Effects of Dietary Arginine to Lysine Ratio on Growth Performance, Body Composition, Serum Biochemical Indices, and Amino Acid Deposition Rate in All-Male Yellow Catfish (Pelteobagrus fulvidraco) Postprint

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Abstract

This experiment aimed to investigate the effects of dietary arginine (Arg) to lysine (Lys) ratio (Arg/Lys) on growth performance, body composition, serum biochemical indices, and amino acid retention rate in all-male yellow catfish. A total of 960 all-male yellow catfish juveniles with an average body weight of (2.34±0.05) g were randomly divided into 8 groups (4 replicates per group, 30 fish per replicate) and fed isonitrogenous and isolipidic diets with Arg/Lys ratios of 2.19/2.61 (Group I, as control), 1.74/2.08 (Group II), 1.75/3.02 (Group III), 2.63/2.08 (Group IV), 2.64/3.12 (Group V), 3.07/2.61 (Group VI), 2.19/3.65 (Group VII), and 3.08/3.65 (Group VIII) for a 10-week growth trial. The results showed: 1) The final body weight, weight gain, weight gain rate, and specific growth rate of all-male yellow catfish reached maximum values at Arg/Lys of 3.07/2.61 (Group VI), and were significantly higher than those of other groups ($P<0.05$), except that the weight gain rate showed no significant difference with Group V ($P>0.05$), and the final body weight, weight gain, weight gain rate, and specific growth rate showed no significant differences with Groups IV and V ($P>0.05$). No significant differences were observed among groups for protein efficiency ratio and survival rate ($P>0.05$). The feed conversion ratio was highest in Group II, which was significantly higher than other groups ($P<0.05$). 2) No significant differences were observed among groups for whole body moisture, crude lipid, and crude ash contents ($P>0.05$), but whole body crude protein content was highest in Group VI, which was significantly higher than that in Groups II and III ($P<0.05$). No significant differences were observed among groups for muscle crude protein and crude lipid contents ($P>0.05$), but muscle moisture content was highest in Group VII, which was significantly higher than that in Groups I and II ($P<0.05$). 3) The retention rates of Lys and valine (Val) in all-male yellow catfish showed a linear relationship with dietary Arg/Lys ratio, increasing with the increase of Arg/Lys ratio. The retention rates of Arg, tyrosine (Tyr), methionine (Met), phenylalanine (Phe), leucine (Leu), histidine (His), and isoleucine (Ile) in all-male yellow catfish showed a quadratic regression relationship with dietary Arg/Lys ratio, reaching maximum values when Arg/Lys ratios were 0.98, 1.16, 1.17, 1.02, 1.28, 1.11, and 1.24, respectively. 4) Dietary Arg/Lys had no significant effects on serum biochemical indices (activities of alanine aminotransferase and aspartate aminotransferase, and contents of total protein, albumin, globulin, glucose, urea nitrogen, total cholesterol, triglyceride, and albumin/globulin ratio) (P>0.05). In conclusion, dietary Arg/Lys ratio affected growth performance, body composition, and amino acid retention rate in all-male yellow catfish. In this experiment, the optimal Arg/Lys ratio in feed for all-male yellow catfish was 3.07/2.61.

Full Text

Effects of Dietary Arginine/Lysine Ratio on Growth Performance, Body Composition, Serum Biochemical Indices and Amino Acid Deposition Rate of All-Male Yellow Catfish

