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The use of a soy product in juvenile yellowtail kingfish (*Seriola lalandi*) feeds at different water temperatures: 1. Solvent extracted soybean meal

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ABSTRACT

Juvenile yellowtail kingfish (*Seriola lalandi*) were fed four iso-nitrogenous and iso-calorific (digestible basis) experimental diets containing 0, 10, 20 or 30% solvent extracted soybean meal (SESBM) for 34 days at optimal (22 °C) and suboptimal (18 °C) water temperatures to determine the effects of diet and water temperature on growth, feed efficiency, nutrient retention, apparent nutrient digestibility and digestive functions. The substitution of fish meal up to 20% SESBM did not significantly affect the growth of fish. No differences were detected in any of the other parameters measured between 0 and 10% inclusion. However, second-order polynomial regression demonstrated that increasing SESBM had a negative effect on growth performance, feed efficiency, nutrient retention and the apparent nutrient and energy digestibility of diets for yellowtail kingfish. Whole body moisture, crude lipid, ash and gross energy were affected by SESBM in the diet, except protein. The apparent nutrient and energy digestibilities all decreased linearly with increasing SESBM. Digestive enzyme activities in the pyloric caeca were not affected by diet, whereas activities in the foregut and hindgut varied with SESBM inclusion. Fish held at 18 °C had significantly reduced growth, feed efficiency and nutrient retention values. The whole body moisture increased at 18 °C, while the apparent nutrient and energy digestibilities and whole body protein and gross energy content were lower at 18 °C and there was no effect of temperature on whole body total fat or ash content. The impact of temperature on digestive enzyme activities depended on the section of the digestive tract. This study demonstrates that 10% inclusion of SESBM (21.7% fish meal substitution) can be used as a substitute for fish meal in diets for yellowtail kingfish.

1. Introduction

Soybean ingredients are widely used in diets for many cultured fish species as a cost-efficient alternative protein source to fish meal (FM) due to their constant availability, consistent protein content and relatively well-balanced amino acid profile (Gatlin et al., 2007; Lim et al., 2008). The substitution of fish meal with increasing levels of solvent extracted soybean meal (SESBM) has been tested in many cultured fish species with varying success (Gatlin et al., 2007; Tomas et al., 2005). Differences in the effects of SESBM inclusion on growth performances and health parameters reflect the sensitivity of the individual species to the variety of problems associated with SESBM inclusion. Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) are more sensitive to the inclusion of SESBM, causing reductions in growth and distinct changes to the distal intestinal epithelium (Baeverfjord and Krogdahl, 1996; Krogdahl et al., 2003). Whereas other species such as Japanese flounder (*Paralichthys olivaceus*) and red drum (*Sciaenops ocellatus*) can tolerate equal amounts of SESBM and FM without adverse effects on growth performance and feed efficiencies (Kikuchi, 1999; Reigh and Ellis, 1992). Juvenile Japanese yellowtail (*Seriola quinqueradiata*) (14 g) have been successfully fed diets with 20% SESBM inclusion (Shimeno et al., 1992) and longer-term trials with larger Japanese yellowtail (230 g) fed diets with 30% SESBM produced no significant reduction on growth performance (Shimeno et al., 1993), whereas in another study, 40% soybean meal inclusion gave significantly poorer growth rates (Lee et al., 1991). There is limited information of the inclusion of SESBM in diets for yellowtail kingfish (*Seriola lalandi*), but changes to the mucus layer thickness and goblet cell abundance have been reported to occur when fed diets containing 10, 20 and 30% SESBM inclusion (Bansemer, 2011).

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Some of the major problems with soybean meals are their low level of the essential amino acids, methionine and lysine, as well as high levels of indigestible carbohydrates, and the presence of anti-nutritional factors (Francis et al., 2001). Even though SESBM is subjected to various processes such as heat-treatment to reduce the level of anti-nutrients, there can still be residual levels of anti-nutritional factors present, such as protease inhibitors, phytates and soyasponins (Francis et al., 2001, 2002). These factors can affect feed efficiencies through reduced palatability, digestibility and nutrient utilisation by inhibiting digestive enzyme activities and compromising gut integrity (Alarcón et al., 1999; Mitchell et al., 1993), and ultimately lead to poor fish growth and health (Bureau et al., 1998; Francis et al., 2001; Gatlin et al., 2007; Hansen et al., 2006).

Decreasing water temperatures to a suboptimal range can influence almost every aspect of the grow-out stage of cultured fish species from reductions in basal metabolic rate to feed intake, gut transit time, activities in the whole enzymatic system, and ultimately growth (Kaushik, 1986). Yellowtail kingfish in southern Australia are cultured in sea-cages where water temperatures that can fluctuate from 10 °C in winter to 24 °C in summer (Miegel et al., 2010). In previous laboratory-based experiments, the optimal water temperatures for maximum growth in this species have been reported as 22 °C by Pirozzi and Booth (2009), 24 °C by Bowyer et al. (2012) and 26 °C by Abbink et al. (2012). However, it has been reported when water temperatures fall below 17 °C, this species has been found to reduce feed intake and growth, and numerous health problems have been reported (Miegel et al., 2010; Sheppard, 2004).

