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Gamma-irradiated soybean meal replaced more fish meal in the diets of Japanese seabass (*Lateolabrax japonicus*)

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ABSTRACT

A feeding trial was conducted to evaluate if gamma-irradiation or fermentation could increase the inclusion level of soybean meal (SBM) in the diet of Japanese seabass *Lateolabrax japonicas*. A basal diet was formulated to contain 320 g/kg fish meal. In the test diets, 25, 50 and 75% of the fish meal in the basal diet was respectively replaced by SBM in three forms (untreated, fermented or gamma-ray irradiated). Juvenile fish (13.0 ± 0.1 g) were fed with the test diets for 8 weeks. SBM treatment affected weight gain, feed intake, feed conversion ratio (FCR), phosphorus retention efficiency (PRE), phosphorus wastes output, body contents of crude protein and phosphorus, while the level of fish meal replacement affected weight gain, apparent digestibility coefficient (ADC) of protein, FCR, nitrogen retention efficiency (NRE), PRE, nitrogen wastes output (NW), condition factor, body contents of moisture and phosphorus. Weight gain, ADC of protein and NRE decreased, whereas FCR and NW increased with increasing fish meal replacement by SBM, irrespective of SBM treatments. No significant differences were found in the weight gain and NRE between fish fed the basal diet and the diets with 25% fish meal replacement by untreated or fermented SBM, or between fish fed the basal diet and the diet with 50% fish meal replacement by irradiated SBM. At the end of the feeding trial, no significant differences were found in hepatosomatic index, viscerasomatic index and proximate body composition between fish fed the basal diet and the diets with fish meal replaced by untreated, fermented or irradiated SBM. This study indicates that the use of gamma irradiation provides a novel approach to enhance the level of fish meal replacement by SBM. Fish meal in the diet for Japanese seabass can be reduced to 160 g/kg when the gamma-irradiated SBM is used as a fish meal substitute.

1. Introduction

Fish meal is a limiting and expensive source of protein that has been used at high levels in fish diets (Tacon and Metian, 2008). Replacement of fish meal in fish diet with proteins sourced from terrestrial plants is important for sustainable

Abbreviations: ADC, apparent digestibility coefficient; ANFs, anti-nutritional factors; FBW, final body weight; FCR, feed conversion ratio; FL, fish meal level; HSD, honestly significant difference; HSI, hepatosomatic index; IBW, initial body weight; NRE, nitrogen retention efficiency; NW, nitrogen wastes output; PRE, phosphorus retention efficiency; PW, phosphorus wastes output; SBM, soybean meal; SBMT, soybean meal treatment; SEM, standard error; VSI, viscerasomatic index.

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Table 1
Proximate composition (g/kg) of the feed ingredients.

Ingredients	Dry matter	Crude protein[a]	Crude lipid[a]	Ash[a]
Fish meal, anchovy	889	756	126	161
Poultry by-product meal	938	681	134	163
Soybean meal, untreated	903	503	17	64
Soybean meal, irradiated	905	496	14	65
Soybean meal, fermented	930	561	25	71
Rapeseed meal	879	464	5	82
Brewer's dried yeast	939	492	6	65
Wheat flour	873	146	13	8

[a] Crude protein, crude lipid and ash are expressed on a dry matter basis ($n = 2$).

aquaculture (Gatlin et al., 2007). Among the terrestrial plant ingredients used for fish diet formulation, soy proteins have been recognized as the most promising plant protein source due to its sufficient supply, low price, balanced amino acids and highly digestible protein (Hardy, 1999; Gatlin et al., 2007). The potential of using soy proteins as a substitute of dietary fish meal has been evaluated in fish in various studies (McGoogan and Gatlin, 1997; Takagi et al., 2001; Tantikitti et al., 2005). Replacement of fish meal with soy proteins at high levels in fish diets results in decline of growth in many fish species (Boonyaratpalin et al., 1998; Wang et al., 2006; Kikuchi and Furuta, 2009). However, some studies reported that more than 90% of the fish meal can be replaced with soy proteins in the diets for rainbow trout (Kaushik et al., 1995), cobia (Salze et al., 2010) and red sea bream (Kader et al., 2012). The determinant mechanisms affecting the replacement of fish meal by soy proteins remain to be tested (Gatlin et al., 2007).