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Abstract

This experiment was conducted to investigate the effects of dietary arginine (Arg) to lysine (Lys) ratio (Arg/Lys) on growth performance, body composition, serum biochemical indices, and amino acid deposition rate in all-male yellow catfish. A total of 960 juvenile all-male yellow catfish with an average initial body weight of (2.34±0.05) g were randomly divided into 8 groups (4 replicates per group, 30 fish per replicate) and fed eight isonitrogenous and isolipidic diets with Arg/Lys ratios of 2.19/2.61 (group , control), 1.74/2.08 (group), 1.75/3.02 (group), 2.63/2.08 (group), 2.64/3.12 (group), 3.07/2.61 (group), 2.19/3.65 (group), and 3.08/3.65 (group) for a 10-week growth trial. The results showed that: 1) Final body weight (FBW), weight gain (WG), weight gain rate (WGR), and specific growth rate (SGR) peaked when dietary Arg/Lys was 3.07/2.61 (group). These values in group were significantly higher than those in other groups (P<0.05), except that WGR showed no significant difference from group (P>0.05), and FBW, WG, WGR, and SGR showed no significant differences from groups and (P>0.05). No significant differences were observed in protein efficiency ratio (PER) or survival rate (SR) among all groups (P>0.05). The feed conversion ratio (FCR) was highest in group , significantly exceeding that of all other groups (P<0.05). 2) No significant differences were detected in whole-body moisture, ether extract (EE), or ash content among groups (P>0.05). However, whole-body crude protein (CP) content was highest in group , significantly higher than in groups and (P<0.05). Muscle CP and EE contents showed no significant differences among groups (P>0.05), while muscle moisture content was highest in group , significantly higher than in groups and (P<0.05). 3) Lys and valine (Val) deposition rates exhibited a linear relationship with dietary Arg/Lys ratio, increasing as the ratio increased. In contrast, Arg, tyrosine (Tyr), methionine (Met), phenylalanine (Phe), leucine (Leu), histidine (His), and isoleucine (Ile) deposition rates showed quadratic relationships with dietary Arg/Lys ratio. Maximum deposition rates for Arg, Thr, Met, Phe, Leu, His, and Ile were achieved at Arg/Lys ratios of 0.98, 1.16, 1.17, 1.02, 1.28, 1.11, and 1.24, respectively. 4) No significant effects of dietary Arg/Lys were observed on serum biochemical indices (alanine aminotransferase and aspartate aminotransferase activities, and total protein, albumin, globulin, glucose, urea nitrogen, total cholesterol, triglyceride contents, and albumin/globulin ratio) (P>0.05). In conclusion, dietary Arg/Lys ratio significantly affects growth performance, body composition, and amino acid deposition rate in all-male yellow catfish. The optimal dietary Arg/Lys ratio for all-male yellow catfish in this study was 3.07/2.61.

Keywords: arginine; lysine; all-male yellow catfish; growth performance; body composition; serum biochemical indices; amino acid deposition rate

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Introduction

Yellow catfish (*Pelteobagrus fulvidraco*) is a freshwater omnivorous fish valued for its delicious taste and lack of intermuscular bones. Since male yellow catfish grow faster than females, all-male populations have become the focus of aquaculture production. Previous research has established protein and amino acid requirements for yellow catfish, with dietary protein levels of 42.9%–43.5% reported for juvenile *Pelteobagrus vachelli*, arginine requirements of 2.38%–2.74%, and optimal lysine requirement of 2.61%. As both arginine and lysine are basic amino acids that share transport carriers, their interactive relationship in absorption and utilization has long been of interest. Studies on rainbow trout and Atlantic salmon have demonstrated clear antagonistic effects between these amino acids, while research on soft-shelled turtle and turbot has shown that high lysine levels exert antagonistic effects on arginine. However, the effects of different dietary Arg/Lys ratios on growth performance of all-male yellow catfish have not been reported. This experiment was designed to investigate the effects of varying dietary Arg/Lys ratios on growth performance, body composition, serum biochemical indices, and amino acid deposition rate in all-male yellow catfish, providing a basis for optimizing nutritional parameters and formulating scientifically balanced diets.

1.1 Experimental Design

Based on preliminary trials and relevant literature, the control diet (group) was formulated with an Arg/Lys ratio of 2.19/2.61. Group was designed with both Arg and Lys levels 20% lower than control (1.74/2.08). Group had Arg 20% lower and Lys 20% higher than control (1.75/3.02). Group had Arg 20% higher and Lys 20% lower than control (2.63/2.08). Group had both Arg and Lys 20% higher than control (2.64/3.12). Group had Arg 40% higher with Lys unchanged (3.07/2.61). Group had Arg unchanged with Lys 40% higher (2.19/3.65). Group had both Arg and Lys 40% higher than control (3.08/3.65).

