Effects of Replacing Fish Meal with Black Soldier Fly Larvae Meal on Growth Performance, Body Composition, Plasma Biochemical Indices, and Histology of Juvenile Largemouth Bass: Postprint

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Abstract

This experiment aimed to investigate the effects of replacing fish meal with black soldier fly larvae meal on growth performance, body composition, plasma biochemical indices, and tissue structure of juvenile largemouth bass. A total of 540 juvenile largemouth bass with an initial average weight of 5.2 g were randomly divided into 6 groups, with 3 replicates per group and 30 fish per replicate. The six groups were fed six isonitrogenous (crude protein content of 39.9%) and isoenergetic (total energy of 17.9 MJ/kg) experimental diets in which 0% (G0, as control), 10% (G10), 20% (G20), 30% (G30), 40% (G40), and 50% (G50) of fish meal in the basal diet (containing 28.00% fish meal with 67.50% crude protein) was replaced by black soldier fly larvae meal, respectively, for a 56-day trial period. The results showed that replacing fish meal with black soldier fly larvae meal at different proportions had no significant effects on final body weight, weight gain rate, specific growth rate, feed intake, protein efficiency, feed coefficient, or survival rate of juvenile largemouth bass ($P>0.05$). No significant differences were observed in condition factor among all groups ($P>0.05$), but the viscerosomatic index and hepatosomatic index in the G50 group were significantly higher than those in the G0 group ($P<0.05$). Whole-body crude protein, crude ash, moisture, calcium, total phosphorus, and essential amino acid contents showed no significant differences ($P>0.05$), while whole-body crude fat content in the G20–G50 groups was significantly higher than that in the G0 group ($P<0.05$). Except for plasma globulin content in the G20 group being significantly higher than that in the G0 group ($P<0.05$), other plasma biochemical indices showed no significant differences between replacement groups (G10–G50) and G0 ($P>0.05$). With increasing replacement levels,

hepatic tissue exhibited cytoplasmic vacuolation and dissolution, with partial or extensive loss of nuclei; intestinal villus length in all replacement groups was lower than that in the G0 group, with significant differences between G0 and G10/G40 groups (P<0.05); except for the G20 group, muscle layer thickness in the other replacement groups was significantly reduced compared to the G0 group (P<0.05). In conclusion, replacing 50% of fish meal in the basal diet with black soldier fly larvae meal (addition level of 27.8% black soldier fly larvae meal in the basal diet, accounting for 23.7% of dietary protein) had no significant effect on growth performance of juvenile largemouth bass, but high replacement levels increased body fat deposition, caused hepatic lesions, and impaired intestinal structural development.

Full Text

Effects of Fish Meal Replacement by Black Soldier Fly (Hermetia illucens) Larvae Meal on Growth Performance, Body Composition, Plasma Biochemical Indexes, and Tissue Structure of Juvenile Japanese Seabass (Lateolabrax japonicus)

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Abstract

This study investigated the effects of fish meal replacement by black soldier fly (Hermetia illucens) larvae meal on growth performance, body composition, plasma biochemical indexes, and tissue structure of juvenile Japanese seabass (Lateolabrax japonicus). Six isonitrogenous (crude protein content 39.9%) and isoenergetic (gross energy 17.9 MJ/kg) experimental diets were formulated by replacing 0 (G0, control), 10% (G10), 20% (G20), 30% (G30), 40% (G40), and 50% (G50) of fish meal protein in a basal diet containing 28.00% fish meal (67.50% crude protein) with black soldier fly larvae meal. A total of 540 juvenile Japanese seabass with initial body weight of 5.2 g were randomly allocated into six groups with three replicates per group and 30 fish per replicate. The feeding trial lasted 56 days. The results showed that different replacement ratios had no significant effects on final body weight, weight gain rate, specific growth rate, feed intake, protein efficiency ratio, feed coefficient, or survival rate (P > 0.05). No significant differences were observed in condition factor among all groups ($P > 0.05$), but viscerosomatic index and hepatosomatic index in the G50 group were significantly higher than those in the G0 group ($P < 0.05$). Whole-body crude protein, ash, moisture, calcium, total phosphorus, and essential amino acid contents showed no significant differences among groups ($P > 0.05$), while whole-body crude lipid content in G20–G50 groups was significantly higher than in the G0 group ($P < 0.05$). Plasma globulin content in the G20 group was significantly higher than in the G0 group ($P < 0.05$), but other plasma biochemical indexes showed no significant differences between replacement groups (G10–G50) and the G0 group ($P > 0.05$). Histological examination revealed progressive hepatocellular vacuolar degeneration and nuclear disappearance with increasing replacement ratios. Intestinal villus height in the G0 group was highest, significantly greater than in G10 and G40 groups ($P < 0.05$). Except for the G20 group, muscular thickness in all other replacement groups was significantly reduced compared to the G0 group ($P < 0.05$). In conclusion, 50% of fish meal could be replaced by black soldier fly larvae meal (27.8% inclusion in basal diet, accounting for 23.7% of dietary protein) without significantly reducing growth performance, but high replacement ratios increased fat deposition, caused hepatic pathological changes, and impaired intestinal structural development.

