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Effect of dietary amino acid composition from proteins alternative to fishmeal on the growth of juveniles of the common snook, *Centropomus undecimalis*

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ABSTRACT - This study investigated the effect of dietary amino acid composition from proteins alternative to fishmeal on the growth performance of the common snook, *Centropomus undecimalis*. Fish of 10.79±0.71 g (n = 150) were stocked in 15 shaded outdoor tanks of 1 m^3. The basal diet contained 643.4 g kg^{-1} salmon byproduct meal (SML) and 200.0 g kg^{-1} soy protein concentrate (SPC). Two other diets replaced 39 and 29% of the SML with poultry byproduct meal (PBM, 170.1 g kg^{-1}) and SPC (334.9 g kg^{-1}), respectively. Fish were fed twice daily for 84 days under 32±1 g L^{-1} water salinity and 27.3±0.9 °C temperature. Final survival (99.5±2.6%) was unaffected by dietary treatment. Snook grew slower (0.24±0.03 and 0.27±0.04 vs 0.35±0.06 g day^{-1}) and achieved the lowest body weight (31.1±6.62 and 33.3±10.20 vs 40.4±13.18 g) and the highest feed conversion ratio (3.69±0.29 and 3.11±0.51 vs 2.33±0.34) when fed SPC and basal diets compared with PBM, respectively. Retention of dietary crude protein varied from 36 to 38% for fish fed the basal and SPC diets, but exceeded 51% in fish fed PBM. Results indicate a greater ability of the common snook to gain weight and increase retention of nutrients when dietary protein is of terrestrial animal origin. Dietary protein from PBM yields a more balanced dietary amino acid composition relative to fish muscle, but possibly in excess of the species requirements.

Key Words: amino acid, fishmeal, fish nutrition, nutritional requirement

Introduction

Marine fish farming is one of the fastest growing aquaculture sectors, in terms of value, harvested volumes, and number of emerging farmed species. From 2000 to 2013, global production of farm-raised marine fish grew at an annual rate of 6.9%, from 0.97 to 2.28 million t, respectively. In 2013, the industry generated USD 9.5 billion or 6.1% of the total aquaculture revenue (FAO, 2014). Several marine fish are reared commercially, including the Asian seabass (*Lates calcarifer*), cobia (*Rachycentron canadum*), groupers (*Epinephelus* spp), snappers (*Lutjanus* spp), pompanos (*Trachinotus* spp), yellowtails, and amberjacks (*Seriola* spp).

In the Americas, the common snook, *Centropomus undecimalis*, is a marine fish of commercial interest. The species attracts high prices as recreational and commercial fish because of its highly valued fillet (Rhody et al., 2010; Muller and Taylor, 2012). The common snook can tolerate a wide range of salinities (Pérez-Pinzón and Lutz, 1991; Tucker and Kennedy, 2003; Gracia-López et al., 2006) and preys on small fish, shrimp, and crabs in its natural habitat (Rivas, 1986; Tsuzuki et al., 2007; Alvarez-Lajonchère and Ibarra-Castro et al., 2013). Broodstock can mature and spawn in captivity (Neidig et al., 2000; Sánchez-Zamora et al., 2002; Ferraz and Cerqueira, 2010; Ibarra-Castro et al., 2011; Rhody et al., 2014; Contreras-García et al., 2015) and thus, pilot-scale mass production of fries has been achieved (Ibarra-Castro et al., 2011).

Compared with other emerging farm-raised warm-water marine fish, such as the Asian seabass (*Lates calcarifer*; Boonyaratpalin, 1997; Glencross, 2006), and cobia (*Rachycentron canadum*; Salze et al., 2010), limited information is available on feeding and nutrition of the common snook. Attempts to raise the species in captivity have relied on diets of fresh food (Tucker, 1987; Zarza-Meza et al., 2006a,b) or on feeds formulated for carnivorous freshwater fish (Gracia-López et al., 2003) or for other warm-water marine species (Soligo et al., 2011). Tucker (1987) found an improved growth when juveniles of the common snook were fed diets with 500 g kg^{-1} of CP and 130 g kg^{-1} fat. The present study investigated the

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effect of the dietary amino acid composition from protein sources alternative to fishmeal on the growth performance of juveniles of the common snook.