1.2 Experimental Diets

Fish meal, expanded soybean, soybean meal, rapeseed meal, and crystalline amino acids served as primary protein sources, while soybean oil and soybean lecithin were the main lipid sources. Basal diets were supplemented with mineral and vitamin premixes. According to the experimental design, different levels of crystalline Arg and Lys were added to the basal diet, with crystalline glycine (Gly) used as an isonitrogenous substitute to formulate the experimental diets. The composition and nutrient levels of the experimental diets are presented in Table 1 .

Feed ingredients were ground and sieved, then mixed according to formulation. Soybean oil and soybean lecithin were added, followed by water to achieve proper consistency. The mixture was manually kneaded and processed into 2 mm hard pellets using an F-26 pellet extruder. The pellets were air-dried, crushed, sieved, and stored at -20 °C until use.

1.3 Experimental Groups and Husbandry

All-male yellow catfish were purchased from Yangzhou Dong' s Special Aquatic Products Co., Ltd. and transported with oxygen supplementation to the experimental facility, where they were acclimated for one week. A total of 960 healthy, responsive fish with an average body weight of (2.34±0.05) g were selected and randomly distributed into 8 groups with 4 replicates each (30 fish per replicate). Each replicate was stocked in a 200 L cylindrical tank. Fish were hand-fed to apparent satiation twice daily at 06:00 and 16:00, with feed amounts recorded. The experiment was conducted under shaded conditions with microcirculation water exchange. Water temperature was maintained at 24–28 °C, with intermittent aeration keeping dissolved oxygen above 5 mg/L. The trial lasted 70 days.

1.4 Sample Collection and Analysis

At the end of the experiment, fish were fasted for 24 h before sampling. Fish in each tank were counted and weighed. Five fish per tank were randomly selected and stored at -20 °C for whole-body proximate analysis. Another 10 fish per tank were sampled for muscle tissue (excised from pectoral to caudal fin) and stored at -20 °C for muscle nutrient analysis. Two fish per tank were randomly selected for blood collection from the caudal vein using 1 mL syringes. Blood was transferred to 1.5 mL centrifuge tubes, left overnight at 4 °C, then centrifuged at 4,000 r/min for 10 min. The serum was collected for biochemical analysis.

Proximate composition of diets and fish samples (whole-body and muscle) was analyzed in duplicate. Moisture content was determined by atmospheric pressure drying, crude protein by automatic Kjeldahl analyzer (FOSS Kjeltec 8400, Denmark), ether extract by Soxhlet extraction, and ash by high-temperature combustion, following methods described by Zhang Liying et al. with modifications. Amino acid composition of diets and whole-body samples was determined using the Venusil amino acid analysis method (Bonna-Agela) with a Shimadzu Prominence LC-10AD high-performance liquid chromatograph.

1.5 Index Calculation

Initial body weight (IBW, g) = total fish weight before trial / number of fish
Final body weight (FBW, g) = total fish weight after trial / number of fish
Weight gain rate (WGR, %) = 100 × (FBW -IBW) / IBW
Specific growth rate (SGR, %/d) = 100 × (ln FBW -ln IBW) / feeding days
Feed conversion ratio (FCR) = feed intake (g) / weight gain (g)
Protein efficiency ratio (PER) = weight gain (g) / protein intake (g)
Survival rate (SR, %) = 100 × number of surviving fish / initial number of fish
Amino acid deposition rate (%, fresh basis) = 100 × (weight gain × amino acid content in whole body) / (feed consumption × amino acid content in diet)

1.6 Statistical Analysis

Data were processed using Excel 2013 and analyzed by one-way ANOVA using SPSS 18.0. Duncan' s multiple range test was used for inter-group comparisons with significance set at $P<0.05$. Results are expressed as mean ± standard deviation (mean±SD).

Results

2.1 Effects of Dietary Arg/Lys on Growth Performance of All-Male Yellow Catfish

As shown in Table 2 , no significant differences were observed in survival rate or protein efficiency ratio among groups ($P>0.05$). Weight gain rate peaked in group , showing no significant difference from group ($P>0.05$) but significantly exceeding all other groups ($P<0.05$). Final body weight, weight gain, and specific growth rate also reached maximum values in group , with no significant differences from groups and ($P>0.05$) but significantly higher than remaining groups ($P<0.05$). Feed conversion ratio was highest in group , significantly greater than all other groups (P<0.05), while other groups showed no significant differences among themselves (P>0.05).