Keywords: black soldier fly (Hermetia illucens) larvae meal; juvenile Japanese seabass (Lateolabrax japonicus); growth performance; plasma biochemical indexes; tissue structure

Introduction

Fish meal is a major protein source in aquafeeds due to its excellent palatability and high digestibility, typically constituting a large proportion of feed formulations. However, climate change, environmental degradation, and overfishing have led to declining global fishery resources and decreasing fish meal production. Meanwhile, global aquaculture has expanded steadily over the past decade, with increasing demand for fish meal. This supply-demand contradiction has become a primary bottleneck restricting sustainable aquaculture development, making it urgent to reduce dependence on fish meal and develop suitable alternative protein resources.

Insects represent the largest group in the animal kingdom with a minimal ecological footprint, requiring no arable land and minimal water and energy inputs. Their bodies are rich in amino acids, lipids, vitamins, and minerals, making them one of the most promising animal protein resources on Earth [1-2]. The black soldier fly (Hermetia illucens L.) belongs to the family Stratiomyidae within Diptera. Its larvae naturally feed on animal manure and decaying organic matter such as carrion, fruits, vegetables, and plant waste [3], converting these waste materials into valuable biomass for protein feed production. Research has demonstrated that black soldier fly feeding activity can reduce chicken and pig manure accumulation while suppressing housefly proliferation [4-5], significantly decrease Salmonella spp. numbers in human feces [6], and reduce nitrogen content in pig manure [7]. The resulting prepupae contain approximately 40% protein and 30% fat [8-9]. Previous studies have shown that black soldier fly larvae or prepupae can partially replace fish meal in diets for channel catfish (Ictalurus punctatus) [10], tilapia (Oreochromis niloticus) [10-12], African catfish (Clarias gariepinus) [13], rainbow trout (Oncorhynchus mykiss) [9,14-15], turbot (Psetta maxima) [16], Pacific white shrimp (Litopenaeus vannamei) [17], Jian carp (Cyprinus carpio var. Jian) [18], and European seabass (Dicentrarchus labrax) [19] with favorable results.

Japanese seabass (Lateolabrax japonicus), commonly known as seven-star seabass or spotted seabass, belongs to Perciformes, Serranidae, and the genus Lateolabrax. Due to its rapid growth, wide adaptability to temperature and salinity, tender meat, delicious taste, and high nutritional value, it has become an important economic fish species in China' s coastal areas with expanding aquaculture scale. As a carnivorous species, Japanese seabass relies heavily on fish meal as the primary protein source in formulated feeds, with fish meal comprising approximately 40% of the basal diet. Currently, no studies have reported on insect meal as a fish meal substitute in Japanese seabass diets. Therefore, this experiment was designed to investigate the effects of replacing different proportions of fish meal with black soldier fly larvae meal on growth performance, plasma biochemical indexes, and tissue structure of juvenile Japanese seabass, providing reference for practical application.

Materials and Methods

1.1 Black Soldier Fly Larvae Meal

The black soldier fly larvae used in this experiment were provided by Guangzhou Fishtech Biotechnology Co., Ltd. and dried using natural gas drying equipment. In the laboratory, the dried larvae were pulverized using a universal grinder to produce black soldier fly larvae meal, which was stored at -20 °C for later use. The dried larvae appeared light yellow, and the resulting meal had a fragrant smell without mold or caking. Analysis revealed that the black soldier fly larvae meal contained 1.90% moisture, 34.00% crude protein, 37.50% crude lipid, 14.80% crude ash, 4.61% calcium, and 1.14% total phosphorus, with lysine and methionine contents of 1.76% and 0.46%, respectively. All measurements were expressed on an air-dry basis.

