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Growth, antioxidant capacity and muscle histochemistry of yellowtail kingfish (*Seriola lalandi* Valenciennes 1883): Selenium and temperature interaction

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ABSTRACT

The aim of this study was to investigate the interactive effects of temperature and dietary selenium concentrations on antioxidant capacity, muscle histochemistry and the growth, of juvenile yellowtail kingfish (*Seriola lalandi*). The yellowtail kingfish were exposed to two temperatures (21 °C or 26 °C) and three selenium levels (0.0, 2.0 or 4.0 mg Se kg^{-1} of feed) for 30 days. Final weight and specific growth rate (SGR) were significantly affected by water temperature ($\rho < 0.001$) and dietary Se ($\rho < 0.001$) supplementation, and there were significant differences in the interaction between these two factors. Juvenile yellowtail kingfish fed Se-supplemented diets, attained a higher final weight and SGR than those without Se supplementation at 21 °C, but not at 26 °C. Regardless of the temperature, the red blood cell (RBC) glutathione peroxidase (GPx) activity of yellowtail kingfish fed Se-supplemented diets was significantly higher ($\rho < 0.05$) than with the control diet. However, GPx activity of yellowtail kingfish when fed either 2.0 mg Se kg^{-1} or 4.0 mg Se kg^{-1} showed no significant difference ($\rho > 0.05$). Se concentration in the muscles of juvenile yellowtail kingfish fed Se-supplemented diets was higher than that of the yellowtail kingfish that were fed the control diet. A histopathological test confirmed that 20.3% of fish muscles exhibited lesions, which occurred in the absence of dietary Se. The outcome of the present study helps in understanding the interactive effects of dietary Se concentrations and the temperature in the farming of yellowtail kingfish.

Abbreviations: RBC, red blood cell; GPx, glutathione peroxidase; SGR, specific growth rate; DNA, deoxyribonucleic acid; ROS, reactive oxygen species; SOD, superoxide dismutase; CAT, catalase; GR, glutathione reductase; ACAAR, Australian Centre for Applied Aquaculture Research; DO, dissolved oxygen; RFI, relative feed intake; BW, body weight; NADPH, nicotinamide adenine dinucleotide phosphate; AES, atomic emission spectrometry; SE, standard error; ANOVA, analysis of variance; SPSS, statistical package for social Sciences; mOsm, milliosmole; RMR, routine metabolic rate; US-EPA, United States Environmental Protection Agency; Se–Se–Se, triselenium linkage; S–Se–S, selenotrisulfide linkage; S–S, disulfide.

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1. Introduction

Disease continues to be the major constraint in the development of sustainable aquaculture. Elevated stress levels are the root of most diseases in farmed fish (Turnbull, 2012; Wedemeyer, 1997). A number of studies have shown that increased disease susceptibility and reduced immune response were attributable to acute or chronic stress responses (Barton and Iwama, 1991; Dang et al., 2012; Davis et al., 2002; Dietrich et al., 2014; Fridell et al., 2007; Iguchi et al., 2003; Li et al., 2014; Nakano et al., 2014; Small and Bilodeau, 2005; Tacchi et al., 2015; Varsamos et al., 2006). Thus, in most cases diseases infect farmed fish following exposure to stress condition.

It is well recognised that fish previously exposed to a stressor may show oxidative stress response (Lushchak and Bagnyukova, 2006), which is a reflection of an imbalance between the levels of prooxidant and antioxidant properties (Sies, 1985). Prooxidant substances include those relating to reactive oxygen species (ROS), chemically reactive molecules containing oxygen, which are responsible for lipids, proteins and deoxyribonucleic acid (DNA) impairment, particularly when fish lack the capacity to deal with accumulated ROS production (Vinagre et al., 2012). Antioxidant properties are classically defined as any substance that provides protection against oxidative damage (Pamplona and Costantini, 2011). The equilibrium between ROS production and antioxidant stores that the fish maintain, therefore, regulate the extent to which oxidative damage can occur in fish. Enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx) establish a fundamental aspect of the antioxidant response (Winston, 1991).