2.2 Effects of Dietary Arg/Lys on Serum Biochemical Indices of All-Male Yellow Catfish

As presented in Table 3 , no significant differences were detected among groups in serum alanine aminotransferase (ALT) or aspartate aminotransferase (AST) activities, nor in total protein (TP), albumin (ALB), globulin (GLOB), glucose (GLU), urea nitrogen (UN), total cholesterol (TC), triglyceride (TG) contents, or albumin/globulin ratio (A/G) (P>0.05).

2.3 Effects of Dietary Arg/Lys on Proximate Nutrients in Whole Body and Muscle of All-Male Yellow Catfish

Table 4 shows that no significant differences were observed among groups in whole-body moisture, ether extract, or ash contents, nor in muscle crude protein or ether extract contents (P>0.05). Whole-body crude protein content was highest in group , significantly higher than in groups and (P<0.05) but not significantly different from group (P>0.05). Muscle moisture content was highest in group , significantly exceeding all other groups (P<0.05), while group showed the lowest value, significantly lower than groups , , and (P<0.05). No significant differences were found among remaining groups (P>0.05).

The relationship between crude protein and ether extract contents in muscle dry matter is shown in Figure 1 [Figure 1: see original paper]. The regression equation ($y = -0.6585x + 65.206$, $R^2 = 0.7505$) indicates a significant negative correlation between ether extract and crude protein contents in muscle dry matter (P<0.05).

2.4 Effects of Dietary Arg/Lys on Amino Acid Deposition Rates of All-Male Yellow Catfish

As shown in Table 5 , arginine deposition rate was highest in group , significantly exceeding all other groups (P<0.05), followed by group which showed no significant difference from group (P>0.05) but was significantly higher than remaining groups (P<0.05). Group exhibited the lowest arginine deposition rate, significantly lower than all other groups (P<0.05). Lysine deposition rate was highest in group , significantly higher than all other groups (P<0.05), followed by groups , , and which were significantly higher than remaining groups (P<0.05). Groups and showed relatively low lysine deposition rates, significantly lower than other groups (P<0.05). Essential amino acid (EAA) deposition rate was highest in group , showing no significant difference from group (P>0.05) but significantly exceeding all other groups (P<0.05). Group exhibited the lowest EAA deposition rate, with group also significantly lower than other groups (P<0.05). Non-essential amino acid (NEAA) deposition rate was highest in group , showing no significant difference from group (P>0.05) but significantly higher than all other groups (P<0.05). Groups and showed relatively low NEAA deposition rates, significantly lower than other groups (P<0.05).

The relationships between dietary Arg/Lys ratio and EAA and total amino acid (TAA) deposition rates are illustrated in Figure 2 [Figure 2: see original paper]. Lysine (Figure 2-a) and valine (Figure 2-f) deposition rates showed linear relationships with dietary Arg/Lys ratio, increasing as the ratio increased. In contrast, arginine (Figure 2-b), tyrosine (Thr) (Figure 2-c), methionine (Met) (Figure 2-d), phenylalanine (Phe) (Figure 2-e), leucine (Leu) (Figure 2-g), histidine (His) (Figure 2-h), isoleucine (Ile) (Figure 2-i), EAA (Figure 2-j), and TAA (Figure 2-k) deposition rates exhibited quadratic relationships with dietary Arg/Lys ratio. Maximum deposition rates for Arg, Thr, Met, Phe, Leu, His, and Ile were achieved at Arg/Lys ratios of 0.98, 1.16, 1.17, 1.02, 1.28, 1.11, and 1.24, respectively.

