Aquaculture 322-323 (2011) 122–127

Contents lists available at SciVerse ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Evaluation of poultry by-product meal in commercial diets for juvenile cobia (*Rachycentron canadum*)

Qi-Cun Zhou [a,*], Juan Zhao [a], Peng Li [b], Hua-Lang Wang [c], Li-Gai Wang [a]

[a] College of Life Science and Biotechnology, Ningbo University, Ningbo 315211, Zhejiang Province, People's Republic of China
[b] The National Renderers, Causeway Bay, Hong Kong
[c] Aqua-feed Research and Development Center, Guangdong Evergreen Group Corp. Zhanjiang 524094, People's Republic of China

ARTICLE INFO

Article history:
Received 17 May 2011
Received in revised form 28 September 2011
Accepted 29 September 2011
Available online 12 October 2011

Keywords:
Rachycentron canadum
Fish meal
Poultry by-product meal
Growth
Hematological characteristics
Enzyme activities

ABSTRACT

A 10-week feeding trial was conducted to evaluate the potential use of poultry by-product meal (PBM) as a partial replacement of fish meal protein in the commercial diets for juvenile cobia. Five isonitrogenous (approximately 45%) and isolipidic (about 11%) diets were formulated to contain graded levels of PBM, and fish meal protein was replaced with a pet food-grade PBM at 15, 30, 45, 60% level (PBM15, PBM30, PBM45, PBM60, respectively) without lysine and methionine supplementation. The reference diet (PBM0) contained fish meal and soybean meal as protein sources. Each diet was fed to groups of 20 juvenile cobia initially averaging approximately 5.8 g in triplicate 500-l tanks twice daily to apparent satiation. The results showed that growth performance and survival for fish fed PBM-supplemented diets were not significantly lower compared to fish fed the reference diet ($P > 0.05$). However, protein efficiency ratio and feed efficiency ratio were significantly affected by the replacement level of fish meal protein with PBM, fish fed the PBM30 and PBM45 diets had higher PER and FER than fish fed the reference diet and the other diets. The condition factor, viscerosomatic index and intraperitoneal fat ratio were not significantly affected by the dietary treatments, however, fish fed the PBM45 diet had a higher hepatosomatic index than fish fed the other diets. There were no significant differences in moisture, crude lipid, ash, calcium and phosphorus content in whole body among all treatments, but the fish fed the reference diet had higher crude protein in whole body than fish fed the PBM-supplemented diets. There were no differences in liver superoxide dismutase, catalase, glutathione S-transferase and glutathione peroxidases activities among fish fed the experimental diets. Hematocrit, hemoglobin, red blood cell and total immunoglobulin were not significantly affected by the replacement level of fish meal protein with PBM. With the exception of plasma glucose content, there were no significant differences in plasma triglyceride, cholesterol and total protein concentration in fish fed the experimental diets. The results of this study indicated that good quality terrestrial PBM can successfully replace fish meal in the commercial diets for cobia, and the optimal level of fish meal replacement with PBM was determined by quadratic regression analysis to be 30.75% on the basis of maximum protein efficiency ratio.

1. Introduction

Cobia, *Rachycentron canadum*, is a large carnivorous marine fish distributed in worldwide tropical and subtropical waters except in the eastern Pacific (Fraser and Davies, 2009). It usually inhabits coastal shallow water and gulf waters, and feeds on shrimp, cephalopod, fingerlings and crabs (Franks et al., 1996), and can grow from fingerling to 4–6 kg marketable size in 1 year with high feed conversion efficiency, and its white flesh is suitable for sashimi (Zhou et al., 2005). Because of its rapid growth, effective feed utilization, high market value, spawning in captivity, high survival post-weaning, ability to withstand shifts in salinity, and responsiveness to vaccination, it has been regarded as the greatest potential among all candidate species for culture in offshore net cage systems (Chou et al., 2001; Faulk et al., 2007; Lin et al., 2006). Moreover, cobia has been regarded as an excellent game fish and highly prized by recreational fishers in many countries (Shaffer and Nakamura, 1989). With the success of artificial propagation and larval production, the culture of cobia has become widely distributed in southern coastal provinces of China (especially in Guangdong and Hainan provinces) as well as Southeast Asia (Zhou et al., 2006). Some nutrient requirements containing dietary optimal level of protein, lipid, methionine, lysine, choline and selenium have been investigated (Chou et al., 2001; Craig et al., 2006; Liu et al., 2010; Mai et al., 2009; Wang et al., 2005; Zhou et al., 2006, 2007). However, currently the limited supply of trash fish as the main feed source for grow-out could be the crucial constraint for cobia culture in China, because of difficulties in storage, variable nutritional quality and low feed conversion rate. Thus, nutritionally complete artificial diets at lower cost (especially

