

Effects of Selenomethionine on Growth Performance, Tissue Selenium Content, Antioxidant Capacity, and Serum Biochemical Indices of Striped Bass (*Morone saxatilis*) Postprint

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Abstract

This experiment aimed to investigate the effects of dietary selenomethionine (Se-Met) supplementation on growth performance, tissue selenium content, antioxidant capacity, and serum biochemical indices of striped seabass. A total of 540 healthy juvenile striped seabass with an initial body weight of (81.62 ± 0.75) g were randomly divided into 6 groups, with 3 replicates per group and 30 fish per replicate. Each group was fed experimental diets with selenium contents of 0.09, 0.21, 0.44, 0.58, 0.77, and 1.05 mg/kg, respectively. The experimental period lasted for 8 weeks. The results showed that: 1) The group fed the 0.58 mg/kg selenium diet had the highest final body weight and weight gain rate, which were significantly higher than those of other groups ($P < 0.05$). The group fed the 0.58 mg/kg selenium diet had the lowest feed conversion ratio, which was significantly lower than those of the groups fed 0.09, 0.77, and 1.05 mg/kg selenium diets ($P < 0.05$). 2) The group fed the 0.77 mg/kg selenium diet had the highest muscle crude fat content, which was significantly higher than those of other groups except the 0.58 mg/kg selenium group ($P < 0.05$). The group fed the 0.44 mg/kg selenium diet had the highest muscle crude ash content, which was significantly higher than those of other groups ($P < 0.05$). 3) The liver selenium content in the group fed the 0.77 mg/kg selenium diet was significantly higher than those in the groups fed 0.09, 0.21, and 0.44 mg/kg selenium diets ($P < 0.05$). The serum selenium content in the group fed the 0.58 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed 0.09, 0.21, 0.44, and 1.05 mg/kg selenium diets ($P < 0.05$). 4) The serum glutathione peroxidase (GPx) activity in the group fed the 1.05 mg/kg selenium diet was significantly higher than those of other groups ($P < 0.05$). The serum glutathione reductase (GR) activity in the group fed the 0.58 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed

0.77 and 1.05 mg/kg selenium diets. The serum catalase (CAT) activity in the group fed the 0.58 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed 0.09, 0.21, and 1.05 mg/kg selenium diets ($P < 0.05$). The serum glutathione S-transferase (GST) activity in the group fed the 1.05 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed 0.09, 0.21, 0.44, and 0.58 mg/kg selenium diets ($P < 0.05$). 5) The liver GPx activity in the group fed the 0.09 mg/kg selenium diet was the lowest, which was significantly lower than those in the groups fed 0.44, 0.58, and 0.77 mg/kg selenium diets ($P < 0.05$). The liver GR activity in the group fed the 0.09 mg/kg selenium diet was the lowest, which was significantly lower than those in the groups fed 0.44, 0.58, and 1.05 mg/kg selenium diets ($P < 0.05$). The liver GST activity in the group fed the 0.09 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed 0.44, 0.58, 0.77, and 1.05 mg/kg selenium diets ($P < 0.05$). The liver superoxide dismutase (SOD) activity in the group fed the 0.77 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed 0.09 and 1.05 mg/kg selenium diets ($P < 0.05$). The liver CAT activity in the group fed the 0.44 mg/kg selenium diet was the highest, which was significantly higher than those of other groups ($P < 0.05$). 6) The serum total protein content in the group fed the 0.58 mg/kg selenium diet was the highest, which was significantly higher than those of other groups ($P < 0.05$). The serum total cholesterol content in the group fed the 0.58 mg/kg selenium diet was the highest, which was significantly higher than those in the groups fed 0.09, 0.21, and 0.44 mg/kg selenium diets ($P < 0.05$). The serum immunoglobulin M content and lysozyme activity in the group fed the 0.77 mg/kg selenium diet were the highest, which were significantly higher than those in the groups fed 0.09, 0.21, 0.44, and 1.05 mg/kg selenium diets ($P < 0.05$). Using weight gain rate, liver selenium content, and serum lysozyme activity as evaluation indices, quadratic curve analysis revealed that the optimal selenium requirements for striped seabass were 0.62, 0.92, and 0.72 mg/kg, respectively, indicating that the optimal dietary selenium level is 0.62-0.92 mg/kg.