Material and Methods

Hatchery-produced fries of the common snook, *C. undecimalis*, were purchased from a commercial hatchery (Danúbio Piscicultura Ltda., Blumenau, SC, Brazil) and transported by air cargo to the laboratory rearing facilities in Eusébio, CE, Brazil. Animals (n = 1,500) were equally distributed at a maximum biomass of 30 g L^{-1} into four transparent double plastic bags containing seawater (pH, 6.6; temperature, 27.5 °C; and salinity, 20 g L^{-1}) enriched with pure oxygen, which were accommodated in two Styrofoam boxes. Transportation lasted 14 h and one dead fish was noted on arrival at the experimental site.

Initially, fish were stocked in four indoor tanks of 0.5 m^3 for acclimation over two days in water salinity of 36 g L^{-1}. Fish were then graded by size and distributed into 50 indoor tanks each of 0.5 m^3, under continuous aeration and water filtration. At this time, fish weighed 1.71±0.62 g (n = 29). Fingerlings were reared under similar conditions for 54 days until reaching an average body weight of 11.21±2.55 g (n = 50).

Following acclimation, juveniles were graded by size, weighed individually (10.79±0.71 g; n = 150; CV = 6.6%), and immediately transferred to 15 outdoor tanks of 1 m^3 (1.02 m^2 bottom surface area by 0.74 m height) at 10 fish m^{-3}. During the rearing period, tanks were covered with a perforated lid and sheltered from the sunlight using a dark net with 70% shading (sombrite 1007 PTO 70%, Equipesca Equipamentos de Pesca Ltda., Nova Odessa, SP, Brazil). Tanks operated with clear water under a closed regime, with continuous water recirculation, filtration, and aeration. Water filtration was carried out using a 240-kg sand filter and a cartridge filter with seven 75 µm filter vessels (model XL-234, FSI Sul Americana Ind. Com. e Serviços Ltda., Taubaté, SP, Brazil).

To avoid any build-up of organic matter on the bottom surface of the tank, feed remains and feces were siphoned twice a week. Water salinity, pH, temperature, and dissolved oxygen were monitored at 09.00 h daily in each rearing tank. Readings of water alkalinity, nitrite, nitrate, and total ammonia nitrogen were conducted with a visible spectrophotometer (DR-2800 Spectrophotometer, Hach Company, Loveland, USA). Water was sampled from a randomly selected tank for each dietary treatment, on the 22nd, 52nd, and 86th days.

During the acclimation period, fish were fed a diet containing 510 g kg^{-1} of crude protein and 120 g kg^{-1} of fat (as is basis), according to recommendations made for the common snook, *C. undecimalis* (Tucker, 1987), and the Asian seabass, *L. calcarifer* (Boonyaratpalin, 1997; Glencross, 2006). This diet was composed of (as fed basis) salmon byproduct meal (590.0 g kg^{-1}), soy protein concentrate (139.3 g kg^{-1}), wheat flour (120.0 g kg^{-1}), krill meal (50.0 g kg^{-1}), salmon oil (33.9 g kg^{-1}), vitamin-mineral premix (20.0 g kg^{-1}), soybean lecithin (15.0 g kg^{-1}), DL-methionine (10.9 g kg^{-1}), L-lysine HCl (8.0 g kg^{-1}), dicalcium phosphate (5.6 g kg^{-1}), synthetic binder (5.0 g kg^{-1}), and ascorbic acid monophosphate (2.3 g kg^{-1}).