* Corresponding author. Tel./fax: +86 574 876 09581.
E-mail address: zhouqicun@nbu.edu.cn (Q.-C. Zhou).

0044-8486/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.aquaculture.2011.09.042

Table 1
Formulation and proximate composition of the experimental diets that these diets were fed to cobia (g 100 g^{-1} diet).

Ingredients	Diet numbers				
	PBM0	PBM 15	PBM 30	PBM 45	PBM 60
Fish meal	50.00	42.50	35.00	27.50	20.00
Poultry by-product meal	0.00	7.55	15.10	22.65	30.20
Soybean meal	11.30	11.30	11.30	11.30	11.30
Wheat flour	25.00	25.00	25.00	25.00	25.00
Fish oil	4.81	4.58	4.35	4.12	3.89
Lecithin	1.50	1.50	1.50	1.50	1.50
Vitamin mix[a]	2.00	2.00	2.00	2.00	2.00
Mineral mix[b]	1.50	1.50	1.50	1.50	1.50
Choline chloride	0.30	0.30	0.30	0.30	0.30
Monocalcium phosphate	0.50	0.50	0.50	0.50	0.50
Cellulose	3.09	3.27	3.45	3.63	3.81
Proximate composition					
Crude protein (%)	46.28	46.25	45.37	45.46	45.58
Crude lipid (%)	10.68	10.50	11.50	11.54	11.50
Energy J mg^{-1}	20.5	20.7	21.0	20.9	21.1
Ash (%)	11.0	11.26	10.61	10.34	10.32

[a, b]Vitamin mix and mineral mix are based on Zhou et al. (2005).

reducing fish meal usage) could be a substitute for the trash fish feed (Zhou et al., 2005).

Feed costs already accounted for half of the total cost of aquaculture production, with protein being the most expensive feed component (Bassompierre et al., 1997). Fish meal is well recognized as the best dietary protein source for most marine carnivorous fish which require high dietary protein levels compared to omnivorous or herbivorous fish (NRC, 1993). Fish meal is known for its balanced amino acids profile, high digestibility and palatability, the presence of potential growth factors, and it is highly improbable that complete replacement will be possible with a single alternative protein source (Craig and McLean, 2005). Therefore, fish meal is in high demand as the principal protein source for many formulated diets. However, fish meal production has been nearly constant annually, and demand for fish meal is growing, putting pressure on fishery stocks and causing the price of fish meal to increase. The search for fish meal substitutes and alternative dietary protein sources has become an international research priority (Lee, 2002). Therefore, alternative proteins, containing dietary plant and animal protein, have been studied by many fish nutritionists and the feed industries (Tacon and Jackson, 1985). However, plant protein inclusion has normally been limited due to deficiencies in essential amino acids, anti-nutrient factors and poor palatability (Gomes et al., 1995). Rendered animal protein ingredients are good sources of amino acids, with high protein content, total digestible dry matter (DM) and digestible protein and energy similar to fish meal (Bureau et al., 1999; Zhou et al., 2004). Poultry by-product meal (PBM) is one potential rendered animal protein which has been tested in diets for some marine fish species (El-Sayed, 1994; Fowler, 1991; Goto et al., 2001; Kureshy et al., 2000; Nengas et al., 1999; Quartararo et al., 1998; Turker et al., 2005; Wang et al., 2006; Yigit et al., 2006).

Some studies replacing fish meal with dietary plant protein in cobia diet have been reported (Chou et al., 2004; Lunger et al., 2006, 2007a, b; Salze et al., 2010; Zhou et al., 2005). As far as we know, currently there is no published information on the use of PBM in the diets of cobia. The objective of this study was to evaluate the effects of replacement of fish meal protein with PBM on growth performance, feed utilization, body composition and immune response for juvenile cobia.