Discussion

3.1 Effects of Dietary Arg/Lys on Growth Performance of All-Male Yellow Catfish

Fish growth performance is closely related to dietary Arg and Lys levels. As limiting amino acids in fish diets, insufficient Arg or Lys directly causes amino acid imbalance, forcing nutrients to be metabolized for energy and consequently impairing growth. Similar phenomena were observed in this trial, where low dietary Arg and Lys levels severely affected growth of all-male yellow catfish. However, as dietary Arg and Lys levels increased, growth performance improved markedly, indicating that elevated Arg and Lys to appropriate levels promotes growth. Conversely, excessive Lys inhibited growth, consistent with reports on Asian sea bass, Japanese sea bass, grass carp, Indian major carp, and rainbow trout. This occurs because excessive Lys induces amino acid imbalance, intensifying deamination of surplus amino acids. The nitrogenous components are excreted as ammonia, urea, and trimethylamine, while non-nitrogenous components are catabolized to water and carbon dioxide for energy release, thereby compromising growth.

Lysine and arginine are both basic amino acids that compete for transport carriers during digestion, absorption, and post-absorptive metabolism, creating competitive inhibition. Excessive Lys reduces arginine absorption and utilization. Research on turbot has demonstrated antagonistic effects between dietary Lys and Arg on growth and feed utilization. In this experiment, when dietary Arg and Lys levels were low, different Arg/Lys ratios did not significantly affect growth or feed utilization. However, when both amino acids were increased by 20% above control levels, growth declined as Lys level increased, suggesting that their interaction depends on absolute dietary levels and that Lys antagonism toward Arg becomes more pronounced with increasing Lys levels.

Zhou et al. reported that imbalanced Arg and Lys supplementation significantly reduced growth performance in black sea bream compared with control. In this trial, from the perspective of growth and feed utilization, the optimal dietary Arg/Lys ratio was 3.07/2.61. Altering either Arg or Lys level from this ratio decreased growth performance, likely because all-male yellow catfish growth is jointly influenced by both amino acids. At Arg/Lys of 3.07/2.61, dietary amino acid balance was optimized, promoting nutrient absorption. Modifying Arg or Lys content disrupted this balance, thereby slowing growth.

3.2 Effects of Dietary Arg/Lys on Serum Biochemical Indices of All-Male Yellow Catfish

Blood indices in fish are closely associated with metabolism, nutritional status, health condition, and immune function. Among serum biochemical parameters, urea nitrogen (UN) content is negatively correlated with protein deposition; higher UN indicates lower net protein synthesis and higher amino acid catabolism. Fico et al. found that in rainbow trout fed amino acid-imbalanced diets, nutrients, particularly amino acids, were not efficiently utilized, requiring additional energy for deamination and excretion. Berge et al. and Tantikitti et al. reported that amino acid-imbalanced diets elevated blood UN levels. In this trial, serum UN content was higher when Lys was excessive or Arg/Lys ratio was low (groups and), indicating that excess Lys or low Arg/Lys ratio caused nutrient imbalance and reduced utilization efficiency.

Under normal conditions, serum AST and ALT activities remain low due to cell membrane barrier functions, but increase when cells are diseased or damaged. In this study, serum ALT activity was highest in the group receiving high levels of both Arg and Lys (group), suggesting that excessive Arg and Lys may cause liver cell damage in all-male yellow catfish, consistent with findings in blunt snout bream.

Serum total protein content reflects nutritional status and metabolic level, while globulin is secreted by plasma cells transformed from B cells, with its content indicating immune capacity. Zhou et al. reported that Arg increased serum TP and GLOB contents in Pacific white shrimp, favoring protein synthesis. In this trial, when dietary Arg and Lys levels were low, serum TP and GLOB contents increased with increasing Arg/Lys ratio. However, when Arg and Lys levels were high, TP and GLOB contents increased initially then decreased with increasing Arg/Lys ratio. This may be because arginase activity is negatively regulated by ornithine, and Lys is an arginase inhibitor. Arginase activity in fish increases with dietary Arg level, so when Arg level rises, increased arginase activity limits the effects of negative feedback regulation and inhibition, thereby enhancing immunity.

In this experiment, dietary Arg/Lys did not significantly affect serum biochemical indices, possibly due to sampling timing. Because fish possess strong self-regulation capacity, all biochemical parameters may have reached a fasting equilibrium after 24 h starvation. Future studies should optimize blood sampling timing and experimental protocols.