For the experimental rearing period, three diets were formulated to be isonitrogeneous, isolipidic, and isoenergetic (Table 1). A basal diet was first designed to

Table 1 - Ingredient and proximate composition of experimental diets

Ingredient	Diets/inclusion (g kg^{-1} of the diet, as is basis)		
	Basal	Poultry	SPC
Salmon byproduct meal[1]	643.4	464.2	499.6
Soy protein concentrate (SPC)[2]	200.0	200.0	334.9
Poultry byproduct meal[3]	0.0	170.1	0.0
Wheat flour[4]	50.0	71.4	45.2
Salmon oil	35.7	23.5	49.5
Others[5]	70.9	70.9	70.9
Proximate composition (g kg^{-1} of the diet, as is basis)			
Dry matter	886.4	886.1	932.3
Crude protein	521.3	517.3	528.8
Fat	110.4	106.4	119.5
Crude fiber	10.9	14.1	15.2
Ash	130.8	119.7	121.0
Nitrogen-free extract[6]	226.6	242.5	215.5
Gross energy (MJ kg^{-1})[7]	19.2	19.2	19.5

[1] Pesquera Pacific Star S.A. (Puerto Montt, Chile): 612.6 g kg^{-1} crude protein (CP); 100.1 g kg^{-1} fat; 148.5 g kg^{-1} ash; 0.9 g kg^{-1} crude fiber (CF); 94.7 g kg^{-1} moisture.

[2] Sementes Selecta S.A. (Goiânia, Brazil): 626.3 g kg^{-1} CP; 7.7 g kg^{-1} of fat; 42.3 g kg^{-1} ash; 43.3 g kg^{-1} CF; 82.2 g kg^{-1} moisture.

[3] Courtesy of InVivo Nutrição e Saúde Animal Ltda. (Paulínia, Brazil): 605.3 g kg^{-1} CP; 173.4 g kg^{-1} fat; 7.6 g kg^{-1} ash; 7.6 g kg^{-1} CF; 72.0 g kg^{-1} moisture.

[4] Farinha de trigo Rosa Branca. Moinhos Cruzeiro do Sul S/A (Olinda, Brazil): 134.1 g kg^{-1} CP; 21.7 g kg^{-1} fat; 12.4 g kg^{-1} ash; 7.4 g kg^{-1} CF; 110.4 g kg^{-1} moisture.

[5] Others included: 20.0 g kg^{-1} of vitamin-mineral premix[8]; 20.0 g kg^{-1} of Krill meal[9]; 15.0 g kg^{-1} of soy lecithin; 10 g kg^{-1} of dicalcium phosphate[10]; 5.0 g kg^{-1} of synthetic binder[11]; and 0.9 g kg^{-1} of ascorbic acid polyphosphate[12].

[6] Calculated by difference (1,000 − crude protein − fat − crude fiber − ash).

[7] Calculated using an energy value of protein, fat, and carbohydrate of 5.64 kcal/g, 9.44 kcal/g, and 4.11 kcal/g, respectively.

[8] Rovimix Camarão Extensivo, DSM Produtos Nutricionais Brasil Ltda. (São Paulo, Brazil). Guaranteed levels per kg of product: vitamin A, 1,000,000 IU; vitamin D3, 300,000 IU; vitamin E, 15,000 IU; vitamin K3, 300.0 mg; vitamin B1, 3,000.0 mg; vitamin B2, 2,500.0 mg; vitamin B6, 3,500.0 mg; vitamin B12, 6.0 mg; nicotinic acid, 10,000.0 mg; pantothenic acid, 5,000.0 mg; biotin, 100.0 mg; folic acid, 800.0 mg; vitamin C, 25,000.0 mg; choline, 40,000.0 mg; inositol, 20,000.0 mg; iron 2,000.0 mg; copper, 3,500.0 mg; chelated copper, 1,500,0 mg; zinc, 10,500.0 mg; chelated zinc, 4,500.0 mg; manganese, 4,000.0 mg; selenium, 15.0 mg; chelated selenium, 15.0 mg; iodine, 150.0 mg; cobalt, 30.0 mg; chromium 80.0 mg; filler, 1,000.0 g.

