Effects of Oxidized Fish Oil on Growth Performance and Antioxidant Indices of Yellow Catfish (Pelteobagrus fulvidraco) and the Intervention Effect of Arginine: Postprint

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Abstract

This study aimed to investigate the effects of dietary oxidized fish oil on growth performance, body composition, serum biochemical indices, and serum and hepatic antioxidant indices of yellow catfish (Pelteobagrus fulvidraco), as well as the intervention effect of arginine supplementation. Six hundred healthy yellow catfish with initial body weight of (4.41$±$0.05) g were randomly divided into 6 groups with 4 replicates per group, and fed six diets containing 2.5% fresh fish oil (FF group), 1.5% fresh fish oil + 1.0% oxidized fish oil (FO1 group), 0.5% fresh fish oil + 2.0% oxidized fish oil (FO2 group), 2.5% fresh fish oil + 0.48% L-arginine hydrochloride (FFA group), 1.5% fresh fish oil + 1.0% oxidized fish oil + 0.48% L-arginine hydrochloride (FOA1 group), and 0.5% fresh fish oil + 2.0% oxidized fish oil + 0.48% L-arginine hydrochloride (FOA2 group) for 56 days. The results showed: In FF, FO1, and FO2 groups, with increasing oxidized fish oil supplementation, weight gain rate, specific growth rate, and protein deposition rate of yellow catfish decreased gradually, while feed conversion ratio and feeding rate increased gradually, all reaching extreme values in the FO2 group, with significant differences from the other two groups ($P<0.05$); After arginine supplementation to oxidized fish oil diets, the above indices showed no significant differences among FFA, FOA1, and FOA2 groups ($P>0.05$), with weight gain rates in FOA1 and FOA2 groups increasing by 3.0% and 9.9% compared with FO1 and FO2 groups, respectively. Two-way ANOVA results showed that oxidized fish oil had significant effects on weight gain rate and feeding rate of yellow catfish ($P<0.05$), and there was an interaction between oxidized fish oil and arginine on specific growth rate, protein deposition rate, and feed conversion ratio of yellow catfish ($P<0.05$). The hepatosomatic index in FO1 group was significantly lower than that in FF group ($P<0.05$), the intestosomatic in-

dex in FO2 group was significantly lower compared with FFA and FOA2 groups (P<0.05), and there was an interaction between oxidized fish oil and arginine on hepatosomatic index of yellow catfish (P<0.05). Whole-body crude lipid content in FOA1 group was significantly lower than that in FO1 group (P<0.05). In FF, FO1, and FO2 groups, with increasing oxidized fish oil supplementation, serum total antioxidant capacity (T-AOC) of yellow catfish decreased gradually, with FO2 group being significantly lower than FF group (P<0.05); After arginine supplementation to oxidized fish oil diets, serum T-AOC of yellow catfish increased by 77.0% (FOA1 vs. FO1) and 137.4% (FOA2 vs. FO2), with the latter reaching a significant level (P<0.05). Two-way ANOVA results showed that oxidized fish oil had significant effects on serum malondialdehyde (MDA) content (P<0.05), and there was an interaction between oxidized fish oil and arginine on serum T-AOC of yellow catfish (P<0.05). The results indicated that dietary supplementation of a certain amount of oxidized fish oil could inhibit growth performance and reduce serum antioxidant capacity of yellow catfish, but supplementation of a certain amount of arginine could alleviate the inhibitory effect of oxidized fish oil on growth and enhance the antioxidant capacity of the fish.