1.2 Experimental Diets

A basal diet containing 28.00% fish meal was first formulated using fish meal (containing 9.76% moisture, 67.50% crude protein, 5.96% crude lipid, 16.06% crude ash, 3.14% calcium, and 2.46% total phosphorus, with lysine and methionine contents of 5.19% and 1.92%, respectively), soybean meal, and peanut meal as the main protein sources; fish oil, soybean oil, and lecithin as lipid sources; and strong flour as the carbohydrate source. Subsequently, six experimental diets were prepared by replacing 0 (control), 10%, 20%, 30%, 40%, and

50% of fish meal protein with black soldier fly larvae meal on an isonitrogenous basis, designated as G0, G10, G20, G30, G40, and G50, respectively. All six experimental diets were isonitrogenous (crude protein content of 39.9%) and isoenergetic (gross energy of 17.9 MJ/kg). The composition and nutrient levels are shown in Table 1 , and the essential amino acid composition is presented in Table 2 . All feed ingredients were ground and passed through a 60-mesh sieve. Vitamin and mineral premixes were mixed using the stepwise expansion method, followed by the addition of fish oil, soybean oil, lecithin, and water. The mixture was then processed into 2.0 mm diameter pellets using an SLX-80 twin-screw extruder, dried at 50 °C, naturally cooled, sealed in bags, and stored at -20 °C for later use.

1.3 Experimental Fish and Rearing Management

Juvenile Japanese seabass were purchased from Yinggang Hatchery in Zhao' an County, Fujian Province, and temporarily reared in an indoor recirculating aquaculture system at the Aquaculture Research Laboratory of the Institute of Animal Science, Guangdong Academy of Agricultural Sciences. The initial water salinity was 3‰–0.5‰, and fish were fed the basal diet to satiation twice daily (09:00 and 16:00) during a two-week acclimation period, during which salinity was gradually reduced to freshwater conditions. The rearing system consisted of 18 cylindrical fiberglass tanks with a capacity of 350 L each (80 cm diameter, 70 cm height), with an actual rearing water volume of 300 L per tank. At the start of the experiment, 540 healthy, uniformly sized juvenile Japanese seabass with an average body weight of 5.19 g were selected and distributed among the 18 tanks at a stocking density of 30 fish per tank. The 18 tanks were randomly divided into six groups (three replicates per group), designated as G0, G10, G20, G30, G40, and G50, and fed the corresponding experimental diets. Fish were hand-fed to satiation twice daily (09:00 and 16:00). Daily feed intake, mortality, water temperature, and water quality were recorded. Continuous aeration was provided 24 hours a day, with natural light conditions. Water temperature was maintained at 25.0–30.0 °C, pH at 7.5–8.0, ammonia nitrogen concentration below 0.1 mg/L, and dissolved oxygen concentration above 7 mg/L. The experimental period lasted 56 days.

1.4 Sample Collection and Analysis

At the start of the experiment, 20 juvenile Japanese seabass with body weight similar to the initial weight of experimental fish were selected for analysis of whole-body proximate composition. At the end of the feeding trial, fish were fasted for 12 hours before being weighed and counted in each tank. Three fish per tank were randomly selected and stored at -20 °C for whole-body proximate composition analysis. Another nine fish per tank were randomly selected for blood collection from the caudal vein. Blood samples from each tank were pooled, centrifuged at 4,000 r/min for 10 min at 4 °C to prepare plasma samples, which were stored at -80 °C for plasma biochemical analysis. Six additional fish per tank were randomly selected for morphometric measurements. Four fish per tank were dissected to isolate the anterior intestine and liver, which were fixed in Bouin' s solution at room temperature for histological section preparation.

Moisture content in feed and whole-body samples was determined using the 105 °C constant pressure drying method (GB/T 6435–1986). Crude protein content was measured by the Kjeldahl method (GB/T 6432-1994). Crude lipid content was extracted using the ether extraction method (GB/T 6432-1994). Crude ash content was determined by incineration at 550 °C (GB/T 6438-1992). Calcium content was measured by ethylenediaminetetraacetic acid (EDTA) titration (GB/T 6436-2002). Total phosphorus content was determined by the molybdenum yellow colorimetric method (GB/T 6437-2002). Gross energy in feeds was measured using an oxygen bomb calorimeter (IKA-C2000). Plasma glucose (GLU), albumin (ALB), globulin (GLOB), urea nitrogen (UN), cholesterol (CHOL), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglyceride (TG) concentrations were analyzed using a Hitachi automatic biochemical analyzer. Amino acid contents in raw materials, feeds, and whole-body samples were determined by high-performance liquid chromatography (Agilent 1260, USA).