Full Text

Effects of Selenomethionine on Growth Performance, Tissue Selenium Content, Antioxidant Capacity and Serum Biochemical Indices of *Centropomus striata*

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Abstract: This experiment was conducted to investigate the effects of dietary

selenomethionine (Se-Met) supplementation on growth performance, tissue selenium content, antioxidant capacity, and serum biochemical indices of juvenile *Centropristis striata*. A total of 540 healthy juvenile fish with initial body weight of (81.62 ± 0.75) g were randomly divided into 6 groups with 3 replicates per group and 30 fish per replicate. The six groups were fed experimental diets containing selenium at levels of 0.09, 0.21, 0.44, 0.58, 0.77, and 1.05 mg/kg for 8 weeks. The results showed: 1) The group fed 0.58 mg/kg selenium achieved the highest final body weight and weight gain rate, which were significantly higher than other groups ($P < 0.05$). This group also exhibited the lowest feed conversion ratio, significantly lower than the 0.09, 0.77, and 1.05 mg/kg groups ($P < 0.05$). 2) The 0.77 mg/kg group showed the highest muscle crude lipid content, significantly higher than all groups except the 0.58 mg/kg group ($P < 0.05$). The 0.44 mg/kg group had the highest muscle crude ash content, significantly higher than all other groups ($P < 0.05$). 3) The 0.77 mg/kg group demonstrated significantly higher liver selenium content compared to the 0.09, 0.21, and 0.44 mg/kg groups ($P < 0.05$). Serum selenium content peaked in the 0.58 mg/kg group, significantly higher than the 0.09, 0.21, 0.44, and 1.05 mg/kg groups ($P < 0.05$). 4) Serum glutathione peroxidase (GPx) activity was highest in the 1.05 mg/kg group, significantly exceeding all other groups ($P < 0.05$). Serum glutathione reductase (GR) activity peaked at 0.58 mg/kg, significantly higher than the 0.77 and 1.05 mg/kg groups. Serum catalase (CAT) activity was also highest at 0.58 mg/kg, significantly higher than the 0.09, 0.21, and 1.05 mg/kg groups ($P < 0.05$). Serum glutathione S-transferase (GST) activity reached maximum at 1.05 mg/kg, significantly higher than the 0.09, 0.21, 0.44, and 0.58 mg/kg groups ($P < 0.05$). 5) Liver GPx activity was lowest in the 0.09 mg/kg group, significantly lower than the 0.44, 0.58, and 0.77 mg/kg groups ($P < 0.05$). Liver GR activity was also lowest at 0.09 mg/kg, significantly lower than the 0.44, 0.58, and 1.05 mg/kg groups ($P < 0.05$). Conversely, liver GST activity was highest in the 0.09 mg/kg group, significantly higher than the 0.44, 0.58, 0.77, and 1.05 mg/kg groups ($P < 0.05$). Liver superoxide dismutase (SOD) activity peaked at 0.77 mg/kg, significantly higher than the 0.09 and 1.05 mg/kg groups ($P < 0.05$). Liver CAT activity was highest in the 0.44 mg/kg group, significantly exceeding all other groups ($P < 0.05$). 6) Serum total protein content was highest in the 0.58 mg/kg group, significantly higher than all other groups ($P < 0.05$). Serum total cholesterol content also peaked at 0.58 mg/kg, significantly higher than the 0.09, 0.21, and 0.44 mg/kg groups ($P < 0.05$). Serum immunoglobulin M content and lysozyme activity were highest in the 0.77 mg/kg group, significantly higher than the 0.09, 0.21, 0.44, and 1.05 mg/kg groups ($P < 0.05$). Using weight gain rate, liver selenium content, and serum lysozyme activity as evaluation indicators, quadratic curve analysis determined that the optimal dietary selenium requirement for *Centropristis striata* was 0.62, 0.92, and 0.72 mg/kg, respectively, indicating that the suitable dietary selenium content ranges from 0.62 to 0.92 mg/kg.