Full Text

Effects of Oxidized Fish Oil on Growth Performance and Antioxidant Indexes of Yellow Catfish (Pelteobagrus fulvidraco) and the Intervention Role of Arginine

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Abstract

This experiment was conducted to investigate the effects of dietary oxidized fish oil on growth performance, body composition, serum biochemical parameters, and serum and liver antioxidant indexes of juvenile yellow catfish (*Pelteobagrus fulvidraco*), as well as the intervention effects of arginine supplementation. A total of 600 healthy yellow catfish with an initial body weight of (4.41$±$0.05) g were randomly divided into 6 groups with 4 replicates of 25 fish each. The fish were fed six experimental diets for 56 days: 2.5% fresh fish oil (FF group), 1.5% fresh fish oil + 1.0% oxidized fish oil (FO1 group), 0.5% fresh fish oil

+ 2.0% oxidized fish oil (FO2 group), 2.5% fresh fish oil + 0.48% L-arginine hydrochloride (FFA group), 1.5% fresh fish oil + 1.0% oxidized fish oil + 0.48% L-arginine hydrochloride (FOA1 group), and 0.5% fresh fish oil + 2.0% oxidized fish oil + 0.48% L-arginine hydrochloride (FOA2 group).

The results showed that among the FF, FO1, and FO2 groups, the weight gain rate, specific growth rate, and protein deposition rate of yellow catfish decreased gradually with increasing oxidized fish oil supplementation, reaching their lowest values in the FO2 group, which were significantly different from the other two groups ($P<0.05$). Feed conversion ratio and feeding rate showed opposite trends, reaching their highest values in the FO2 group with significant differences from the other groups ($P<0.05$). After arginine supplementation to the oxidized fish oil diets, no significant differences were observed in these indices among the FFA, FOA1, and FOA2 groups ($P>0.05$). However, the weight gain rate in the FOA1 and FOA2 groups increased by 3.0% and 9.9% compared to the FO1 and FO2 groups, respectively. Two-way ANOVA revealed that oxidized fish oil had significant effects on weight gain rate and feeding rate ($P<0.05$), and there were significant interactions between oxidized fish oil and arginine on specific growth rate, protein deposition rate, and feed conversion ratio ($P<0.05$).

The hepatosomatic index in the FO1 group was significantly lower than that in the FF group ($P<0.05$), while the intestinesomatic index in the FO2 group was significantly decreased compared to the FFA and FOA2 groups ($P<0.05$). Two-way ANOVA indicated a significant interaction between oxidized fish oil and arginine on hepatosomatic index ($P<0.05$). The crude lipid content of whole fish in the FOA1 group was significantly lower than that in the FO1 group ($P<0.05$). Among the FF, FO1, and FO2 groups, serum total antioxidant capacity (T-AOC) decreased gradually with increasing oxidized fish oil, with the FO2 group being significantly lower than the FF group ($P<0.05$). After arginine supplementation to the oxidized fish oil diets, serum T-AOC increased by 77.0% (FOA1 vs. FO1) and 137.4% (FOA2 vs. FO2), with the latter reaching a significant level ($P<0.05$). Two-way ANOVA showed that oxidized fish oil had a significant effect on serum malondialdehyde (MDA) content ($P<0.05$), and there was a significant interaction between oxidized fish oil and arginine on serum T-AOC ($P<0.05$).

These results indicate that dietary supplementation with a certain amount of oxidized fish oil inhibits the growth performance and reduces the serum antioxidant capacity of yellow catfish, while arginine supplementation can alleviate this growth inhibition and enhance the body' s antioxidant capacity.

Keywords: Yellow catfish; oxidized fish oil; arginine; growth performance; antioxidant indexes

Introduction

Yellow catfish (*Pelteobagrus fulvidraco*) belongs to the order Siluriformes, family Bagridae, and genus *Pelteobagrus*. With high protein content, rich nutrition, and delicious taste, its aquaculture scale has been expanding rapidly in recent years, leading to increasing demands for both quantity and quality of formulated feeds. Feed oxidation and rancidity are important factors affecting feed quality and animal growth. Previous studies have demonstrated that yellow catfish fed oxidized diets exhibit reduced growth performance and compromised immune and antioxidant functions. Therefore, enhancing the antioxidant capacity of yellow catfish and mitigating the effects of oxidized substances in feed on their growth performance and antioxidant capacity would positively contribute to healthy aquaculture of this species.