2. Materials and methods

2.1. Ingredients and experimental diets

The reference diet, which utilized menhaden fish meal and soybean meal as protein sources and menhaden oil as the lipid source, was formulated to contain 45% crude protein and 11% lipid on a dry-matter basis. This diet satisfied all known nutrient requirements of cobia (Zhou et al., 2005). Five isonitrogenous and isolipidic experimental diets were formulated and the proximate analysis and the amino acids of the diets are given in Tables 1 and 2, respectively. The experimental diets were formulated to produce diets in which 0 (PBM0), 15 (PBM15), 30 (PBM 30), 45 (PBM 45) and 60% (PBM 60) of protein from fish meal were replaced by that from PBM. The pet food-grade PBM (crude protein 70.5%) was provided by the Asian Regional Office of the National Renderers Association (NRA, USA). Menhaden fish meal was from Peru, and the other feed ingredients were obtained from Guangdong Evergreen Group (Zhanjiang, China). All the dry ingredients were thoroughly mixed until homogenous in a Hobart-type mixer, then lipid and water were added and thoroughly mixed, Cold-extruded pellets (2.0 mm and 3.0 mm diameter) were produced and air-dried to about 10% moisture, sealed in vacuum-packed bags, and stored frozen (−20 °C) prior to use in the feeding trial.

2.2. Fish and experimental conditions

Disease-free cobia fingerlings (*R. canadum*) were obtained from a commercial fish hatchery in Sanya (Hainan, China). Prior to the experiment, fish were acclimated for 2 weeks. A commercial diet (45% crude protein, 12% crude lipid, Guangdong Evergreen Group, Zhanjiang, China) was fed to all fish during the conditioning period. At the beginning of the experiment, fish (initial weight about 5.8 g) were weighed and sorted into 15, 500-l cylindrical fiberglass tanks with 20 individuals per tank. Each diet was randomly assigned to three replicate groups of fish. Each tank was provided with a continuous flow of water (2 l min^{-1}). Continuous aeration was provided to each tank through air stones to maintain dissolved oxygen levels at or near saturation. All groups of fish were fed at the same fixed rate, two times daily at 8:00 and 17:00 h. The feeding rate was adjusted every 2 weeks to maintain a level approaching apparent satiation, without overfeeding. During the experimental period, temperature ranged from 26 to 30 °C, pH was 7.6–7.8, unionized ammonia nitrogen was lower than 0.05 mg/l, and dissolved oxygen was not less than 6.0 mg l^{-1}. Salinity was 24–26 g l^{-1}. Each tank was cleaned biweekly at the time the fish were removed and weighed as a group. The feeding trial lasted for 10 weeks.

2.3. Samples collection techniques and chemical analyses

At the termination of the 10-week feeding trial, fish in each tank were individually weighed and sampled for tissue analysis 24 h after the last feeding. Hepatosomatic index (HSI), viscerosomatic

Table 2
Amino acids composition of the experimental diets that these diets were fed to cobia (% in dry matter).

Diet	Asp	Thr	Ser	Glu	Gly	Ala	Val	Met	Ile	Leu	Tyr	Phe	Lys	His	Arg	Pro	Total
PBM0	3.57	1.62	1.59	5.95	2.10	2.21	1.96	0.96	1.66	2.91	1.11	1.67	2.86	0.88	2.13	1.71	34.89
PBM15	3.40	1.54	1.57	5.79	2.21	2.16	1.86	0.88	1.57	2.78	1.01	1.65	2.71	0.84	2.11	1.76	33.94
PBM30	3.43	1.56	1.61	5.94	2.44	2.22	1.88	0.87	1.59	2.83	1.07	1.67	2.72	0.85	2.23	1.95	34.86
PBM45	3.41	1.55	1.61	5.95	2.65	2.26	1.85	0.81	1.57	2.80	1.03	1.65	2.67	0.83	2.30	2.09	35.03
PBM60	3.21	1.46	1.56	5.71	2.69	2.17	1.76	0.75	1.49	2.66	0.93	1.60	2.50	0.80	2.24	2.03	33.56