Keywords: *Centropristis striata*; selenomethionine; growth performance; tissue selenium content; antioxidant capacity

Introduction

Selenium (Se) is an essential trace mineral element for organisms and a component of glutathione peroxidase (GPx) and deiodinase (DIO). Selenium can utilize reduced glutathione to convert hydrogen peroxide and fatty acid hydroperoxides into water and fatty acids, thereby protecting cell membranes from oxidative damage. It plays important roles in growth performance, antioxidant capacity, and immune function of aquatic animals [1-2]. Selenomethionine (Se-Met) is an organic selenium compound synthesized by replacing the sulfur element in methionine with selenium under certain conditions [3]. Unlike inorganic selenium, which is absorbed through passive diffusion, organic selenium such as selenium-containing amino acids and selenium yeast is absorbed through active transport in the small intestine, offering advantages of rapid absorption, high utilization efficiency, low toxicity, and reduced environmental pollution [4]. The application of organic selenium to improve growth rate, antioxidant capacity, and immunity has received widespread attention and is widely used as a feed additive in livestock and poultry, though research in aquaculture remains limited.

Centropristis striata, also known as black sea bass, belongs to the family Serranidae, subfamily Serraninae, and genus *Centropristis*, with biological characteristics similar to those of the *Epinephelus* genus [5]. Introduced to China in 2002, *C. striata* was successfully domesticated and artificially bred in 2006 [6]. The species is valued for its rich meat quality, fresh and tender taste, few bones, and easy processing, with high muscle yield containing substantial crude protein and lipid, offering high nutritional value and health benefits [7]. In aquaculture, *C. striata* exhibits low disease incidence, strong stress resistance, and rapid growth [8]. In recent years, artificial breeding and culture techniques have matured, demonstrating great aquaculture potential [9-11]. However, research on *C. striata* has primarily focused on physiology, pathology, seed breeding, and culture technology [12-16], with limited studies on dietary trace element requirements. Numerous studies have investigated the effects of inorganic selenium on growth and antioxidant function in fish such as *Lateolabrax japonicus* [17], *Ctenopharyngodon idellus* [18], *Ictalurus punctatus* [19], *Cyprinus carpio* [20], *Oncorhynchus mykiss* [21], *Larimichthys crocea* [22], *Pelteobagrus fulvidraco* [23], and *Haliotis discus hannai* [24]. In contrast, research on organic selenium application in aquaculture is limited to species including *Oreochromis niloticus* [25], *Epinephelus* spp. [26], *Carassius auratus gibelio* [27], *Acipenser transmontanus* [28], and *Macrobrachium nipponense* [29]. This study investigated the effects of dietary Se-Met supplementation at different levels on growth performance, tissue selenium content, antioxidant capacity, and serum biochemical indices of *C. striata* to provide a scientific basis for organic selenium application in formulated feeds for grouper species.

1. Materials and Methods

1.1 Experimental Materials and Reagents The selenomethionine used in this experiment was L-selenomethionine purchased from Shanghai Yuanye Biotechnology Co., Ltd. with a purity of 98%. Assay kits for GPx, glutathione reductase (GR), glutathione S-transferase (GST), superoxide dismutase (SOD), catalase (CAT), lysozyme (LZM) activity, total antioxidant capacity (T-AOC), total protein (TP), triglyceride (TG), and total cholesterol (TC) were purchased from Nanjing Jiancheng Bioengineering Institute. The enzyme-linked immunosorbent assay (ELISA) kit for immunoglobulin M (IgM) was purchased from Shanghai Enzyme-linked Biotechnology Co., Ltd.

1.2 Experimental Diets The basal diet was formulated using casein and gelatin as primary protein sources, fish oil and soybean oil as main lipid sources, supplemented with mineral and vitamin premixes. Selenomethionine was added to the basal diet at levels of 0 (control), 0.2, 0.4, 0.6, 0.8, and 1.0 mg/kg, with measured selenium contents of 0.09 (control), 0.21, 0.44, 0.58, 0.77, and 1.05 mg/kg, respectively. The composition and nutrient levels of experimental diets are shown in Table 1. All feed ingredients were ground to pass through an 80-mesh sieve, mixed using the stepwise expansion method, combined with fish oil and soybean oil until no oil particles remained, moistened with appropriate water, extruded into 3 mm diameter pellets using a pelletizer, dried in an oven for 12 hours, bagged separately, and stored at -20°C until use.