Arginine, as an essential amino acid for fish, participates in various metabolic reactions within the organism, including protein, urea, and ornithine synthesis, glutamate and proline metabolism, creatine and polyamine synthesis, and insulin and glucagon secretion. It plays important roles in promoting fish growth, enhancing immunity, and improving stress resistance. Previous studies have shown that dietary arginine supplementation can improve growth performance in fish such as yellow grouper (*Epinephelus awoara*) and golden pompano (*Trachinotus ovatus*), and enhance antioxidant capacity in channel catfish (*Ictalurus punctatus*), yellow catfish, and hybrid striped bass (*Morone chrysops* × *Morone saxatilis*). Our laboratory' s previous research also indicated that supplementation of conventional diets with a certain amount of arginine could promote growth performance and improve antioxidant capacity in juvenile yellow catfish, with an appropriate supplementation level of 2.74%-2.81% of the diet. However, the intervention effects of arginine on fish damage induced by oxidized fish oil have not been reported. To further elucidate the effects of arginine on yellow catfish' s ability to resist feed oxidation factors, this study investigated the effects of different combinations of dietary oxidized fish oil and arginine on growth performance, body composition, serum biochemical parameters, and serum and liver antioxidant indexes in juvenile yellow catfish, analyzed the inhibitory effects of oxidized fish oil and the intervention effects of arginine, aiming to provide further theoretical basis for the rational utilization of arginine in yellow catfish feed.

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1. Materials and Methods

1.1 Preparation of Oxidized Fish Oil The preparation of oxidized fish oil followed the method of Yin Yongfeng et al. with slight modifications. Five hundred grams of fresh fish oil were placed in a 1 L flask and continuously aerated for oxidation in a 50°C constant temperature water bath. Peroxide value (POV) of the oxidized fish oil was measured every 2 days using methods described in references. When the POV reached the expected value, aeration

was stopped and the oxidized fish oil was stored at -20°C.

1.2 Experimental Diets Fish meal (containing 73.7% crude protein, 7.9% crude lipid, and 13.1% crude ash), soybean meal (45.7% crude protein, 2.6% crude lipid, and 6.6% crude ash), rapeseed meal (32.4% crude protein, 3.5% crude lipid, and 6.3% crude ash), and corn gluten meal (62.0% crude protein, 7.4% crude lipid, and 2.0% crude ash) were used as the main protein sources. High-gluten flour served as the primary carbohydrate source, while soybean oil and fish oil were used as lipid sources. The ratio of fresh fish oil to oxidized fish oil (m/m) was 2.5:0, 1.5:1.0, and 0.5:2.0 to formulate three experimental diets (FF, FO1, FO2). Based on these three diets, 0.48% L-arginine hydrochloride (purity $ $99%, purchased from Ningbo Haide Amino Acid Industry Co., Ltd.) was added to formulate three arginine-supplemented diets (FFA, FOA1, FOA2). The composition and nutrient levels of the experimental diets are shown in Table 1 . Feed ingredients were ground to pass through a 60-mesh sieve, weighed accurately according to the formula, and mixed thoroughly at various levels. The corresponding oils were then added and mixed using a mixer. After uniform mixing, appropriate amounts of water were added and stirred in a blender. The mixture was extruded into 1.5 mm strips using an SLX-80 twin-screw extruder (produced by South China University of Technology Science and Technology Industry General Factory) and then pelleted into granular feed using a G-500 granulator (produced by South China University of Technology Science and Technology Industry General Factory). The pellets were dried at 55°C, naturally cooled, sealed in bags, and stored at -20°C.

The POV of the six diets (FF, FO1, FO2, FFA, FOA1, FOA2) was determined using the export animal and plant oil POV detection method (SN/T 0801.3-2011), with results of 12.70, 14.09, 33.70, 12.15, 14.06, and 34.00 meq/kg, respectively.

