameters measured daily were as follows (means \pm standard deviation): temperature, $30.8 \pm 0.19^{\circ}\text{C}$; dissolved oxygen, 5.7 ± 0.10 mg/l; salinity, $35.0 \pm 0.17\%$. Total ammonia–nitrogen, nitrate–nitrogen levels and pH were monitored twice each week using photometric methods (Spotte, 1979) and a pH meter and were determined to be 0.09 ± 0.02 mg/l and 0.04 ± 0.02 mg/l and 7.8 ± 0.1 , respectively.

At the end of the experiment, fish were weighed to obtain a final mean weight. A random sample of six fish from each tank were collected, homogenized in a food processor and frozen at -60°C for subsequent proximate analyses. All biochemical analyses were conducted in triplicate. Representative portions of samples were dried to a constant weight in an oven maintained at 90°C . Protein content was determined by the micro-Kjeldahl method (Ma and Zuazago, 1942). Crude lipids were determined by the method of Folch et al. (1957). Feed conversion efficiency (FCE) was calculated for each treatment as the weight gain per unit of dry weight of feed fed (weight gain/dry feed $\times 100$). In addition, protein conversion efficiency (PCE) was calculated as the grams of protein gain per grams of protein fed (protein gain/protein offered $\times 100$). Protein efficiency ratio (PER) was calculated as the ratio of grams of protein feed per unit of wet weight gain (protein fed/wet weight gain). Percent daily feed consumption (PDFC) was calculated as the average feed consumed per day divided by the average body weight of the fish at the beginning of each week (feed consumed/body weight $\times 100$).

All data were analyzed using one-way analysis of variance. To minimize the effects of body weight on the analysis of PDFC, analysis of covariance was used with weekly initial body weight as the covariant. The Student–Neuman Keul's multiple-range test (Steel and Torrie, 1980) was used to determine significant differences ($P < 0.05$) between treatments means. Statistical analyses were performed using SAS System for Windows (v 6.11, SAS Institute, Cary, NC).

3. Results

Total feed intake during the 7-week experiment increased with decreasing dietary protein content, but there were no significant differences among dietary treatments.

Table 2

Response of juvenile Florida pompano (mean initial weight 4.54 g) fed diets containing varying levels of dietary protein levels on growth parameters and feed consumption¹

Diet	Dietary protein (%)	Weight gain	% PDFC ²	Protein intake g	PER ³	Percentage		
						FCE ⁴	PCE ⁵	Survival
1	30	18.9 ^a	13.2 ^a	18.1 ^a	1.0	31.2 ^a	17.6	100
2	35	19.4 ^a	12.0 ^{ab}	19.7 ^a	0.9	34.6 ^a	16.5	100
3	40	21.9 ^{ab}	10.9 ^{bc}	21.9 ^{ab}	1.0	40.1 ^b	17.3	100
4	45	26.2 ^b	9.1 ^c	22.9 ^b	1.5	51.4 ^c	19.7	100
PSE ⁶		1.52	0.66	0.96	0.03	1.44	0.89	

¹ Means of three replicates. Numbers in the same column with different superscript are significantly different ($P < 0.05$).

² Percent daily feed consumption (daily feed consumed/body weight * 100)

³ Protein efficiency ratio (protein fed/wet weight gain).

⁴ Feed conversion efficiency (weight gain/dry fed * 100).

⁵ Protein conversion efficiency (protein gain/protein offered * 100).

⁶ Pooled standard error.

Total feed intake values (mean \pm standard deviation) for fish receiving diets containing protein levels of 45, 40, 35 and 30% were 50.95 ± 3.54 , 54.76 ± 2.24 , 56.27 ± 3.58 and 60.24 ± 8.35 g of feed, respectively. Percent daily feed consumption averaged over the 7-week period ranged from 13.2 to 9.1%. These values increased significantly as dietary protein decreased (Table 2).

Protein intake, weight gain and FCE increased significantly with protein content of the diet (Table 2). Fish offered diets containing 45% protein consumed significantly more dietary protein than did fish fed diets containing 30 or 35% protein. Highest growth and FCEs were observed for the fish fed diet containing 45% protein, however weight gain was not significantly different from the group fed the 40% protein diet. No significant differences were found among any of the variables measured for fish fed diets containing 35 and 30% protein. No significant differences in PCE or PER were

Table 3

Body composition of Florida pompano fed graded levels of dietary protein^a

Diet	Dietary protein (%) ^b	Dry matter (%)	Protein (%) ^b	Lipid (%) ^b
1	30	31.1	53.5	21.6
2	35	31.1	55.1	20.9
3	40	30.8	55.8	19.6
4	45	30.7	55.1	18.5
PSE ^c		0.60	1.16	2.03

^a No significant differences were found ($P > 0.05$).

^b Express on a dry weight basis.

^c Pooled standard error.