Cultured yellowtail kingfish are subjected to fluctuating water temperatures during their grow-out cycle and are fed commercial diets that generally contain unspecified levels of plant and/or animal protein ingredients. In addition, there is limited published information on the feasibility of using known quantities of various soybean products as a source of dietary protein in feed formulations for yellowtail kingfish (Bowyer et al., 2012). Therefore, it is important to understand the impacts of varying water temperatures and the inclusion of dietary plant protein on fish growth, feed efficiency and digestive functioning to determine maximal inclusion levels. The aim of this study was to investigate the suitability of substituting fish meal with SESBM at 0, 10, 20 and 30% inclusion, and the response of growth performance, feed efficiency, nutrient utilisation and digestive functioning of juvenile yellowtail kingfish when cultured at suboptimal (18 °C) and optimal water temperature (22 °C).

2. Materials and methods

2.1. Experimental diets

Solvent extracted soybean meal was included into the basal diet at 0 (control), 10, 20 and 30% inclusion levels, reducing the level of fish meal incorporation by 0, 21.7, 43.5 and 65.2%, respectively. The formulation of the control and three experiment diets are displayed in Table 1, and the proximate composition and calculated amino acid values of the diets are shown in Table 2. The diets were formulated to contain 41.5% digestible protein (50% crude protein) and 14.5% digestible lipid (20% crude lipid) with a gross energy level of 22 MJ kg^{-1} as described by Booth et al. (2010). The amino acid composition of the diets was calculated using analysed amino acid ingredient values and the diets were formulated to satisfy the nutritional requirements for a carnivorous marine fish (NRC, 2011). The level of lysine and methionine was balanced in all the diets according to the requirements for the Japanese yellowtail (Ruchimat et al., 1997a, 1997b) and to reflect the content of the fish meal control diet (0% SESBM). Based on the fact that fish meal often contains taurine in excess of 0.5%, plus the diets contained some animal products which also contain taurine (Gaylord et al., 2006), it was assumed that the dietary levels of taurine were between 0.25 and 0.5%. Therefore, the taurine level was over supplemented to contain 0.8% across all the diets, which was based on current commercial formulations for yellowtail kingfish (R Smullen, Ridley Aquafeed Pty Ltd., pers. comm.). Yttrium oxide was included in all diets (0.02% inclusion) as an inert maker for digestibility determination at the completion of the growth trial. The diets were produced at the South Australian Research and Development Institute (SARDI), Australasian Experimental Stockfeed Extrusion Centre (Roseworthy, Adelaide, Australia) as cooked, extruded and slow sinking pellets (2.5 mm) using a Wenger X-85 (Sabetha, Kansas, USA). The production parameters were recorded for each diet. During diet production, the maximum levels reached for the following parameters were: extruder temperature, 85 °C; cone head pressure, 100 psi; feeder screw and extruder rotations, 16 and 300 rpm, respectively,

Table 1
Diet formulations (g kg^{-1} dry basis) of the four experimental diets (formulated on a digestible protein and lipid basis) fed to yellowtail kingfish.

Ingredients[a]	Diet (%)			
	0	10	20	30
Herring meal	460.0	360.0	260.0	160.0
Solvent extracted soybean meal	0.0	100.0	200.0	300.0
Wheat 14	90.0	90.0	90.0	90.0
Wheat gluten meal	73.9	77.7	77.7	95.0
Fish oil	93.4	99.5	105.6	111.9
Soy lecithin	5.0	5.0	5.0	5.0
Wheat starch	81.9	46.6	11.8	0.0
Poultry by-product meal	60.6	60.7	60.7	60.7
Blood meal	23.6	45.3	70.8	97.2
Choline chloride	3.0	3.0	3.0	3.0
Corn gluten meal	90.0	90.0	90.0	47.8
Vitamin/mineral premix[b]	2.0	2.0	2.0	2.0
Vitamin C (Stay C)[c]	3.0	3.0	3.0	3.0
Vitamin E	0.4	0.4	0.4	0.4
Betaine	5.0	5.0	5.0	5.0
Monosodium phosphate	4.6	5.5	6.5	7.6
Taurine	3.6	4.5	5.3	6.1
Lysine	0.0	0.7	1.0	1.6
Methionine	0.0	1.1	2.2	3.7
Total	1000.0	1000.0	1000.0	1000.0

Yttrium oxide was added to the diets at a rate of 200 mg kg^{-1}.
[a] Supplied by Ridley Aquafeeds, QLD, Australia.
[b] A proprietary product supplied by Lienert Australia Pty Ltd., Australia.
[c] Rovimix® Stay-C® 35, DSM Nutritional Products, Basel, Switzerland.