1.3 Experimental Fish and Feeding Management Juvenile yellow catfish were purchased from Huangsha Fisheries Base in Qingyuan City, Guangdong Province. Prior to the experiment, the fish were acclimated in outdoor cement ponds for 2 weeks and fed commercial feed twice daily. The feeding trial was conducted in an indoor recirculating aquaculture system at the Aquaculture Research Laboratory of the Institute of Animal Science, Guangdong Academy of Agricultural Sciences. The system consisted of cylindrical fiberglass tanks (80 cm diameter × 70 cm height) with a water volume of approximately 300 L. At the start of the experiment, 600 yellow catfish with an initial average body weight of (4.41$±$0.05) g were selected and randomly divided into 6 groups with 4 replicates of 25 fish each. The six experimental diets were fed to the respective groups labeled FF, FO1, FO2, FFA, FOA1, and FOA2.

During the experiment, fish were fed twice daily at 08:30 and 18:30 at 5%-6% of body weight using apparent satiation feeding. The aquaculture system used recirculating water filtration with aerated tap water at an inflow rate of

1.5 L/min, with regular water changes. The experiment was conducted under natural light conditions with water temperature maintained at 29.5-33.0°C, ammonia nitrogen concentration <0.20 mg/L, nitrite concentration <0.01 mg/L, dissolved oxygen concentration >6.0 mg/L, and pH 7.4-7.9. The feeding trial lasted for 56 days.

Table 1 Composition and nutrient levels of experimental diets (air-dry basis, %)

Note: The table content is preserved as in the original format.

1.4 Sample Collection At the end of the feeding trial, fish were fasted for 24 h. Final body weight of fish in each tank was measured and survival rate (SR) was recorded. Eighteen fish were randomly selected from each replicate and anesthetized in 120 mg/L MS-222 solution. Three fish were stored at -20°C for determination of whole body conventional nutrients; five fish were used to measure body weight, body length, viscera weight, liver weight, and intestine weight for calculation of growth performance and morphological indices; and ten fish were used for caudal vein blood collection. Blood was left at room temperature for 4 h, then centrifuged at 4,000 r/min for 10 min to prepare serum, which was aliquoted and stored at -80°C for determination of serum biochemical and antioxidant indices.

Liver supernatant preparation: A certain amount of liver sample was weighed and mixed with 9 volumes of 0.86% pre-cooled physiological saline, homogenized in an ice-water bath, and centrifuged at 3,000 r/min for 10 min. The supernatant was collected and stored at -20°C for determination of liver antioxidant indices.

1.5 Index Determination and Analysis

1.5.1 Calculation of Growth Performance and Morphological Indices

- Survival rate (%) = 100 × final fish number / initial fish number
- Weight gain rate (WGR, %) = 100 × [final body weight (g) - initial body weight (g)] / initial body weight (g)
- Specific growth rate (SGR, %/d) = 100 × [ln(final body weight (g)) - ln(initial body weight (g))] / feeding days (d)
- Feed conversion ratio (FCR) = total feed intake (g) / [final body weight (g) - initial body weight (g)]
- Feeding rate (FR, %) = 100 × total dry matter intake (g) / {feeding days (d) × [final average weight (g) + initial average weight (g)] / 2}
- Protein deposition rate (PDR, %) = 100 × [final body weight (g) × final body protein content (%) - initial body weight (g) × initial body crude protein content (%)] / [feed intake (g) × dietary crude protein content (%)]
- Condition factor (CF, %) = 100 × body weight (g) / body length (cm^3)

- Viscerosomatic index (VSI, %) = 100 × viscera weight (g) / body weight (g)
- Hepatosomatic index (HSI, %) = 100 × liver weight (g) / body weight (g)
- Intestinesomatic index (ISI, %) = 100 × intestine weight (g) / body weight (g)

1.5.2 Analysis of Conventional Nutrient Content in Feed and Whole Fish Moisture content was determined by drying in an oven at 105°C to constant weight (GB/T 6435-1986). Crude protein content was measured using the semi-automatic Kjeldahl method (GB/T 6432-1994). Crude lipid content was determined by ether extraction (GB/T 6433-1994). Crude ash content was measured by incineration at 550°C to constant weight (GB/T 6438-1992).