1.5 Index Calculations

The following formulas were used for calculating various indices: - Weight gain rate (WGR, %) = 100 × (final mean weight - initial mean weight) / initial mean weight - Specific growth rate (SGR, %/d) = 100 × (ln final mean weight - ln initial mean weight) / feeding days - Feed intake (FI, g/fish) = total feed intake / [(initial fish number + final fish number) / 2] - Feed coefficient (FC) = total feed intake / (final body weight + dead fish weight - initial body weight) - Protein efficiency ratio (PER, %) = 100 × (final body weight + dead fish weight - initial body weight) / protein intake - Survival rate (SR, %) = 100 × final fish number / initial fish number - Condition factor (CF, g/cm^3) = 100 × body weight / body length^3 - Viscerosomatic index (VSI, %) = 100 × viscera weight / body weight - Hepatosomatic index (HSI, %) = 100 × liver weight / body weight

1.6 Statistical Analysis

Experimental data were expressed as means ± standard error (n=3). Statistical analysis was performed using SPSS 11.5 software. Data were first tested for normal distribution and homogeneity of variance. If both conditions were satisfied, one-way ANOVA was conducted, followed by Duncan' s multiple comparison test for significant differences. If homogeneity of variance was not met, Dunnett' s T3 test was used for multiple comparisons. $P < 0.05$ was considered statistically significant.

Results

2.1 Effects of Fish Meal Replacement on Growth Performance

As shown in Table 3 , replacement of fish meal with different proportions of black soldier fly larvae meal had no significant effects on final mean weight, weight gain rate, specific growth rate, feed intake, protein efficiency ratio, feed coefficient, or survival rate of juvenile Japanese seabass ($P > 0.05$). However, the viscerosomatic index and hepatosomatic index increased with increasing replacement levels, with the G50 group showing significantly higher values than the G0 group ($P < 0.05$).

2.2 Effects on Body Composition and Essential Amino Acid Contents

As shown in Table 4 , replacement of fish meal with different proportions of black soldier fly larvae meal had no significant effects on whole-body crude protein, crude ash, moisture, calcium, or total phosphorus contents of juvenile Japanese seabass ($P > 0.05$). However, whole-body crude lipid content increased with increasing replacement levels, with G20–G50 groups showing significantly higher values than the G0 group ($P < 0.05$). No significant differences were observed in whole-body essential amino acid contents among all groups ($P > 0.05$).

2.3 Effects on Plasma Biochemical Indexes

As shown in Table 5 , except for plasma globulin content in the G20 group, which was significantly higher than that in the G0 group ($P < 0.05$), no significant differences were observed in other plasma biochemical indexes between the replacement groups (G10–G50) and the G0 group ($P > 0.05$).

2.4 Effects on Liver Histological Structure

As shown in Figure 1 [Figure 1: see original paper], hepatocytes in the G0 group exhibited normal morphology without obvious lesions. However, with increasing replacement ratios of black soldier fly larvae meal, hepatocytes showed extensive cytoplasmic loosening, dissolution, or vacuolation, with partial or complete disappearance of nuclei.

2.5 Effects on Intestinal Histological Structure

As shown in Table 6 , intestinal villus length in the G0 group was higher than that in all replacement groups, with significant differences observed compared to G10 and G40 groups ($P < 0.05$). Compared with the G0 group, no significant changes were observed in intestinal villus width, lamina propria thickness, or goblet cell numbers in the replacement groups ($P > 0.05$), although a decreasing trend was noted. Except for the G20 group, muscular thickness in all other replacement groups was significantly lower than that in the G0 group ($P < 0.05$).