3.3 Effects of Dietary Arg/Lys on Body Composition of All-Male Yellow Catfish

Both dietary Arg and Lys levels influence fish body composition. Research on turbot found that whole-body crude protein content was primarily affected by Lys level, increasing significantly with higher Lys levels. Alam et al. reported that whole-body crude protein, ether extract, moisture, and ash contents were significantly affected by dietary Arg level in Japanese flounder. In this trial, dietary Arg/Lys did not significantly affect whole-body ether extract, ash, or moisture contents, but significantly influenced whole-body crude protein content, which was primarily affected by Arg level. This may be related to Arg being an essential amino acid for fish; insufficient dietary Arg causes nutrient imbalance that directly impairs protein synthesis.

Lysine, as the first limiting amino acid in fish, is a precursor of L-carnitine, which plays a crucial role in transporting long-chain fatty acyl groups for mitochondrial oxidation, thereby reducing fat deposition. In this study, muscle moisture content and muscle dry matter crude protein and ether extract contents were primarily affected by dietary Lys level. As dietary Lys level increased, muscle ether extract content gradually decreased while crude protein content increased. This occurred because higher dietary Lys reduced protein catabolism for energy, thereby promoting protein synthesis. Similar findings have been reported in other fish species.

3.4 Effects of Dietary Arg/Lys on Amino Acid Deposition Rate of All-Male Yellow Catfish

Amino acid deposition rate is related to dietary amino acid levels and balance. Zhou et al. reported antagonistic effects between high Lys and Arg levels in soft-shelled turtles, and similar antagonism has been demonstrated in yellow catfish. In this trial, dietary Arg/Lys not only affected Arg and Lys deposition but also influenced other essential and non-essential amino acids. When dietary Arg and Lys levels were either low or high, amino acid deposition rates showed similar trends, with most amino acids increasing initially then decreasing as Arg/Lys ratio increased. This indicates that when high Lys levels are used, Arg levels must also increase appropriately within a certain Arg/Lys range. Quadratic regression analysis revealed maximum deposition rates for Arg, Thr, Met, Phe, Leu, His, and Ile at Arg/Lys ratios of 0.98, 1.16, 1.17, 1.02, 1.28, 1.11, and 1.24, respectively. Additionally, at Arg/Lys of 0.98, Arg deposition rate peaked, while Lys and Val deposition rates increased linearly with Arg/Lys ratio. This suggests that appropriate Arg levels can mitigate negative effects of excessive Lys-induced amino acid imbalance. The mechanism involves Arg supplementation upregulating hepatic arginase mRNA expression, promoting Arg catabolism to ornithine and subsequently to polyamines via ornithine decarboxylase (ODC), spermidine synthase, and spermine synthase. Polyamines play important roles in cell growth, proliferation, and differentiation, thereby improving growth performance and amino acid deposition. This explains why Arg deposition rate peaked earlier than other essential amino acids. The linear relationship between Lys deposition rate and Arg/Lys ratio primarily resulted from different dietary Lys levels. When Arg and Lys levels differed but Arg/Lys ratio remained the same, amino acid deposition rates appeared unaffected, possibly because identical ratios create a relative balance in Arg-Lys interactions. At Arg/Lys of approximately 1.20, EAA and TAA deposition rates were highest, consistent with optimal growth performance and body nutrient composition, indicating minimal antagonism and optimal nutritional balance at this ratio. Studies in terrestrial animals have shown that Lys can either stimulate or inhibit Arg absorption depending on their relative concentrations, suggesting that Lys-Arg antagonism intensifies when Arg/Lys exceeds certain ranges. This occurs because Lys, as an arginase inhibitor, regulates Arg metabolism and utilization at the transcriptional level, thereby affecting Arg and other amino acid deposition.

Conclusion

1. Dietary Arg/Lys ratio significantly affects growth performance of all-male yellow catfish, with optimal performance observed at Arg/Lys of 3.07/2.61.

2. Dietary Arg/Lys ratio influences body composition, with whole-body crude protein content highest at Arg/Lys of 3.07/2.61.

3. Dietary Arg/Lys ratio does not significantly affect serum biochemical indices in all-male yellow catfish.

4. Dietary Arg/Lys ratio affects amino acid deposition rates, with the optimal Arg/Lys ratio ranging from 1.02 to 1.28.

5. The recommended dietary Arg/Lys ratio for all-male yellow catfish is 3.07/2.61.

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