1.5.3 Analysis of Serum Biochemical Indices Serum albumin, globulin, triglyceride, cholesterol, glucose, urea nitrogen contents, and aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase activities were determined by Guangzhou Kingmed Center for Clinical Laboratory using a Hitachi 7600 automatic biochemical analyzer.

1.5.4 Analysis of Antioxidant Indices Serum and liver supernatant antioxidant indices were measured using assay kits purchased from Nanjing Jiancheng Bioengineering Institute, following the instructions provided. Superoxide dismutase (SOD) activity was measured by the hydroxylamine method, glutathione peroxidase (GSH-Px) activity by colorimetry, catalase (CAT) activity by visible light spectrophotometry, total antioxidant capacity (T-AOC) by colorimetry, and malondialdehyde (MDA) content by the thiobarbituric acid (TBA) method.

1.6 Statistical Analysis Experimental data were expressed as mean ± standard deviation (mean±SD, n=4). One-way ANOVA was performed using SPSS 20.0 software, and Duncan' s method was used for multiple comparisons among groups. Differences were considered significant at $P<0.05$. Two-way ANOVA was performed using SAS 9.0 software, with significance level set at $P<0.05$.

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2. Results

2.1 Growth Performance and Morphological Indices As shown in Table 2 , the survival rate of yellow catfish in all groups was 100% with no mortality observed. Among the FF, FO1, and FO2 groups, the weight gain rate, specific growth rate, and protein deposition rate of yellow catfish decreased gradually with increasing oxidized fish oil supplementation, reaching their lowest values in the FO2 group, which were significantly different from the other two groups ($P<0.05$). Feed conversion ratio and feeding rate showed opposite trends, reaching their highest values in the FO2 group with significant differences from the other two groups ($P<0.05$). Among the FFA, FOA1, and FOA2 groups, no

significant differences were found in these indices (P>0.05). The weight gain rate in the FOA1 and FOA2 groups increased by 3.0% and 9.9% compared to the FO1 and FO2 groups, respectively, while feed conversion ratio decreased by 2.7% and 7.4%, respectively, though these differences were not significant (P>0.05). Two-way ANOVA revealed that oxidized fish oil had significant effects on weight gain rate and feeding rate (P<0.05), and there were significant interactions between oxidized fish oil and arginine on specific growth rate, protein deposition rate, and feed conversion ratio (P<0.05).

Table 2 Influences of oxidized fish oil and Arg on growth performance of yellow catfish (*Pelteobagrus fulvidraco*)

Note: The table content is preserved as in the original format. In the same column, values with no or the same letter superscripts mean no significant difference (P>0.05), while different small letter superscripts mean significant difference (P<0.05). The same applies below (except Table 5).

As shown in Table 3 , no significant differences were observed in condition factor among the six groups (P>0.05). The viscerosomatic index in the FO2 group was significantly lower than that in the FOA1 group (P<0.05), with no significant differences among other groups (P>0.05). The hepatosomatic index in the FF group was significantly higher than that in the FO1 group (P<0.05), with no significant differences among other groups (P>0.05). The intestinesomatic index in the FO2 group was significantly decreased compared to the FFA and FOA2 groups (P<0.05). Two-way ANOVA indicated that arginine had a highly significant effect on intestinesomatic index (P<0.01), and there was a significant interaction between oxidized fish oil and arginine on hepatosomatic index (P<0.05).

Table 3 Influences of oxidized fish oil and Arg on biometric parameters of yellow catfish (*Pelteobagrus fulvidraco*)

Note: The table content is preserved as in the original format.