Selenium (Se), an essential micro-mineral required for maintaining the growth and metabolic function of fish, serves as an integral structural element of the active core of GPx enzymes in red blood cells (RBCs) (Rotruck et al., 1973). Although Se is needed only in trace amounts, Se engrosses a distinctive attention among micro-minerals as the constraint in the antioxidant enzyme biosynthesis. Se-containing GPx plays an important role in protecting cells and membranes from oxidative stress by catalysing the reduction of hydrogen peroxide and lipid peroxides using reduced glutathione (GR) (Watanabe et al., 1997). The activity of this enzyme is modulated by sufficient Se intake (Dhur et al., 1990) and it is well known that, although fish can accumulate Se via both surrounding water and food, dietary exposure to Se compounds comprises the predominant source of Se for fish (Janz, 2011). Dietary supplementation of Se has been reported to enhance the antioxidant enzyme capacity precursor in crayfish *Procambarus clarkii* (Dörr et al., 2008), freshwater prawn *Macrobrachium rosenbergii* (Chiu et al., 2010), whiteleg shrimp *Litopenaeus vannamei* (Parrilla-Taylor and Zenteno-Savín, 2011; Parrilla-Taylor et al., 2013), common carp *Cyprinus carpio* (Elia et al., 2011), crucian carp *Carassius auratus gibelio* (Zhou et al., 2009), rainbow trout *Oncorhynchus mykiss* (Kucukbay et al., 2009), and cod *Gadus morhua* (Penglase et al., 2010). An additional benefit of using Se as a feed supplement is that elevated dietary levels improve growth and feed utilisation in a variety of aquatic species, including African catfish, *Clarias gariepinus* (Abdel-Tawwab et al., 2007), gibel carp *C. auratus gibelio* (Han et al., 2011), and abalone, *Haliotis discus hannai* Ino (Wang et al., 2012). In most fish, Se deficiency leads to poor growth performance, lipid peroxidation and decreased GPx enzymatic activity (Bell et al., 1986; Hilton et al., 1980; Wang et al., 2007).

Se exists in two forms, namely inorganic Se (selenate and selenite) and organic Se (selenomethionine and selenocysteine) (Sunde, 2006). The amount of dietary Se demanded to enhance growth and antioxidant capacity is dependent on Se sources. For instance, using sodium selenite, Hilton et al. (1980) recommended that a concentration of 0.38 mg Se kg^{-1} is suitable for rainbow trout *O. mykiss*. With the similar form of Se, Gatlin and Wilson (1984) demonstrated that the optimum dietary supplementation of Se for channel catfish *Ictalurus punctatus* is 0.25 mg Se kg^{-1}. However, in an investigation employing selenomethionine, the juvenile grouper *Epinephelus malabaricus* required 0.77 mg Se kg^{-1} for their best growth performance (Lin and Shiau, 2005). Han et al. (2011) found that the dietary selenomethionine requirement for gibel carp *C. auratus gibelio* is 1.18 mg Se kg^{-1}. Another experiment on African catfish *C. gariepinus*, conducted by Abdel-Tawwab et al. (2007), showed that a selenomethionine concentration of 3.67 mg Se kg^{-1} was proposed as the optimum level needed to improve fish growth and vitality against environmentally-induced stress.

Se nutrition of yellowtail kingfish (*Seriola lalandi*), an emerging species in Australia and New Zealand aquaculture, has been recently studied. Le and Fotedar (2014a) reported that selenomethionine and seleno-yeast were the most bioavailable sources of Se to yellowtail kingfish. Se from fishmeal-based diets was inadequate to maintain the growth performances of the species and therefore supplementation with organic Se was recommended. In addition, dietary Se significantly improved yellowtail kingfish survival, antibodies, and haematocrit, following exposure to bacterial challenge, and the role of Se as an antioxidant was established by activities such as resistance of RBCs to peroxidation and GPx (Le and Fotedar, 2014b). However, very limited data and information is available on the effects of temperature on micro-minerals such as Se utilisation, which may in turn, influence the growth and health of the cultured species. In commercial aquaculture, yellowtail kingfish are exposed to fluctuating water temperatures, which can affect the level of basal metabolism (De Silva, 1995), and thus induce stress (Bowden et al., 2007; Nakano et al., 2014). The species are presently cultured in sea cages at temperatures ranging from 12 °C to 28 °C in Australia (Tanner and Fernandes, 2010) and 14 °C to 22 °C in New Zealand (Moran et al., 2009). Therefore, this study was designed to investigate the effect of organic Se supplementation on growth as well as health performance of juvenile yellowtail kingfish at two temperatures that represent ambient and elevated water temperatures. Adequate knowledge of mineral utilisation at relevant environmental temperatures is important for optimising dietary composition and feeding conditions (Kim et al., 2006), thus, improving fish performance under culture situations, particularly during the grow-out phase.