[9] Qrill™ meal, Aker Biomarine ASA (Oslo, Norway): 593.0 g kg^{-1} CP; 203.0 g kg^{-1} fat; 123.0 g kg^{-1} ash; 203.0 g kg^{-1} CF; 62.0 g kg^{-1} moisture.

[10] Serrana Foscálcio20. Bunge Fertlizantes S/A. (Cubatão, Brazil): 205 g kg^{-1} calcium, 202 g kg^{-1} total phosphorus, 19.1% available phosphorus.

[11] Nutri-Bind Aqua Veg Dry, Nutri-Ad International NV (Dendermonde, Belgium). Synthetic pellet binder consisting of calcium lignosulfonate (94.00%) and guar gum (6.00%).

[12] Rovimix Stay-C® 35%, L-ascorbic acid 2-monophosphate. DSM Produtos Nutricionais Brasil Ltda. (São Paulo, Brazil).

contain 520.0 g kg^{-1} of crude protein (as fed basis) with salmon byproduct meal (643.4 g kg^{-1}, as fed basis) and soy protein concentrate (SPC, 200.0 g kg^{-1}) as the main protein sources. From this diet, two other diets were formulated to replace 39 and 29%, respectively, of the salmon byproduct meal with two alternative proteins: poultry byproduct meal (170.1 g kg^{-1}) and SPC (334.9 g kg^{-1}).

Because of a general lack of information on the nutrient requirements of *Centropomus* spp, the dietary essential amino acid (EAA) profile approximated that of a freeze-dried muscle sample obtained from a wild-caught adult *C. undecimalis* (4 kg body weight). This formulation approach was in accordance with the work of Portz and Cyrino (2003) and Meyer and Fracalossi (2005). However, no attempt was made to balance the dietary amino acid (AA) composition in relation to the fish muscle using crystalline sources of EAA (Table 2).

Sinking feeds were prepared with a laboratory extruder as described by Browdy et al. (2012). Starter pellets (2.1 × 8.2 mm; diameter by length) were given to fish during acclimation and over the first 28 days of experimental culture. For the remaining culture period, fish were fed pellets of 4.0 × 10.0 mm. During the course of the acclimation and experimental rearing periods, fish were hand-fed twice daily, at 08.00 am and 16.00 h, until apparent satiation.

Fish were reared with the experimental diets for 84 days, with two additional days allowed for acclimation. At harvest, growth performance was assessed by counting and individually weighing each animal. Fish specific growth rate (SGR, % day^{-1}) was calculated by the equation: $\text{SGR} = [(\ln Wf - \ln Wi) \div t] \times 100$, in which Wi = fish wet body weight (g) at stocking, Wf = fish wet body weight (g) at harvest, and t = days of culture. Daily weight gain (DWG, g day^{-1}) was determined by the formula: $\text{DWG} = [(Wf - Wi) \div t]$. Feed conversion ratio (FCR) was expressed on a dry matter basis and calculated by dividing the apparent fish feed intake by the wet fish biomass gained.

Table 2 - Analyzed amino acid composition (g 16 g N^{-1}) of experimental diets and muscle protein of a wild adult of the common snook, *C. undecimalis*

Amino acid	Composition (g 16 g N^{-1}, dry matter basis)			
	Experimental diet			Muscle
	Basal	Poultry	SPC	
Essential				
Arginine	5.97	6.09	6.05	5.59
Histidine	2.06	1.98	2.16	2.43
Isoleucine	3.73	3.89	3.79	4.35
Leucine	6.78	7.04	6.98	8.56
Lysine	12.78	12.17	13.34	12.41
Methionine	2.92	2.74	2.59	5.81
Phenylalanine	4.05	4.17	4.31	4.30
Threonine	3.88	3.65	3.41	4.66
Tryptophan	0.43	0.42	0.47	0.79
Valine	4.59	4.84	4.58	4.98
Nonessential				
Alanine	5.98	5.85	5.55	6.15
Aspartate	8.36	7.67	8.77	9.85
Cystine	0.95	0.94	0.75	3.35
Glycine	8.54	8.37	7.83	4.83
Glutamate	13.37	13.53	14.30	15.61
Proline	5.35	5.80	5.27	3.60
Serine	3.75	3.68	3.23	4.15
Tyrosine	2.80	2.70	2.63	3.70

SPC - soy protein concentrate.