2.2 Whole Body Conventional Nutrient Content As shown in Table 4 , no significant differences were observed in dry matter, crude protein, or crude ash contents of whole fish among the six groups (P>0.05). However, the crude lipid content in the FOA1 group was significantly lower than that in the FO1 group (P<0.05). Two-way ANOVA revealed that arginine had a significant effect on whole body crude lipid content (P<0.05).

Table 4 Influences of oxidized fish oil and Arg on whole body unconventional nutritional contents of yellow catfish (*Pelteobagrus fulvidraco*) (DM basis, %)

Note: The table content is preserved as in the original format.

2.3 Serum Biochemical Indices As shown in Table 5, no significant differences were observed in serum albumin, globulin, triglyceride, cholesterol, urea

nitrogen, glucose contents, or aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase activities among the six groups (P>0.05).

Table 5 Influences of oxidized fish oil and Arg on serum biochemical indexes of yellow catfish (*Pelteobagrus fulvidraco*)

Note: The table content is preserved as in the original format. In the same row, values with no or the same letter superscripts mean no significant difference (P>0.05), while different small letter superscripts mean significant difference (P<0.05).

2.4 Serum and Liver Antioxidant Indices As shown in Table 6 , among the FF, FO1, and FO2 groups, serum SOD activity showed a downward trend, while GSH-Px activity and MDA content showed upward trends with increasing oxidized fish oil supplementation, though these differences were not significant (P>0.05). Serum T-AOC decreased gradually, with the FO2 group being significantly lower than the FF group (P<0.05). After arginine supplementation to the oxidized fish oil diets, serum T-AOC increased by 77.0% (FOA1 vs. FO1) and 137.4% (FOA2 vs. FO2), with the latter reaching a significant level (P<0.05). Serum MDA content decreased by 12.0% (FOA1 vs. FO1) and 17.4% (FOA2 vs. FO2). Two-way ANOVA revealed a significant interaction between oxidized fish oil and arginine on serum T-AOC (P<0.05), and oxidized fish oil had a significant effect on serum MDA content (P<0.05).

Table 6 Influences of oxidized fish oil and Arg on serum antioxidant indexes of yellow catfish (*Pelteobagrus fulvidraco*)

Note: The table content is preserved as in the original format.

As shown in Table 7 , no significant differences were observed in liver SOD activity, CAT activity, T-AOC, or MDA content among the six groups (P>0.05). However, among the FF, FO1, and FO2 groups, liver SOD activity and MDA content showed upward trends with increasing oxidized fish oil supplementation. Liver GSH-Px activity in the FO2 and FOA1 groups was significantly higher than that in the FF, FO1, and FOA2 groups (P<0.05).

Table 7 Influences of oxidized fish oil and Arg on liver antioxidant indexes of yellow catfish (*Pelteobagrus fulvidraco*)

Note: The table content is preserved as in the original format.

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3. Discussion

3.1 Effects of Oxidized Fish Oil on Growth Performance of Yellow Catfish and Arginine Intervention The results of this experiment showed that dietary supplementation with a certain amount of oxidized fish oil decreased the weight gain rate, specific growth rate, and protein deposition rate of juvenile yellow catfish, while increasing feed conversion ratio. Liu Wei et al. found

that common carp (*Cyprinus carpio*) fed oxidized oil showed decreased feed conversion ratio and weight gain rate. Peng Shiming et al. reported that dietary oxidized fish oil significantly reduced the weight gain rate, feed efficiency, and protein efficiency of juvenile black sea bream (*Acanthopagrus schlegeli*). Han Yuzhe et al. observed that Japanese sea bass (*Lateolabrax maculatus*) showed slowed growth when fed diets containing oxidized fish oil. Chen Kequan et al. found that dietary oxidized fish oil reduced the growth rate, feed efficiency, and lipid deposition rate of grass carp (*Ctenopharyngodon idellus*). Xue Jipeng noted that the specific growth rate and condition factor of darkbarbel catfish (*Pelteobagrus vachelli*) showed downward trends due to dietary oxidized fish oil. Gao Chunren et al. demonstrated that oxidized fish oil decreased the weight gain rate and survival rate of juvenile sea bream, with weight gain rate showing a linear relationship with dietary POV. These reports from various researchers and the results of this experiment consistently indicate that dietary oxidized fish oil has inhibitory effects on growth performance across different aquatic animals. However, Chen Yongjun found that dietary oxidized fish oil promoted the growth of juvenile largemouth bass (*Micropterus salmoides*). The reasons for this discrepancy may be related not only to decreased feed nutritional value but also to oxidative stress induced by oxidation products inhibiting normal fish growth, and possibly different tolerance levels to oxidized oils among fish species.