Values represent means of three replicates.

observed among dietary treatments. Over the course of the experiment survival was 100% and hence not affected by dietary treatment. Biochemical analyses indicated that the lipid content of the fish decreased with increasing dietary protein levels, but no significant differences in the proximate composition of whole body samples were observed (Table 3).

4. Discussion

The fish easily adapted to the culture systems and had excellent survival (100%). During the acclimation period and feeding trials fish readily accepted both commercial and experimental diets and were satiated within 35 to 45 min of each feeding period. Final weight of fish fed the 45% protein diet was comparable to values reported by other authors for Florida pompano juveniles of about the same size (about 4 g) and fed diets of 40 to 45% protein (ca. 0.5 g/d; Tatum, 1972; Gomez and Larez, 1983).

For maximum growth and feed conversion efficiency the Florida pompano required a minimum dietary protein level of 45%. This value is within the range of 40–55% reported for a variety of carnivorous fish species (NRC, 1983; Steffens, 1989; Wilson, 1989; Jobling, 1994). Improved growth and feed conversion efficiency with increasing dietary protein levels as observed in this study are well documented with other species. Jirsa et al. (1997) obtained a significant increase in weight gain, feed conversion efficiency and protein conversion efficiency with red drum (*Sciaenops ocellatus*) fed increasing levels of dietary protein and energy levels (from 32 to 44% protein and 3.4 to 3.8 kcal/kg energy). Similarly other authors have reported higher weight gain and better FCEs with increasing protein content of the diet with several other species of fish such as rainbow trout (Tiews et al., 1976); Arctic char (Tabacheck, 1986); and European catfish; (Hilge and Grop, 1985). Since no growth plateau was observed over the protein levels tested, a minimal dietary protein requirement cannot be determined (i.e., 'broken-line' technique; Zeitoun et al., 1973). One can only conclude that under the described culture conditions the protein requirement is no less than 45% of the diet.

Since no significant differences were observed in PCE and PER it appears that the energy provided by the experimental diets was not limiting with respect to protein. It seems that protein intake was proportionally utilized for growth and energy sources such as lipids and carbohydrates were adequately utilized to meet energy requirements. There were no significant differences in the proximate composition of the fish, hence one can conclude that the P:E ratio of the diets was adequate.

If feed intake is expressed as feed consumed per unit of body weight, there were significant differences in average percent daily feed consumption (PDFC) per unit of body weight (Table 2). Fish fed the highest protein diet had lower PDFC than those fish fed the lowest protein diet. These results indicate that the fish fed the low protein diet were eating more feed on a per weight basis, possibly to compensate for the lower protein content of the diet. In addition, a positive correlation was observed between weight gain and total protein intake ($r^2 = 0.81$).

The FCEs obtained in the present study (31 to 51%) are within the range of published studies with Florida pompano and are similar to values obtained in preliminary studies

performed at our laboratory. Tatum (1972) recorded a FCE of 30% for Florida pompano fed a commercial floating trout chow, while Gomez and Larez (1983) achieved values of 22% when Florida pompano juveniles were fed an experimental dry feed containing 42.8% protein. Reported FCE values for other species of pompano (Liao et al., 1995) are similar to values obtained with the high protein diet (ca. 50%), but higher than those obtained with the fish fed the low protein diets (30 and 35% protein diets, ca. FCE 30%).

It is clear that the FCEs obtained with the Florida pompano are lower than those reported for other species of marine fish, such as red drum (e.g., 82% to 98%; Serrano et al., 1992). A relatively high metabolic demand or poor digestibility of the feed may explain the relatively poor utilization of the feed. Florida pompano are extremely active fish, constantly swimming at high speeds. The energy required to maintain this swimming activity would reduce the available energy for growth and consequently may reduce FCE.

Another possible explanation for the poor feed utilization, is that the feed was not efficiently digested. Williams et al. (1985) determined the transit time of feed through the gut of Florida pompano to be about 3 h. They suggest that the short transit time might explain the relatively low digestion rates obtained for some nutrients (i.e., lipids). It is possible that feeding to satiation twice per day might lead to reduce digestion and assimilation rates by Florida pompano. Fish were observed to eat voraciously until fully satiated. This large intake of food over a relatively short period of time may result in increased movement of food through the digestive system and a subsequent reduction in digestion. It has been demonstrated in the sockeye salmon that growth can be improved if the are fed continuously for 15 h/day as compared to satiation three times per day (Shelbourne et al., 1973). Consequently, further research is warranted to evaluate digestion rates and feeding strategies for this species.

5. Conclusions

For maximum growth and highest feed utilization our results indicate that juvenile Florida pompano require a minimum of 45% protein in their diets when fish meal and soybean meal are the primary sources of protein. Florida pompano appears to be a promising species for marine aquaculture due to its good growth rates, high survival, ease of handling and ready acceptance of formulated feeds.