Japanese seabass, *Lateolabrax japonicas*, is a carnivorous fish species widely cultured in Asia (Wang et al., 2013). When a commercial soybean meal (SBM) was used as a fish meal substitute, the level of dietary fish meal for Japanese seabass can be reduced to 320 g/kg (Li et al., 2012) or 160 g/kg (Zhang et al., 2014). The presence of anti-nutritional factors (ANFs), such as protease inhibitors, lectins, phytates, glucosinolates, saponins and tannins has been considered a factor limiting the level of raw soybean inclusion in fish diet (Francis et al., 2001). Technical removal of ANFs is essential to increase the level of fish meal replacement by SBM in fish diet (Gatlin et al., 2007). Various processing techniques, such as soaking, dehulling, cooking and fermentation, are used to neutralize the ANFs in plant ingredients (Egounlety and Aworh, 2003; Refstie et al., 2005; Yamamoto et al., 2010). Fish meal replacement by defatted (Catacutan and Pagador, 2004; Tantikitti et al., 2005), dehulled (Choi et al., 2004), heated (Peres et al., 2003), solvent-extracted (Boonyaratpalin et al., 1998) and fermented (Refstie et al., 2005; Yamamoto et al., 2010) SBM in fish diet has been well documented. Besides these techniques, irradiation has been demonstrated an approach to improve the utilization of plant ingredients by terrestrial animals (DeRouchey et al., 2003; Mani and Chandra, 2003; Ghanbari et al., 2012). To our best knowledge, the effect of gamma-ray irradiation on the suitability of plant ingredients as a fish meal substitute in fish diets has been rarely studied. The objective of the present study aimed to evaluate the effect of fermentation and gamma-irradiation on SBM as a fish meal substitute in the diet for Japanese seabass, with emphasis on exploring a novel approach to increase the level of SBM inclusion in fish diet.

2. Materials and methods

2.1. Feed ingredients and test diets

Poultry by-product meal was supplied by the Hong Kong office of National Rendered Association. Fish meal (anchovy meal), SBM (defatted) and other feed ingredients were purchased from Haihuang Feed Company (Hangzhou, China). The SBM was irradiated with ^{60}Co gamma-ray at 100 kGy (Zhejiang Yin-Du Irradiation Technology Co., Ltd., Hangzhou, China), or fermented with *Lactobacillus* spp., *Saccharomyces* spp. and *Bacillus* spp. at 40 °C (Shanghai Yuan-Yao Biological Technology Co., Ltd., Shanghai, China). The proximate composition of feed ingredients is shown in Table 1. Amino acid profiles of fish meal, poultry by-product meal, SBM with different processing treatment are shown in Table 2.

A 3 × 3 layout included three SBM treatments (untreated, fermented or irradiated) and three levels of fish meal replacement (25, 50 and 75%) from a basal diet containing 320 g/kg fish meal. The resulting 10 diets were three untreated SBM diets (S1, S2 and S3), three fermented SBM diets (FS1, FS2 and FS3), three irradiated SBM diets (IS1, IS2 and IS3) and a basal diet

Table 2
Amino acid profile (g/kg) of fish meal, poultry by-product meal and soybean meal.

Ingredients	Lys	Met	Thr	Phe	His	Arg	Val	Ile	leu	Ser	Asp	Glu	Gly	Ala	Cys	Tyr	Pro
Fish meal, anchovy	55.0	22.9	30.8	28.1	20.1	38.8	30.3	27.5	49.9	29.0	64.2	114.0	41.8	44.2	6.0	22.4	22.5
Poultry by-product meal	40.3	15.8	26.2	25.8	13.3	45.5	25.2	22.7	42.7	27.7	52.8	105.2	67.0	43.8	5.1	39.5	18.6
Soybean meal, untreated	30.7	5.7	21.2	28.0	12.5	34.0	19.1	16.2	36.5	27.2	55.5	109.8	21.4	19.8	4.9	20.0	18.0
Soybean meal, fermented	31.1	5.9	21.1	24.6	12.2	33.0	19.3	19.2	36.0	27.1	55.6	108.7	20.4	22.1	5.3	18.8	16.5
Soybean meal, irradiated	29.6	5.9	20.5	24.1	11.8	32.9	19.0	19.1	35.0	26.8	53.7	106.2	19.3	21.0	5.2	18.4	15.6

Amino acids are expressed on a dry matter basis ($n = 2$).