This experiment showed that with increasing dietary oxidized fish oil supplementation, feed conversion ratio and feeding rate of yellow catfish increased gradually, further indicating that oxidized fish oil significantly decreased nutritional value without affecting feed palatability. Previous studies have reported that arginine can promote growth in fish such as cobia (*Rachycentron canadum*), channel catfish, hybrid striped bass (*Moront saxatuis*), Indian catfish (*Silurus asotus*), Indian carp (*Parupeneus indicus*), black sea bream, and yellow catfish, while enhancing antioxidant function. The results of this experiment showed that supplementation of arginine to diets containing 1.00% and 2.00% oxidized fish oil increased weight gain rate by 3.0% and 9.9%, respectively, and decreased feed conversion ratio by 2.7% and 7.4%, respectively. Two-way ANOVA revealed significant interactions between oxidized fish oil and arginine on specific growth rate, protein deposition rate, and feed conversion ratio, indicating that arginine can alleviate the inhibitory effects of oxidized fish oil on yellow catfish growth performance. This may be due to arginine alleviating oxidative stress caused by oxidized fish oil by enhancing related enzyme activities, or through internal regulation to meet nutritional requirements, though the specific mechanism requires further investigation.

In this experiment, there was a significant interaction between dietary oxidized fish oil and arginine on hepatosomatic index. This result contrasts with findings in common carp by Ren Zelin et al. and in Nile tilapia by Huang Kai et al. The discrepancy may be due to different tolerance levels to oxidized oils among fish species, or different accumulation levels of oxidation products in the liver due to varying culture periods, leading to different developmental trends

of liver cells. Previous studies have found that arginine participates in regulating various physiological and biochemical processes, can maintain intestinal morphology, promote proliferation of intestinal mucosal epithelial cells, and inhibit apoptosis of intestinal mucosal epithelial cells. Cheng et al. reported that dietary arginine supplementation promoted growth hormone and insulin secretion in hybrid striped bass. In this experiment, two-way ANOVA showed that dietary arginine had a highly significant effect on intestinesomatic index. This may be because appropriate arginine content in the diet can accelerate proliferation of intestinal mucosal epithelial cells to improve digestion and absorption of dietary nutrients, thereby meeting the nutritional requirements for normal fish growth.

3.2 Effects of Oxidized Fish Oil on Whole Body Conventional Nutrient Content of Yellow Catfish and Arginine Intervention The results of this experiment showed that with increasing dietary oxidized fish oil supplementation, whole body dry matter, crude protein, crude lipid, and crude ash contents of yellow catfish showed a trend of first increasing then decreasing, though these differences were not significant. However, arginine had a significant effect on whole body crude lipid content. Ren Zelin et al. reported that at low doses of oxidation products, common carp increased whole body crude lipid content to reduce oxidative stability; at high doses of oxidation products, the decrease in whole body crude lipid content may be due to decreased fatty acid synthesis capacity in liver and other tissues. In this experiment, supplementation of appropriate arginine to oxidized fish oil diets may have affected oxidative stability by altering whole body crude lipid content, possibly by stimulating secretion of certain enzymes to regulate fatty acid synthesis and catabolism pathways.

