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The use of a soy product in juvenile yellowtail kingfish (*Seriola lalandi*) feeds at different water temperatures: 2. Soy protein concentrate

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ABSTRACT

Juvenile yellowtail kingfish (*Seriola lalandi*) were fed four iso-nitrogenous and iso-calorific (digestible basis) experimental diets containing 0, 20, 30 or 40% soy protein concentrate (SPC) for 34 days at optimal (22 °C) and suboptimal water temperatures (18 °C) to measure the responses of growth, feed efficiency, nutrient digestibility, gut histology and digestive enzyme activity to dietary manipulation. The substitution of fish meal with 20% SPC did not significantly affect the growth of fish. However, second-order polynomial regression analyses demonstrated that there was a negative impact on the growth of the fish with increasing inclusions of SPC. By contrast, the feed intake was not affected by SPC inclusion, but the apparent feed conversion ratio was significantly increased (worse) above 30% SPC inclusion. The protein and energy efficiency ratios were significantly reduced above 30% SPC inclusion. The whole body moisture and total fat composition were affected above 20% SPC inclusion, but there was no effect on apparent dietary nutrient digestibilities. Suboptimal water temperature significantly decreased all measured growth performance and feed efficiency variables. By contrast, the protein and energy efficiency ratios were higher at 18 °C, while the protein and energy retentions were not affected by temperature. The apparent dietary protein digestibility was influenced by temperature, and its increase at 18 °C suggests the influence of a slower gut transit time at the cooler temperature. This study indicates that juvenile yellowtail kingfish can effectively utilise 20% SPC, regardless of water temperature.

1. Introduction

Substitutions for dietary fish meal with more economical and widely available alternative plant protein ingredients have been studied extensively for many cultured fish species (Bowyer et al., 2013; Gatlin et al., 2007). The types of alternative protein sources with the ability to substitute for fish meal include poultry by-products and animal meals, soybean meal, concentrates from oilseeds and grain by-products, marine proteins from processing plants and fisheries by-catch as well as marine invertebrates and single-cell proteins (Aas et al., 2006; Gatlin et al., 2007; Salze et al., 2010; Stone et al., 2011; Tomas et al., 2005; Zhou et al., 2011). Protein sources from soybeans have received the most attention due to their low cost, high quality and high annual yields. The highly refined soy protein concentrate (SPC) has a similar protein content (minimum 65% protein) and apparent dietary protein and amino acid digestibility to fish meal, but the amino acid profile is lacking in the essential amino acids, methionine and lysine, which are required for marine carnivorous fish species (Hardy, 2008). As SPC is a highly refined ingredient, most of the anti-nutritional factors such as protease inhibitors, lectins, saponins, antigenic proteins, phenolic compounds, oligosaccharides and phytates present in soybean meal have been removed during processing. However, the inclusion of SPC, particularly at high levels has caused reductions in feed intake due to a lowered palatability of the diet (Blaufuss and Trushenski, 2012; Gomes et al., 1995; Medale et al., 1998). The partial or total substitution of fish meal with SPC in diets for marine carnivorous fish species such as cobia (*Rachycentron canadum*), red seabream (*Pagrus major*) and Japanese yellowtail (*Seriola quinqueradiata*) has found that the inclusion of taurine into diets was necessary to significantly improve fish production characteristics (Lunger et al., 2007; Takagi et al., 2008, 2010). Therefore, the substitution of fish meal with SPC requires the supplementation of methionine and lysine, as well as the addition of taurine, in diets substituting high levels or the entire fish meal component.

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The nutritional value of an alternative protein ingredient is dependent on the ability of the fish to digest and absorb the diet (Allan et al., 2000) along with the type, amount and location of digestive enzymes in the gastrointestinal tract (Debnath et al., 2007). The main digestive enzymes responsible for breaking down nutrients are proteases, lipases and amylases. The capacity of nutrient utilisation and transport can be limited by the production of digestive enzymes or by the nutrient transport mechanisms (Debnath et al., 2007; Lemieux et al., 1999). Studies have found that the secretion levels of proteases, lipases and amylases do change in response to the level of ingredient inclusion (Lhoste et al., 1994). In addition, it has been reported that seasonal variations in digestive enzymes are directly correlated to water temperature in species such as Japanese yellowtail (Kofuji et al., 2005), Atlantic salmon (*Salmo salar*) (Einarsson et al., 1996), and pike perch (*Lucioperka lucioperka*) and bream (*Abramis brama*) (Gelman et al., 1984). Reductions in apparent dietary protein digestibility at winter water temperatures have been identified in starved Japanese yellowtail (48 h) due to reduced pepsin activity in the stomach mucus (Kofuji et al., 2005).

