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Effects of dietary corn gluten meal on growth, digestion and protein metabolism in relation to IGF-I gene expression of Japanese seabass, *Lateolabrax japonicus*

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ABSTRACT

A 60-day feeding trial in seawater floating cages (1.5 × 1.5 × 2.0 m) was conducted to investigate the effects of dietary corn gluten meal (CGM) levels on feed intake, growth performance, survival, digestion and protein metabolism in relation to IGF-I gene expression of Japanese seabass (initial body weight 18.09 ± 0.10 g). Six isonitrogenous (crude protein 43%) and isoenergetic (18 kJ g^{-1}) practical diets were formulated by replacing 0 (the control), 15, 30, 45, 60 and 75% of fish meal protein with CGM protein. Each diet was randomly fed to triplicate groups of fish, and each cage was stocked with 30 fish. Fish were fed twice daily (05:30 and 16:30) to apparent satiation. The survival rate ranged from 96 to 100%, and no significant difference was observed among dietary treatments ($P > 0.05$). With increasing dietary CGM levels, feed intake (FI) and specific growth rate (SGR) decreased, however, feed efficiency (FE) showed a contrary changing trend. Fish fed the diet with 75% of protein from CGM had significantly lower SGR than the control group ($P < 0.05$), and FI was significantly lower compared with the control group with a 60% substitution level ($P < 0.05$). Apparent digestibility coefficient (ADC) of protein significantly decreased in fish fed diets with 75% of protein from CGM compared with the control group ($P < 0.05$), but ADCs of lipid and phosphorus both increased with increasing dietary CGM levels, while ADC of dry matter (DM) showed no significant difference among dietary treatments. There were no significant differences in activities of digestive enzymes (protease, alpha-amylase and lipase) among dietary treatments ($P > 0.05$). When the substitution level was equal to or above 15%, the activities of protein metabolism enzymes (alanine aminotransferase, ALT; aspartate aminotransferase, AST) were significantly lower compared with the control group ($P < 0.05$). Hepatic insulin-like growth factor I (IGF-I) gene expression level significantly decreased in fish fed the diet with 60% protein from CGM compared with the control group ($P < 0.05$), but no significant difference was observed in IGF-I gene expression level in dorsal muscle. Results of the present study suggested that protein from CGM could substitute up to 60% of fish meal protein without influencing the growth of Japanese seabass. Dietary CGM level may affect fish growth by regulating digestion, absorption and FI, which partly accounted for the down-regulation of hepatic IGF-I gene expression level.

1. Introduction

Corn gluten meal (CGM) is a high protein ingredient produced as a byproduct during the corn starch processing with protein content between 60% and 62% (Mente et al., 2003). Of the plant-derived protein sources, corn gluten meal has potential to replace fish meal in that it is lack of antinutritional factors, low in fiber and, except for lysine and arginine and to a lesser extent methionine, has an adequate indispensable amino acid profile (Pereira and Oliva-Teles, 2003). Studies on rainbow trout (Gomesa et al., 1995), European seabass (Kaushik et al., 2004), tilapia (Wu et al., 1995), gilthead seabream (Pereira and Oliva-Teles, 2003; Robaina et al., 1997), Japanese flounder (Kikuchi, 1999), turbot (Regost et al., 1999), Atlantic salmon (Mente et al., 2003), Atlantic cod (Hansen et al., 2007a), sunshine bass (Lewis and Kohler, 2008) and *Fugu obscurus* (Zhong et al., 2011b) suggested that corn gluten meal was able to partially replace fish meal without compromising the growth in fish.

Nutritional status highly affects the growth hormone/insulin-like growth factor (IGF) system (Duan, 1998; Moriyama et al., 2000; Thissen et al., 1994, 1999), and insulin-like growth factor I (IGF-I) is the major anabolic agent responsible for tissue growth (Thissen et al., 1999). Of the growth factors, insulin-like growth factor-I (IGF-I), known for its direct role in increasing animal size through the

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somatotropic axis, has also been shown to stimulate muscle growth by suppressing protein breakdown and expression of atrophy-related ubiquitin ligases (Sacheck et al., 2004). Studies on fish (Gomez-Requeni et al., 2004; Hevrøy et al., 2007, 2008; Matthews et al., 1997; Pedroso et al., 2006) suggested that food deprivation, high plant protein and low lysine intake could down-regulate hepatic IGF-I expression levels.

Japanese seabass (*Lateolabrax japonicus*) is a carnivorous species widely cultured in China because of its delicious meat and rapid growth. Protein content in diets of Japanese seabass usually accounts for more than 41%, most of which should be supplied by fish meal due to its nutritional value and palatability (Ai et al., 2004). However, as the aquaculture industry developed rapidly, the yield of fish meal is far from satisfied to maintain the growth rate of aquaculture. Studies on replacing fish meal with high-protein plant ingredients (Cheng et al., 2010; Li et al., 2012) have been conducted in diets of Japanese seabass. The objective of the present study was to evaluate CGM as a partial replacement for fish meal in diets of Japanese seabass by examining growth, survival, digestion and protein metabolism in relation to IGF-I gene expression, expecting that the results obtained might be helpful in developing cost effective and sustainable dietary formulations for Japanese seabass.