3.3 Effects of Oxidized Fish Oil on Serum and Liver Antioxidant Indices of Yellow Catfish and Arginine Intervention SOD and GSH-Px are important components of the biological antioxidant defense system, scavenging reactive oxygen free radicals and protecting cell membranes and intracellular nucleic acids. The results of this experiment showed that serum SOD activity in yellow catfish decreased with increasing dietary oxidized fish oil supplementation. This result is consistent with findings in large yellow croaker (*Pseudosciaena crocea* R) by Tang Xiao et al. and Wang Jun, but contrary to results in gilthead sea bream (*Sparus aurata* L) by Mourente et al. The discrepancy may be due to different tolerance levels to oxidized oils among fish species. This experiment also showed that serum GSH-Px activity increased with increasing dietary oxidized fish oil supplementation, which is consistent with results in Nile tilapia by Huang Kai et al. This may be because oxidized fish oil increases the content of reactive oxygen species and other bioactive substances in cells after ingestion, increasing substrate concentration for antioxidant enzymes and thereby enhancing GSH-Px activity. However, when oxidation product accumulation becomes too high, the balance of antioxidant-related enzymes is disrupted, causing toxic effects on the organism.

T-AOC is a comprehensive index used to measure antioxidant system function, reflecting the organism' s compensatory capacity to external stimuli and free radical metabolism status. This experiment showed that dietary oxidized fish oil decreased serum T-AOC in yellow catfish, reaching a significant level in the FO2 group, indicating that with increasing dietary oxidized substances, the compensatory capacity to exogenous oxidation products and free radical scavenging ability gradually weakened. However, after supplementation of appropriate arginine to oxidized fish oil diets, serum T-AOC increased by 77.0% (FOA1 vs. FO1) and 137.4% (FOA2 vs. FO2). This indicates that arginine supplementation in oxidized fish oil diets can improve serum antioxidant capacity and alleviate the decline in antioxidant capacity caused by exogenous oxidation products, which is consistent with arginine' s effect in alleviating growth inhibition by oxidized fish oil.

MDA content often reflects the degree of lipid peroxidation in the organism and indirectly indicates cell damage. In this experiment, serum MDA content showed an upward trend with increasing dietary oxidized fish oil supplementation. Two-way ANOVA revealed that oxidized fish oil had a significant effect on serum MDA content, which is consistent with results in black sea bream by Peng Shiming et al., indicating that with accumulation of oxidation products, lipid peroxidation substances accumulated in yellow catfish, possibly due to damage to cell membranes and loss of selective permeability function, leading to intracellular fluid outflow. This phenomenon indirectly indicates increased cell damage. After supplementation of appropriate arginine to oxidized fish oil diets, serum MDA content decreased by 12.0% (FOA1 vs. FO1) and 17.4% (FOA2 vs. FO2). This may be due to arginine reducing cell damage or promoting cell proliferation to replace damaged cells, thereby improving the toxic effects caused by oxidized fish oil.

In the liver of yellow catfish, SOD activity, GSH-Px activity, and MDA content showed upward trends with increasing dietary oxidized fish oil supplementation, which is consistent with results in Nile tilapia by Huang Kai et al. and in Japanese sea bass by Han Yuzhe et al. However, Ren Zelin et al. reported that oxidized fish oil decreased SOD and CAT activities in hepatopancreas of common carp, while Chen Yongjun reported that oxidized fish oil decreased GSH-Px activity in hepatopancreas of largemouth bass. These different results may be due to variations in dietary nutrients, culture conditions, experimental periods, degree of fish oil oxidation, and different tolerance capacities to oils among aquatic animals. In this experiment, after dietary arginine supplementation, liver GSH-Px activity showed a trend of first increasing then decreasing, while T-AOC did not show similar changes as observed in serum, the reasons and mechanisms of which require further investigation.

Conclusion

Dietary supplementation with a certain amount of oxidized fish oil inhibits the growth performance and reduces the serum antioxidant capacity of yellow catfish, while supplementation with a certain amount of arginine can alleviate the growth inhibition caused by oxidized fish oil and enhance the body's antioxidant capacity.

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