To determine the retention of dietary protein, lipid, and energy from each dietary treatment, muscle samples were collected at stocking and at harvest. Fish collection was carried out in accordance with applicable federal, state, and local laws governing animal welfare. Whole fish were pooled per tank, their muscle removed, chopped, freeze-dried, and then grounded to a fine powder. Nutrient and energy retention was calculated as retention (%) = (final weight × final nutrient or energy content) – (initial weight × initial nutrient or energy content) × 100 ÷ nutrient or energy intake (NRC, 2011).

Growth performance and somatic parameters were analyzed through one-way ANOVA for completely randomized experiments. When significant differences were detected between means, they were compared pairwise with the Tukey's honestly significant difference (HSD) test. Significant level of 5% was set for all statistical analyses. The statistical package SPSS 15.0 for Windows (SPSS Inc., Chicago, Illinois, USA) was used in all analyses. Amino acid concentration in experimental diets were analyzed by reverse-phase high-performance liquid chromatography (HPLC) following procedures described by Figueiredo-Silva et al. (2015). Along with experimental diets, fish tissue samples were analyzed for dry matter (drying in a convection oven for 24 h at 105 °C), crude protein (Kjeldahl method of nitrogen estimation), and lipid (determined gravimetrically with Soxhlet extraction using acetone as the solvent), following standard methods (AOAC, 1995). Energy content was determined by combustion in a bomb calorimeter.

Results

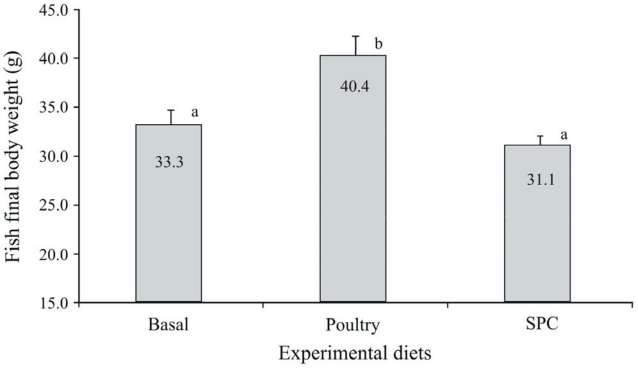
Water quality parameters were consistent throughout the culture period ($P>0.05$). Water salinity, pH, temperature, and dissolved oxygen reached mean (minimum – maximum) values of 32±1 g L^{-1} (30-34 g L^{-1}, n = 1080); 7.81±0.19 (6.7-8.1, n = 1073); 27.3±0.9 °C (24.5-30.5 °C, n = 1073); and 5.94±0.21 mg L^{-1} (5.08-6.70, n = 1080). Similarly, water alkalinity (160±15 mg L^{-1} $CaCO_3$; n = 18), total ammonia nitrogen (0.18±0.10 mg L^{-1}; n = 18), nitrite (0.04±0.01 mg L^{-1}; n = 12), and nitrate (0.43±0.17 mg L^{-1}; n = 12) did not vary significantly over the culture period ($P>0.05$).

Fish final survival reached 99.5±2.6% and was unaffected by dietary treatment ($P>0.05$). Over the rearing period, fish reached a DWG, SGR, and a final body weight ranging from 0.24 to 0.35 g day^{-1}, 1.24 to 1.57% day^{-1} (Table 3), and 31.1 to 40.4 g, respectively (Figure 1). Significant differences among dietary treatments were noted in DWG, SGR, fish yield, FCR, and final body weight ($P<0.05$) (Table 3).