2. Materials and methods

2.1. Experimental diets

Six isonitrogenous (crude protein 43%) and isoenergetic (18 kJ g^{-1}) practical diets were formulated by replacing 0 (the control), 15, 30, 45, 60 and 75% of protein from white fish meal with corn gluten meal (CGM). The ingredients, proximate composition and amino acid profile of ingredients are given in Tables 1 and 2. Crystalline amino acids were supplemented to meet the essential amino acid requirements based on the whole-body amino acid composition of Japanese seabass. Monocalcium phosphate was supplemented to meet the phosphorus requirement of Japanese seabass (Zhang et al., 2006). In addition, 500 mg/kg yttrium oxide (Y_2O_3, Fluka Chemicals®) was used as an inert tracer in each diet for determining apparent digestibility of nutrients.

Ingredients were grounded into fine powder through a 246-μm mesh. All the ingredients were mixed with menhaden fish oil, and water was added to produce stiff dough. The dough was then pelleted with an experimental feed mill (F-26 (II), South China University of Technology, China) and dried for about 12 h in a ventilated oven at 45 °C. After drying, the diets were broken and sieved into proper pellet size (1.5 × 3.0 mm and 2.5 × 5.0 mm), and were stored at −20 °C.

2.2. Feeding trial procedures

Japanese seabass (*L. japonicus*) juveniles of the same batch were obtained from a commercial farm in Ningbo, China. The juvenile seabass were fed with the control diet for 10 days to acclimate the experimental diets and conditions. At the start of the experiment, the fish were fasted for 24 h and weighted after anesthetized with eugenol (1:10,000) (Shanghai Reagent Corporation, China). Fish of homogenous size (18.09 ± 0.10 g) were randomly distributed into 18 seawater floating cages (1.5 × 1.5 × 2.0 m), and each cage was stocked with 30 fish. Each diet was randomly assigned to triplicate cages. Fish was hand-fed to apparent satiation twice daily (05:30 and 16:30) for 8 weeks. During the experimental period, rearing water temperature ranged from 18.0 to 24.5 °C, salinity was 26 to 30‰, and dissolved oxygen was approximately 7 mg/L.

Table 1
Formulation and proximate composition of the experimental diets (% dry matter).

Ingredients	Diet no. (protein substitution level)					
	Diet 1 (0)	Diet 2 (15%)	Diet 3 (30%)	Diet 4 (45%)	Diet 5 (60%)	Diet 6 (75%)
Fish meal[1]	52.00	44.20	36.40	28.60	20.80	13.00
CGM[1]	0.00	8.50	17.00	25.30	33.60	42.10
Wheat meal[1]	31.80	30.00	28.30	26.50	24.80	22.90
Fish oil	4.60	5.10	5.60	6.10	6.60	7.10
Soybean oil	1.54	1.23	0.92	0.62	0.31	0.00
Lecithin	2.00	2.00	2.00	2.00	2.00	2.00
Mineral premix[2]	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[2]	2.00	2.00	2.00	2.00	2.00	2.00
Attractants[3]	0.50	0.50	0.50	0.50	0.50	0.50
Antimold	0.10	0.10	0.10	0.10	0.10	0.10
Ethoxyquin	0.05	0.05	0.05	0.05	0.05	0.05
$Ca(H_2PO_4)$[2]	0.00	0.50	1.10	1.70	2.30	2.90
Cellulose	2.00	1.69	1.15	0.83	0.43	0.00
Yttrium oxide	0.05	0.05	0.05	0.05	0.05	0.05
Arginine	0.09	0.29	0.50	0.71	0.92	1.13
Isoleucine	0.17	0.21	0.26	0.30	0.35	0.40
Lysine	0.62	1.06	1.50	1.94	2.37	2.82
Methionine	0.30	0.31	0.32	0.33	0.33	0.34
Valine	0.18	0.21	0.24	0.28	0.32	0.36
Threonine	0.00	0.00	0.01	0.09	0.17	0.25
Proximate composition (% dry matter)[4]						
Crude protein (%)	43.36	43.37	43.43	43.43	43.44	43.31
Crude lipid (%)	11.78	11.77	11.77	11.77	11.76	11.75
Gross energy (%)	18.67	18.67	18.69	18.68	18.68	18.63
Digestible phosphorus (%)	0.94	0.91	0.90	0.89	0.88	0.87
Ash (%)	14.69[a]	13.29[b]	12.02[c]	11.24[d]	10.37[e]	9.72[f]

[1] Fish meal, crude protein 71% dry matter, crude lipid 6% dry matter; corn gluten meal, crude protein 62.4% dry matter, crude lipid 1.8% dry matter; wheat meal, crude protein 16% dry matter, crude lipid 1.4% dry matter.
[2] According to Ai et al. (2004).
[3] Taurine: glycine: betaine = 1:3:3.
[4] Means of three analyses.