Discussion

3.1 Effects on Growth Performance

The results of this experiment indicated that replacing 50% of fish meal with black soldier fly larvae meal (corresponding to 27.8% inclusion level in the basal diet, accounting for 23.7% of dietary protein) had no significant effects on final mean weight, weight gain rate, specific growth rate, feed intake, protein efficiency ratio, feed coefficient, or survival rate of juvenile Japanese seabass. However, when the replacement ratio exceeded 40%, weight gain rate, specific growth rate, and protein efficiency ratio reached their lowest values while feed coefficient peaked. If growth performance is used as the criterion for production purposes, the tolerance level of juvenile Japanese seabass to black soldier fly larvae meal can reach 22.22% (accounting for 19.0% of dietary protein) during an 8-week culture period. Magalhães et al. [19] reported that black soldier fly prepupae meal could replace 45% of fish meal in European seabass diets, with an optimal inclusion level of 19.5% (accounting for 22.5% of dietary protein), which is slightly higher than our results. This discrepancy may be attributed to differences in nutritional value between the two insect meals used. The black soldier fly prepupae meal used by Magalhães et al. [19] contained 55.8% crude protein, whereas the black soldier fly larvae meal used in this experiment contained 34.0% crude protein, which is lower than that of the prepupae meal. Furthermore, this study found that besides the crude protein content of black soldier fly larvae or prepupae, the fish meal level in the basal formulation, the contents of essential amino acids such as lysine, methionine, and tryptophan in the larvae or prepupae, as well as their palatability and anti-nutritional factors [16], also influence the replacement level [19]. Although Kroeckel et al. [16] reported that the amino acid composition of black soldier fly prepupae meal used in turbot diets was similar to that of fish meal, and Magalhães et al. [19] found no essential amino acid deficiency when using black soldier fly prepupae meal to replace fish meal in European seabass, normal growth of the experimental animals was affected when replacement ratios exceeded the optimal level.

With increasing replacement ratios of black soldier fly larvae meal, the viscerosomatic index and hepatosomatic index of juvenile Japanese seabass increased, with the 50% replacement group showing significantly higher values than the control group. However, Li et al. [18] found no significant effects on hepatosomatic index or viscerosomatic index of juvenile Jian carp when using defatted black soldier fly meal. Catacutan et al. [20] reported a significant positive correlation between hepatosomatic index and dietary lipid level in fish. Therefore, this phenomenon may be related to the fact that the black soldier fly larvae meal used in this experiment was not defatted, leading to increased dietary crude lipid content with higher inclusion levels.

3.2 Effects on Body Composition and Essential Amino Acids

Studies have shown that body lipid content in rainbow trout and turbot decreased with increasing black soldier fly prepupae meal inclusion [9,16]. Similarly, Li et al. [18] observed significantly reduced liver lipid content in juvenile Jian carp when using defatted black soldier fly meal. St-Hilaire et al. [9] attributed the reduced lipid deposition in rainbow trout to decreased dietary fish oil and crude lipid content when replacing fish meal with black soldier fly prepupae meal. Kroeckel et al. [16] suggested that reduced feed intake led to insufficient lipid and energy intake. Both studies also noted that changes in dietary lipid levels altered fatty acid composition, which subsequently affected muscle fatty acid deposition in the experimental animals [9,16]. Li et al. [18] proposed that chitin in insects affected fatty acid catabolism and synthesis in the liver of juvenile Jian carp. In contrast, this experiment showed that dietary crude lipid content increased with higher replacement ratios of black soldier fly larvae meal, resulting in increased whole-body crude lipid content. This may be due to the non-defatted nature of the black soldier fly larvae meal used in this study (crude lipid content as high as 37.5%), which elevated dietary crude lipid content as replacement ratio increased, thereby promoting lipid deposition in fish. Previous research has demonstrated that when dietary crude lipid content exceeds the requirement of Japanese seabass (7.4%–9.9%), whole-body and liver lipid contents increase with rising dietary lipid levels [21]. Similarly, high-lipid diets significantly increased lipid accumulation in whole-body, muscle, and liver of largemouth bass [22]. Therefore, increased dietary crude lipid content is an important factor contributing to enhanced lipid deposition in Japanese seabass. Replacement of fish meal with different proportions of black soldier fly larvae meal had no significant effects on whole-body crude protein or crude ash contents of juvenile Japanese seabass, which is consistent with findings in rainbow trout [9], turbot [16], and juvenile Jian carp [18]. Magalhães et al. [19] found that black soldier fly prepupae meal improved the digestibility of arginine and histidine in European seabass, though they did not investigate muscle amino acid composition. Hu et al. [23] reported that when black soldier fly larvae meal replacement exceeded 10%, the apparent digestibility of essential amino acids such as arginine, lysine, and methionine decreased in yellow catfish, while no significant differences were observed in muscle essential amino acid contents except for methionine and phenylalanine. Santos [24] observed that black soldier fly meal replacement affected dietary amino acid composition, resulting in significant differences in lysine, arginine, and methionine contents in rainbow trout muscle. However, in this experiment, replacement of fish meal with different proportions of black soldier fly larvae meal did not significantly affect whole-body essential amino acid composition of Japanese seabass.