1.3 Experimental Design and Management The feeding trial was conducted at a culture facility in Rizhao, Shandong Province. Experimental fish were two-year-old juveniles produced from *C. striata* broodstock maintained in our laboratory. A total of 540 healthy juvenile fish with body weight of (81.62 ± 0.75) g were randomly divided into 6 groups with 3 replicates per group and 30 fish per replicate. Fish were stocked in 18 culture tanks (500 L each) with 30 fish per tank. Juvenile *C. striata* were acclimated for 2 weeks and fed a commercial grouper diet to adapt to the culture environment. Each group was fed experimental diets containing 0.09, 0.21, 0.44, 0.58, 0.77, and 1.05 mg/kg selenium, respectively. Prior to the experiment, all fish were fasted for 24 hours and weighed. Fish were hand-fed the experimental diets twice daily at 07:00 and 17:00 for 1 hour each time to apparent satiation at 4-6% of body weight, adjusted according to feeding and growth performance. The experiment lasted for 8 weeks.

The culture water was underground seawater from Rizhao, Shandong with pH 6.8-7.3. Water temperature was maintained at 18-24°C, salinity at 22-24‰, and ammonia nitrogen concentration below 0.2 mg/L. Continuous aeration was provided using air pumps with an overflow water system. Seawater selenium content was measured every 2 weeks, with no detectable selenium throughout the experimental period.

1.4 Sample Collection At the end of the experiment, all fish were fasted for 24 hours, then lightly anesthetized with 100 mg/L eugenol. Fish in each tank were counted and weighed to calculate weight gain rate (WGR) and survival rate (SR). After weighing, 5 fish were randomly selected from each tank for caudal vein blood collection into 1.5 mL centrifuge tubes, stored overnight at 4°C, then centrifuged at 3,000 r/min for 15 minutes. The resulting serum was aliquoted into 1.8 mL cryovials, snap-frozen in liquid nitrogen, and stored for serum biochemical and antioxidant enzyme analysis. Kidney, liver, and muscle tissues were collected in sealed bags and stored at -20°C for selenium content determination. From each tank, 5 fish were lightly anesthetized with eugenol, livers were weighed to calculate hepatosomatic index (HSI), and muscle samples were collected for proximate composition analysis (crude protein, crude lipid, moisture, and crude ash). Additionally, 3 fish were randomly selected from each tank, anesthetized, and livers were excised, pooled into cryovials, snap-frozen in liquid nitrogen, and stored at -80°C for determination of liver GPx, GR, GST, SOD, CAT activities and T-AOC.

1.5 Measurement Indicators and Methods Proximate composition of whole fish and diets was determined using AOAC methods. Tissue selenium content was measured by hydride generation atomic fluorescence spectrometry (GB/T 13883-2008). Liver and serum antioxidant enzyme activities were determined using assay kits from Nanjing Jiancheng Bioengineering Institute with a multifunctional microplate reader (SpectraMax iD3). Serum LZM activity was measured using a UV-2000 spectrophotometer, while TP and IgM contents were determined using a Hitachi 7020 automatic biochemical analyzer.

Growth performance parameters were calculated as follows:

Weight gain rate (%) = [(final body weight - initial body weight) / initial body weight] × 100

Survival rate (%) = (final fish number / initial fish number) × 100

Feed conversion ratio (FCR) = feed intake / (final average weight - initial average weight)

Hepatosomatic index (%) = (liver weight / body weight) × 100

1.6 Data Processing Experimental data (except survival rate) are expressed as mean ± standard error. One-way analysis of variance (ANOVA) was performed using SPSS 19.0 software. When significant differences were detected ($P < 0.05$), Tukey's test was used for pairwise comparisons among groups. Quadratic regression analysis was applied to weight gain rate, liver selenium content, and serum LZM activity to determine the optimal dietary selenium requirement for *C. striata*.