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References

- Armitage, T.M., Alevizon, W., 1980. The diet of the Florida pompano (*Trachinotus carolinus*) along the east coast of central Florida, USA. Fla. Sci. 43, 19–26.
- Bellinger, J.W., Avault, J.W., 1971. Food habits of juvenile pompano (*Trachinotus carolinus*) in Louisiana. Trans. Am. Fish. Soc. 100, 464–486.
- Berry, F., Iversen, E.S., 1966. Pompano: Biology Fisheries and Farming Potential. Proc. Gulf Carib. Fish Inst. 19th Annu. Sess. pp. 116–128.
- Folch, J., Lees, R., Sloane-Stanley, G.H., 1957. A simple method for isolation and purification of total lipids from animal tissue. J. Biol. Chem. 226, 497–507.
- Gomez, A., Larez, F., 1983. Crecimiento de pampanos (*Trachinotus goodei*), (*T. Falcatus*), (*T. carolinus*) alimentados con dieta seca GSCA en la isla de Margarita, Venezuela. Bol. Inst. Oceanogr. de Venez. Univ. Oriente 22, 21–28.
- Gomez, A., Scelzo, M., 1982. Polyculture experiments of Pompano *Trachinotus carolinus* (Carangidae) and Spotted red shrimp *Penaeus brasiliensis* (Penaeidae) in concrete ponds, Margarita Island, Venezuela. J. World Aquacult. Soc. 13, 146–153.
- Hilge, V., Grop, H.J., 1985. Zum Protein und Fettbedarf des Europäischen Welses (*Silurus glanis* L.). In: Steffens, W. (Ed.), Principles of Fish Nutrition. Ellis Horwood, England, p. 3810.
- Hoese, H.D., Moore, R., 1992. Fishes of the Gulf of Mexico: Texas, Louisiana and Adjacent Waters. Texas A&M University Press, College Station, TX, USA, 327 pp.
- Jirsa, D., Davis, D.A., Arnold, C.R., 1997. Effects of dietary nutrient density on water quality and growth of red drum (*Sciaenops ocellatus*) in closed systems. J. World Aquacult. Soc. 28, 68–78.
- Jobling, M., 1994. Fish Bioenergetics. Chapman & Hall, London, UK, 309 pp.
- Liao, I.C., Su, M.S., Chang, S.L., 1995. A review of the nursery and grow-out techniques of high value marine fishes in Taiwan. In: Main, K., Rosenfeld, C. (Eds.), Culture of High-Value Marine Fishes in Asia and the United States. The Oceanic Institute Press, Honolulu, HI, USA, pp. 121–138.
- Ma, T.S., Zuazago, G., 1942. Micro-Kjeldahl determination of nitrogen. A new indicator and improved rapid method. Ind. Eng. Chem. 14, 280–282.
- National Research Council (NRC). 1983. Nutrient Requirements of Warmwaters Fishes and Shellfishes. National Academy Press, Washington, DC, USA, 102 pp.
- Serrano, J., Nematipour, G.R., Gattlin, D.M., 1992. Dietary protein requirements of the red drum (*Sciaenops ocellatus*) and relative use of dietary carbohydrate and lipid. Aquaculture 101, 283–291.
- Shelbourne, J.E., Brett, J.R., Shirahata, S., 1973. Effect of temperature and feeding regime on the specific growth rate of sockeye salmon fry (*Oncorhynchus nerka*) with a consideration of size effect. J. Fish Res. Board Can. 30, 1191–1194.
- Spotte, S., 1979. Fish and Invertebrate Culture: Water Management in Closed Systems, 2nd edn. Wiley, New York, USA.
- Steel, R.G., Torrie, J.H., 1980. Principles and Procedures of Statistics: a Biometrics Approach. McGraw-Hill, New York, NY, USA.
- Steffens, W., 1989. Principles of Fish Nutrition. Ellis Horwood, England, 383 pp.
- Tabacheck, J.L., 1986. Influence of dietary protein and lipid levels on growth, body composition and utilization efficiencies of Arctic Char, *Salvelinus alpinus*. J. Fish Biol. 29, 139–151.
- Tatum, W., 1972. Comparative growth, mortality and efficiency of pompano (*Trachinotus carolinus*) receiving a diet of ground industrial fish with those receiving a diet of trout chow. Proc. World Mar. Soc. 3, 65–69.
- Tiews, K., Grop, J., Beck, H., 1976. On the development of optimal rainbow trout pellets feeds. Arc. Fischereiwiss 27, 1–29.
- Williams, S., Lovell, R., Hawke, J.P., 1985. Value of menhaden oil in diets of Florida pompano. Prog. Fish-Cult. 47, 159–165.
- Wilson, R.P., 1989. Amino acids and proteins. In: Halver, J. (Ed.), Fish Nutrition. Academic Press, London, pp. 112–153.
- Zeitoun, I.H., Halver, J.E., Ulrey, D.E., Tack, P., 1973. Influence of salinity on protein requirements of rainbow trout (*Salmo gairdneri*) fingerlings. J. Fish. Res. Board. Can. 30, 1867–1973.