Fish fed the diet containing a partial replacement of fishmeal by SPC grew slower and achieved the lowest yield and the highest FCR in comparison with fish fed the poultry diet ($P<0.05$). No differences were noted in these parameters between fish fed the basal diet and those fed poultry diet ($P>0.05$). Final fish body weight was higher in fish fed poultry in comparison with those fed SPC and the basal diet (Figure 1; $P<0.05$).

Retention of dietary protein, lipid, and energy in muscle samples of the common snook was higher in fish fed poultry (Figure 2). While retention of crude protein was in the range of 36-38% for fish fed the basal and SPC diets, it exceeded 51% in fish fed the poultry diet. Similarly, both lipid and energy exceeded 40% retention in fish fed the poultry diet in comparison with fish fed other diets, for which values were below 36%. Retention of dietary energy was the lowest among all values in fish fed the SPC diet, which may be the reason these fish also demonstrated the highest FCR values.

The essential amino acid profile relative to lysine (EAA Lys^{-1}) concentration was relatively similar among experimental diets (Table 4). The overall EAA Lys^{-1} ratio in the muscle samples did not differ from the experimental diets ($P>0.05$). However, with the exception of Arg Lys^{-1}, Phe Lys^{-1}, and Val Lys^{-1}, all other EAA Lys^{-1} ratios in the muscle samples showed differences greater than 10% for the experimental diets.



Values with different letters are significantly different according to Turkey's HSD test ($P<0.05$).

Figure 1 - Final body weight (g) of common snook, *C. undecimalis* (n = 150), fed diets with partial replacement of salmon meal (basal) by poultry byproduct meal (poultry) and soy protein concentrate (SPC).

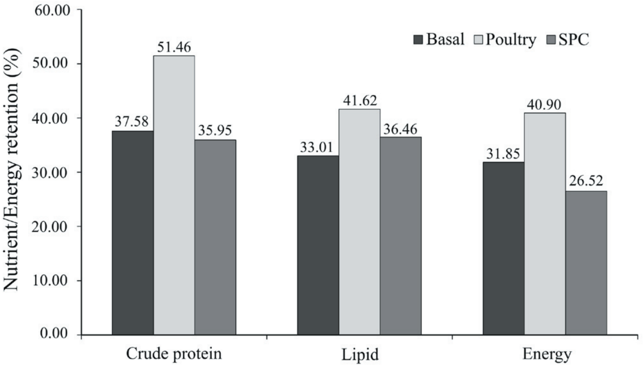


Figure 2 - Retention of dietary protein, lipid, and energy in muscle samples of the common snook, *C. undecimalis*, fed diets with partial replacement of salmon meal by poultry byproduct meal (poultry) and soy protein concentrate (SPC).

Table 3 - Growth performance of the common snook fed diets with progressive replacement of a salmon byproduct meal for poultry byproduct meal and soy protein concentrate (SPC)[1]

Performance variable	Dietary treatment			ANOVA P[2]
	Basal	Poultry	SPC	
Survival (%)	100±<0.1	100±<0.1	98±4.5	0.397
Daily weight gain (g day^{-1})	0.27±0.04a	0.35±0.06a	0.24±0.03b	0.007
Specific growth rate (% day^{-1})	1.35±0.12a	1.57±0.13a	1.24±0.08b	0.002
Gained yield (g m^{-3})	226±35a	297±53a	196±12b	0.003
Feed intake (g fish day^{-1})	0.82±0.03	0.81±0.03	0.86±0.04	0.052
Feed conversion ratio	3.11±0.51a	2.33±0.34a	3.69±0.29b	<0.0001

[1] Fish were stocked with 10.8±0.7 g (n = 150) body weight.
[2] One-way ANOVA.
Common letters denote no significant difference at the $\alpha = 0.05$ level by Tukey's honestly significant difference test.
Values are presented as means ± standard deviation obtained from five rearing tanks stocked with 10 fish each.