2. Results

2.1 Effects of Selenomethionine on Growth Performance of *Centropristis striata* As shown in Table 2, final body weight and weight gain rate of

groups fed 0.21-1.05 mg/kg selenium were significantly higher than the control group (0.09 mg/kg) ($P < 0.05$). Weight gain rate increased with dietary selenium levels from 0.09 to 0.58 mg/kg, then decreased and plateaued at higher levels. Quadratic curve analysis of weight gain rate indicated that the optimal dietary selenomethionine supplementation level was 0.62 mg/kg (Figure 1 [Figure 1: see original paper]). The 0.58 mg/kg group exhibited the lowest feed conversion ratio, significantly lower than the 0.09 mg/kg group ($P < 0.05$). Hepatosomatic index decreased initially, then increased, then decreased again with rising dietary selenium levels. No significant differences in survival rate were observed among groups ($P > 0.05$).

2.2 Effects of Selenomethionine on Muscle Nutrient Composition of *Centropristis striata* As presented in Table 3, no significant differences in muscle moisture (73.06-77.32%) or crude protein content (21.53-22.60%) were detected among groups ($P > 0.05$). Muscle crude lipid content decreased initially then increased with dietary selenium levels, with the 0.77 mg/kg group showing the highest value, significantly higher than all groups except the 0.58 mg/kg group ($P < 0.05$). The 0.44 mg/kg group exhibited the highest muscle crude ash content, significantly higher than all other groups ($P < 0.05$), with no significant differences among the remaining groups ($P > 0.05$).

2.3 Effects of Selenomethionine on Tissue and Serum Selenium Content of *Centropristis striata* As shown in Table 4, no significant differences in selenium content were observed in muscle or kidney among groups ($P > 0.05$). Liver selenium content increased initially then decreased with dietary selenium levels, with the 0.77 mg/kg group showing significantly higher levels than the 0.09, 0.21, and 0.44 mg/kg groups ($P < 0.05$). Serum selenium content followed a similar trend, peaking in the 0.58 mg/kg group, which was significantly higher than the 0.09, 0.21, 0.44, and 1.05 mg/kg groups ($P < 0.05$). Quadratic curve analysis of liver selenium content indicated that the optimal dietary selenomethionine supplementation level was 0.92 mg/kg (Figure 2 [Figure 2: see original paper]).

2.4 Effects of Selenomethionine on Antioxidant Enzyme Activities in Serum and Liver of *Centropristis striata* As shown in Table 5, serum GPx activity increased linearly with dietary selenium levels, with the 1.05 mg/kg group significantly higher than all other groups ($P < 0.05$). Serum GR activity increased initially then decreased, peaking in the 0.58 mg/kg group, which was significantly higher than the 0.77 and 1.05 mg/kg groups. Serum CAT activity also increased initially then decreased, with the 0.58 mg/kg group significantly higher than the 0.09, 0.21, and 1.05 mg/kg groups ($P < 0.05$). No significant differences in serum SOD activity were observed among groups ($P > 0.05$). Serum GST activity decreased initially then increased, with the 1.05 mg/kg group significantly higher than the 0.09, 0.21, 0.44, and 0.58 mg/kg groups ($P < 0.05$).

As presented in Table 6 , liver GPx activity increased initially then decreased with dietary selenium levels, with the 0.09 mg/kg group showing the lowest activity, significantly lower than the 0.44, 0.58, and 0.77 mg/kg groups ($P < 0.05$). Liver GR activity increased with dietary selenium levels from 0.09 to 0.58 mg/kg, with the 0.09 mg/kg group significantly lower than the 0.44, 0.58, and 1.05 mg/kg groups ($P < 0.05$). Liver GST activity decreased with increasing dietary selenium levels, with the 0.09 mg/kg group showing the highest activity, significantly higher than the 0.44, 0.58, 0.77, and 1.05 mg/kg groups ($P < 0.05$). Liver SOD activity increased initially then decreased, peaking in the 0.77 mg/kg group, which was significantly higher than the 0.09 and 1.05 mg/kg groups ($P < 0.05$). Liver CAT activity increased initially, then decreased, then increased again, with the 0.44 mg/kg group showing the highest activity, significantly higher than all other groups ($P < 0.05$). No significant differences in liver T-AOC were observed among groups ($P > 0.05$).