The culture of the marine, carnivorous yellowtail kingfish (*Seriola lalandi*) is currently being undertaken in many regions of the world, including Australia, New Zealand, Japan, Taiwan and North and South America (Fowler et al., 2003; Nakada, 2002). The genus *Seriola* belongs to the Carangidae family and includes the commonly cultured Mediterranean yellowtail (*Seriola dumerili*) and Japanese yellowtail. Yellowtail kingfish is a good candidate for aquaculture due to its fast growth (Booth et al., 2010), reaching market size of 3–4 kg in 15–18 months (Fernandes and Tanner, 2008), and is a high quality sushi and sashimi product in Asian countries, particularly in Japan (Jirsa et al., 2011). However, the cost-effective production of yellowtail kingfish requires the ability to incorporate alternative protein ingredients into the diets to replace expensive fish meals. There is very limited knowledge on how much fish meal can be substituted with soy products to grow juvenile yellowtail kingfish (Bowyer et al., 2013). The high level of protein replacement by a single ingredient is unlikely to be used in practical feed formulations, but a range of SPC inclusions was used in this study to explore the physiological response of fish to this ingredient. Therefore, the aim of this study was to investigate the potential of SPC as a substitute for fish meal at 0, 43.5, 65.2 or 87.0% fish meal substitution (0, 20, 30 or 40% SPC inclusion, respectively) based on the response of yellowtail kingfish growth performance, feeding efficiencies, nutrient utilisation, digestive tract histology and digestive enzyme functioning, at optimal and suboptimal water temperatures.

2. Materials and methods

2.1. Experimental diets

Four experimental diets were formulated to contain 0% (the control diet) and 20, 30 or 40% soy protein concentrate (Table 1). The diets were formulated to contain 41.5% digestible protein (50% crude protein) and 14.5% digestible lipid (20% crude lipid) and 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 to satisfy the nutritional requirements for a carnivorous marine fish species (NRC, 2011) (Table 2). The levels of lysine and methionine were balanced in all diets according to the values for Japanese yellowtail (Ruchimat et al., 1997a, 1997b), and to reflect their content in the fish meal control diet (0% SPC). 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 added to all the diets (0.02% inclusion) as an inert maker for apparent digestibility determinations. The diets were produced, at the South Australian Research and Development Institute (SARDI), Australasian Experimental Stockfeed Extrusion Centre (Roseworthy, South Australia, Australia), as cooked-extruded slow sinking pellets (2.5 mm) using a Wenger X-85 (Sabetha, KS, USA). The production parameters were recorded for each diet. During diet

Table 1
Ingredient formulation (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	20	30	40
Herring meal	460.0	260.0	160.0	60.0
Soy protein concentrate	0.0	200.0	300.0	400.0
Wheat 14	90.0	90.0	90.0	90.0
Wheat gluten meal	73.9	71.2	71.2	71.2
Fish oil	93.4	107.4	114.5	121.5
Soy lecithin	5.0	5.0	5.0	5.0
Wheat starch	81.9	60.3	49.1	38.1
Poultry by-product meal	60.6	60.6	60.6	60.7
Blood meal	23.6	25.6	25.5	25.1
Choline chloride	3.0	3.0	3.0	3.0
Corn gluten meal	90.0	90.0	90.0	90.0
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	6.4	7.4	8.3
Taurine	3.6	5.4	6.2	7.1
Lysine	0.0	2.6	4.0	5.5
Methionine	0.0	2.1	3.1	4.1
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.

Table 2
Proximate composition and calculated amino acid composition (dry basis) of the SPC ingredient and the four experimental diets (formulated on a digestible protein and lipid basis) fed to yellowtail kingfish.

Ingredients	SPC	Diet (%)			
		0	20	30	40
Analysed proximate composition					
Dry matter (g kg^{-1})	879.0	938.2	938.5	949.9	935.0
Crude protein (g kg^{-1})	720.6	496.2	498.5	491.6	490.2
Crude lipid (g kg^{-1})	1.0	208.8	177.4	184.0	178.1
Ash (g kg^{-1})	63.0	82.1	66.9	60.2	50.9
NFE (g kg^{-1})[a]	215.4	199.8	241.3	250.9	262.6
Starch (g kg^{-1})	0.0	151.7	127.1	114.6	102.4
NSP (g kg^{-1})[b]	215.4[c]	48.1	114.2	136.3	160.2
Phosphorous (g kg^{-1})	n/a	14.8	12.7	11.6	10.0
Gross energy (MJ kg^{-1})	20.6	23.1	23.3	23.2	23.0
Calculated amino acids (g kg^{-1})					
Arginine	57.2	29.0	30.1	30.6	31.2
Histidine	19.2	15.8	14.7	14.1	13.5
Isoleucine	33.5	24.3	23.5	23.2	22.8
Leucine	56.4	48.0	47.0	46.5	45.9
Lysine	46.7	33.5	32.4	31.9	31.4
Methionine	8.9	14.0	13.7	13.5	13.3
Phenylalanine	36.4	24.6	25.4	25.8	26.1
Threonine	29.6	21.9	21.0	20.6	20.1
Tryptophan	8.9	5.5	5.5	5.5	5.5
Valine	35.0	29.3	28.2	27.6	27.0
Σ IAA[d]	331.8	245.9	241.5	239.1	236.7
Taurine (g kg^{-1})	n/a	8.0	8.0	8.0	8.0

NFE, nitrogen-free extract; NSP, non-starch polysaccharides; IAA, indispensable amino acids.
[a] By difference: NFE = (100 − crude protein − total fat − ash).
[b] By difference: NSP = (NFE − starch).
[c] NSP of SPC ingredient based on the assumption that SPC contains no starch.
[d] Σ IAA: total indispensable amino acid.