Table 4 - Balance of essential amino acids relative to lysine ($EAA\ Lys^{-1}$), including cysteine, in experimental diets and in the muscle tissue of an adult of common snook

Amino acid	EAA Lys^{-1} (%)			Muscle
	Basal	Poultry	SPC	
Arginine	47	50	45	45
Histidine	16	16	16	20
Isoleucine	29	32	28	35
Leucine	53	58	52	69
Methionine	23	22	19	47
Methionine + cysteine	30	30	25	74
Phenylalanine	32	34	32	35
Phenylalanine + threonine	54	56	52	64
Threonine	30	30	26	38
Tryptophan	3	3	3	6
Valine	36	40	34	40

SPC - soy protein concentrate.

Discussion

The present study demonstrates that juveniles of the common snook can be fed diets with poultry byproduct meal as a partial replacement of fishmeal, without deleterious growth effects. Although dietary inclusion levels of fishmeal were still high in poultry diets (464.2 g kg^{-1} of the diet), fish growth responses were equal or superior to the basal diet of 643.4 g kg^{-1} fishmeal. The dietary amino acid composition was not affected when poultry byproduct meal replaced 39% of the fishmeal. The fact that muscle retention of protein, lipid, and energy was better in fish fed the poultry diet, compared with those fed the basal diet, is suggestive of the enhanced digestibility and/or well-balanced nutrient composition of the poultry diet.

The basal diet (3.87 g 16 g N^{-1}) contained 5.2% more of total sulfur amino acids (TSAA, methionine and cysteine) compared with the diet with poultry meal (3.68 g 16 g N^{-1}). However, this did not contribute to a superior fish performance. Therefore, the dietary amino acid composition obtained with a combination of poultry byproduct meal (170.1 g kg^{-1} of the diet) and salmon meal (464.2 g kg^{-1}) was better utilized by fish than using salmon meal (643.4 g kg^{-1}) alone.

Comparatively, the use of soy protein concentrate (SPC) as a partial replacement of fishmeal resulted in slow fish growth, although no significant effect could be attributed to feed intake levels. The inclusion of krill meal at 20.0 g kg^{-1} appeared to have provided sufficient attractiveness and palatability to all tested diets. The slow fish growth related to the dietary use of SPC at levels beyond 200 g kg^{-1} can be associated with antinutritional factors, lower digestibility of nutrients, and/or amino acid imbalances (Francis et al., 2001; Zhou et al., 2005; Gatlin et al., 2007). Total sulfur amino acids in the SPC diet reached 3.34 g 16 g N^{-1}, inferior than values obtained for the basal and poultry diets. The balance of essential amino acids relative to lysine ($EAA\ Lys^{-1}$) in the SPC diet showed the greatest differences relative to fish muscle. The use of dietary plant protein sources have resulted in similar growth responses for other carnivorous marine fish, including the rainbow trout (*Oncorhynchus mykiss*; Refstie et al., 2000), cobia (*Rachycentron canadum*; Chou et al., 2004), Mediterranean yellowtail (*Seriola dumerili*, Tomás et al., 2005), and sea bream (*Diplodus puntazzo*, Mérida et al., 2010).

In the present study, dietary methionine varied from 1.37 to 1.52% (in a dry matter basis). This value is above methionine requirements determined for barramundi (*Lates calcarifer*) and other warm-water marine fish (0.8-0.9% of the diet; NRC, 2011). The increase in dietary methionine and other amino acids was driven by an attempt to approximate dietary lysine content to fish muscle. Conversely, this resulted in dietary EAA Lys^{-1} ratios below that of fish muscle. Estimations of EAA requirements in fish have also been made based on the composition of the body tissues relative to ratios of key amino acids to lysine (Glencross, 2006). However, balancing EAA Lys^{-1} is more effectively reached through the dietary supplementation of crystalline amino acids (Nunes et al., 2014).