2.5 Effects of Selenomethionine on Serum Biochemical Indices of *Centropristis striata* As shown in Table 7 , the 0.58 mg/kg group exhibited the highest serum TP content, significantly higher than all other groups ($P < 0.05$). Serum TC content also peaked in the 0.58 mg/kg group, significantly higher than the 0.09, 0.21, and 0.44 mg/kg groups ($P < 0.05$). No significant differences in serum TG content or T-AOC were detected among groups ($P > 0.05$). Serum IgM content increased initially then decreased with dietary selenium levels, reaching maximum in the 0.77 mg/kg group, which was significantly higher than the 0.09, 0.21, 0.44, and 1.05 mg/kg groups ($P < 0.05$). Serum LZM activity followed a similar trend, peaking in the 0.77 mg/kg group, significantly higher than the 0.09, 0.21, 0.44, and 1.05 mg/kg groups ($P < 0.05$). Quadratic curve analysis of serum LZM activity indicated that the optimal dietary selenium requirement for *C. striata* was 0.72 mg/kg (Figure 3 [Figure 3: see original paper]).

3. Discussion

3.1 Effects of Selenomethionine on Growth Performance of *Centropristis striata* Numerous studies have demonstrated that appropriate dietary selenium supplementation promotes fish growth and reduces feed conversion ratio. Wei et al. [27] reported that organic selenium (selenium-enriched polysaccharides and selenium protein) at 0.2 mg/kg increased weight gain rate by 15.29% and decreased feed conversion ratio by 12.49% in gibel carp. Lin et al. [30] found that dietary selenomethionine at 0.7 mg/kg produced the highest weight gain rate and feed efficiency in grouper. Our results indicate that 0.58 mg/kg dietary selenium yielded the highest weight gain rate and lowest feed efficiency in juvenile *C. striata*, while feeding a purified diet without selenium supplementation inhibited growth. Thus, dietary selenium is essential for maintaining normal growth and physiological function in *C. striata*. Using weight gain rate as the evaluation indicator, quadratic model analysis determined the selenium requirement to be 0.62 mg/kg, which is comparable to findings in tilapia [25]

(0.6 mg/kg) and grouper [30] (0.7 mg/kg).

3.2 Effects of Selenomethionine on Tissue and Serum Selenium Content of *Centropristis striata* Selenium can accumulate in organisms, and increased selenomethionine not only enhances selenium absorption and deposition but also serves as an endogenous selenium pool for rapid utilization during oxidative stress. Bell et al. [31] investigated selenium bioavailability from different sources in Atlantic salmon and identified liver, kidney, and muscle as the primary sites of selenium metabolism. Sele et al. [32] used HPLC-ICP-MS to analyze selenium forms in muscle of Atlantic salmon fed organic versus inorganic selenium, demonstrating that selenomethionine is the predominant selenium form in salmon muscle. Our results showed the tissue selenium content ranking as kidney > liver > muscle > serum in *C. striata*, with the highest kidney selenium accumulation observed at 1.05 mg/kg dietary selenium. Elia et al. [33] fed carp diets containing 0.25 and 1.00 mg/kg selenium and found selenium accumulation followed the pattern kidney > liver > muscle, with maximum kidney accumulation at 1.00 mg/kg, consistent with our findings. In this study, liver selenium content in juvenile *C. striata* increased initially then decreased with dietary selenium levels, similar to the accumulation pattern observed in cobia [34]. Kidney selenium content increased with dietary selenium levels, consistent with findings in rainbow trout [35]. Using liver selenium content as the evaluation indicator, quadratic analysis determined the optimal dietary selenium requirement to be 0.92 mg/kg. The highest selenium content in kidney suggests that *C. striata* kidney exhibits a greater dose-response to dietary selenomethionine than liver or muscle. Tashjian et al. [28] fed white sturgeon diets containing 0.4-20.5 mg/kg selenomethionine for 8 weeks and found significant increases in kidney and muscle selenium content but not in liver, indicating that selenium accumulation varies among tissues and species even with the same selenium source.