3.3 Effects on Plasma Biochemical Indexes

Previous studies have found that black soldier fly meal replacement reduced plasma cholesterol content in European seabass [19] and juvenile Jian carp [18], though no significant differences in plasma cholesterol were observed among groups in this experiment. Research has indicated that black soldier fly prepupae contain high levels of chitin polysaccharides, which can inhibit cholesterol absorption and increase hydrolysis of hepatic lipoproteins and triglycerides as well as bile acid excretion [19,25-27]. Although chitinase activity has been detected in some fish species, it remains relatively low in most fish [16,28]. Additionally, it has been speculated that lower cholesterol content in black soldier fly prepupae compared to fish meal may reduce dietary cholesterol levels, which could explain the decreased plasma cholesterol in juvenile Jian carp [18], as dietary cholesterol directly affects blood cholesterol levels in cultured animals [29-30]. Wen et al. [31] also observed reduced serum cholesterol in yellow catfish when replacing fish meal with maggot meal. In this experiment, no significant differences in plasma triglyceride content were found between the replacement groups and the control group. Therefore, whether chitin polysaccharides or cholesterol content in black soldier fly larvae affect cholesterol and triglyceride metabolism in Japanese seabass, as observed in European seabass [19] and juvenile Jian carp [18], requires further verification. Elevated plasma albumin and globulin levels can increase the incidence of diseases related to immune disorders, hepatic dysfunction, and renal impairment [24,32]. Li et al. [18] found that plasma albumin and globulin contents in juvenile Jian carp were not affected by black soldier fly prepupae replacement, suggesting that its use may not impact the immune system of juvenile Jian carp. In this experiment, except for the 20% replacement group which showed higher plasma albumin content than the control group, no significant differences were observed between other replacement groups and the control.

3.4 Effects on Liver and Intestinal Histological Structure

In this experiment, increasing the replacement ratio of black soldier fly larvae meal caused certain damage to liver cells of Japanese seabass. Li et al. [18] found that defatted black soldier fly meal reduced the number of fatty liver cells in juvenile Jian carp. Belforti et al. [33] also observed decreased fat content in histological sections of rainbow trout with increasing yellow mealworm meal inclusion, speculating that this might be related to the high chitin content in insects, which affects fatty acid synthesis [26-27]. However, Wen et al. [31] found that increasing replacement ratios of maggot meal exacerbated fatty degeneration in the hepatopancreas of yellow catfish, attributing this to changes in dietary n-3 polyunsaturated fatty acid content and n-3/n-6 ratio. As maggot meal replacement increased, dietary n-3 polyunsaturated fatty acid content and n-3/n-6 ratio gradually decreased. Although fatty acid composition of experimental diets was not analyzed in this study, analysis of black soldier fly larvae fatty acid composition revealed high levels of saturated and monounsaturated fatty acids [34]. Schiavone et al. [35] found that black soldier fly typically negatively affected the fatty acid composition of meat products, resulting in decreased polyunsaturated fatty acid content or increased monounsaturated fatty acid content. Therefore, changes in dietary polyunsaturated fatty acid composition may be one of the factors causing liver cell damage in Japanese seabass.

The intestine is the primary site for nutrient digestion and absorption in fish, and normal intestinal mucosal morphology is essential for ensuring proper fish growth. Li et al. [18] found that when defatted black soldier fly meal replacement exceeded 75%, the intestinal integrity of juvenile Jian carp was compromised. Wen et al. [31] reported that when maggot meal replacement exceeded 80%, obvious damage occurred to the integrity and morphological structure of the intestine in yellow catfish. In this experiment, increasing the replacement ratio of black soldier fly larvae meal negatively affected villus length and muscular thickness, indicating that higher replacement ratios can cause intestinal damage. Certain anti-nutritional factors present in insects, such as chitin, are major factors affecting intestinal health.

Conclusion

After 8 weeks of culture, replacing 50% of fish meal with black soldier fly larvae meal (corresponding to 27.8% inclusion level in the basal diet, accounting for 23.7% of dietary protein) had no significant effect on growth performance of juvenile Japanese seabass. However, high replacement ratios increased body fat deposition, caused hepatic lesions, and impaired intestinal structural development.

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Note: Figure translations are in progress. See original paper for figures.