In the present study, juveniles of the common snook grew at a maximum DWG of 0.35±0.06 g day^{-1} when fed the PBM diet. This finding is consistent with other growth studies conducted with *Centropomus* spp., which have shown a DWG below 1 g day^{-1} for fish of 100 g or less. Zarza-Meza et al. (2006a) farmed wild-caught juveniles of the common snook and the fat snook (*Centropomus parallelus*) together, at a 3:2 ratio in a freshwater concrete pond of 96 m^3 over a 12-month period. Juveniles with body weights of 28.9 g and 5.6 g, respectively, were stocked under 2.1 animals m^{-3} and fed fresh tilapia (*Oreochromis* sp.) and ornamental fish (*Poecila* sp.) *ad libitum*. At harvest, DWG of 0.50 and 0.32 g day^{-1} were recorded for the common and fat snook, respectively. Soligo et al. (2007) tested diets containing 463 and 572 g kg^{-1} fishmeal protein for *C. undecimalis* juveniles with initial body weight of 0.13±0.05 g under a stocking density of 1.25 fish L^{-1}. The authors reported obtaining DWG of 0.60±0.05 and 0.72±0.08 g day^{-1}, respectively, after 30 days. Ostini et al. (2007) farmed *C. undecimalis* juveniles with initial body weight of 32.53±6.54 g on a commercial feed with 400 g kg^{-1} protein under 20 and 40 fish m^{-3}. After 160 days of rearing, the total weight gain and DWG observed were 98.6 and 87.9 g and 0.62 and 0.55 g day^{-1}, respectively.

Tucker (1987) carried out a series of growth studies with the common snook. In one of the studies, the author stocked 10 fish (from wild larvae) with 13.4 g in three earthen ponds of 140 m^2 with freshwater. Fish were fed fresh food (shrimp and scallops), but also preyed on forage fish (tilapia and mosquitofish). After 210 days, snook achieved a final body weight of 252 g and a DWG of 1.14 g day^{-1}. In the same study, Tucker (1987) compared the snook growth performance reared in fresh (24-32 °C, mean 28 °C, hardness 705 mg L^{-1}) and in salt water (25-34 °C, mean 29 °C, 21-33 g L^{-1} salinity, mean 28 g L^{-1}). Fish grew from 190 to 306 g in freshwater and from 201 to 286 g in saltwater over 70 days, achieving a DWG of 0.33 g day^{-1}. In another study, Tucker (1987) evaluated six diets containing from 449 to 539 g kg^{-1} of crude protein and from 85 to 129 g kg^{-1} fat. Starting with a body weight between 15.6 and 23.9 g (17.3±2.1 g), snook reached a final weight and DWG between 21.9-44.2 g (33.4±7.2 g) and 0.11-0.57 g day^{-1}(0.32±0.16 g day^{-1}) after 50 days of rearing, respectively.

The common snook can increase its DWG over a higher body weight range. Tucker (1987) reported DWG of 2.51, 2.74, and 4.09 g day^{-1} for snooks that grew from 240.7 to 376.5 g, 382.2 to 529.9 g, and 504.4 to 725.5 g, respectively. For 54 days, fish were fed a 516 g kg^{-1} crude protein diet containing 600 g kg^{-1} anchovy meal in combination with 135 g kg^{-1} poultry meal.

Disparities observed in the growth responses of *C. undecimalis* between studies can be attributed to differences in rearing methods, culture systems (*i.e.*, stocking densities, green versus clear water), and fish body weight, which frequently results in hierarchical dominance and food competition. In general, there is a lack of scientifically rigorous studies on the nutritional requirements of this species, which further contributes to the variations observed in results (Tucker, 1987; Higby and Beulig, 1988; Bagley et al. 1994; Souza-Filho and Cerqueira, 2003). However, the common snook reportedly shows superior performance in comparison with other fish species of the family Centropomidae (Rubio et al., 2003; Tucker and Kennedy, 2003; Zarza-Meza et al., 2006a,b).

Conclusions

Our results indicate a greater ability of the common snook to gain weight and increase retention of nutrients when dietary protein is of animal origin. Protein from poultry byproduct meal yields a more balanced dietary amino acid composition relative to fish muscle, but possibly in excess of the species requirements.

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