3.3 Effects of Selenomethionine on Antioxidant Enzyme Activities in Serum and Liver of *Centropristis striata* The antioxidant effects of selenium are primarily mediated through selenoproteins such as GPx. Selenium is an essential component of GPx, with four selenium atoms bound to selenocysteine at its active center serving as the redox center. GPx is a crucial antioxidant enzyme that catalyzes the reduction of lipid hydroperoxides (ROOH) to harmless hydroxyl compounds using reduced glutathione (GSH) and decomposes hydrogen peroxide, thereby preventing further damage from reactive oxygen species (ROS) [36]. Behne et al. [37] demonstrated that GPx activity in rat plasma, liver, kidney, and muscle was significantly correlated with selenium content. GR is a flavoprotein oxidoreductase that uses NADPH as a hydrogen donor to catalyze the reduction of oxidized glutathione (GSSG) to GSH, playing an important role in maintaining redox balance [38]. In this study, serum GPx activity increased linearly with dietary selenium levels, while liver GPx activity increased initially then decreased, mirroring liver selenium accumulation pat-

terns, indicating that high tissue selenium levels can induce liver GPx activity and enhance free radical defense capacity. These findings are consistent with studies on grouper [30] and cobia [34]. GST, another detoxification enzyme, showed decreased activity with increasing dietary selenium levels.

SOD and CAT constitute the primary antioxidant defense system and the first line of cellular defense. The effects of organic selenium on fish antioxidant capacity have been investigated in grouper [30], cobia [34], and hybrid snakehead [39]. Under normal conditions, superoxide anion radicals (O_2^-) are catalyzed by SOD to produce hydrogen peroxide and oxygen, which are then decomposed by GPx and CAT into water [40]. In this study, both liver and serum SOD activities increased initially then decreased with dietary selenium levels, consistent with results from selenomethionine supplementation in cobia [34] and tilapia [25]. Liver CAT activity showed an increase-decrease-increase pattern with dietary selenium levels, with all selenomethionine-supplemented groups showing higher activity than the control group, similar to liver SOD activity patterns, indicating that dietary selenomethionine supplementation can enhance antioxidant capacity.

Although selenium is essential for maintaining selenoprotein function and normal physiological processes, it is also toxic at excessive levels. Selenium accumulation beyond nutritional requirements may cause significant harm [41]. Xiong et al. [42] reported pathological changes and hepatotoxicity in channel catfish fed selenium-enriched yeast at 0.67 mg/kg for 56 days. Due to the narrow margin between nutritional requirement and toxicity, selenium is considered a “double-edged sword” [43]. Studies in mice have shown that selenomethionine has lower chronic toxicity than sodium selenite [44]. In this study, serum GR, CAT, GST activities and liver SOD, GST activities all showed initial increases followed by decreases, reaching minimum values at the highest dietary selenium level (1.05 mg/kg), suggesting that excessive selenium may exceed physiological requirements, causing antioxidant enzyme system disruption or oxidative stress in *C. striata*.

3.4 Effects of Selenomethionine on Serum Biochemical Indices of *Centropristis striata* Serum IgM content is an important indicator of immune function and disease resistance in fish. Wang et al. [45] found that serum IgM content in common carp decreased with dietary selenium deficiency, attributing this to selenium deficiency-induced damage to liver, head kidney, and spleen, reducing IgM synthesis capacity. In this study, serum IgM content and LZM activity in *C. striata* increased with dietary selenium levels, peaking at 0.77 mg/kg, indicating maximal immune function at this level. Quadratic curve analysis of serum LZM activity determined the optimal dietary selenium requirement to be 0.72 mg/kg. LZM is another crucial component of non-specific immunity that defends against bacterial, viral, and parasitic infections by hydrolyzing pathogen cell wall mucopolysaccharides. Kong et al. [29] reported that serum LZM activity in oriental river prawn was significantly higher at dietary selenium levels

of 0.31, 0.47, 0.59, and 0.88 mg/kg compared to 0.11 and 1.17 mg/kg, similar to our findings. In conclusion, dietary selenomethionine supplementation can enhance the immune function of *C. striata*.

4. Conclusion

Dietary selenomethionine supplementation significantly affects growth performance, antioxidant capacity, and immune function of *Centropristis striata*. Based on quadratic curve analysis of weight gain rate, liver selenium content, and serum lysozyme activity, the optimal dietary selenium requirements were determined to be 0.62, 0.92, and 0.72 mg/kg, respectively, indicating that the suitable dietary selenium content ranges from 0.62 to 0.92 mg/kg.

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