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Phytase Enzyme Improves Growth Performance and Body Chemical Composition of Sangkuriang Catfish (*Clarias gariepinus* var. Sangkuriang) Juvenile

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ABSTRACT

Due to their nutritional value, alternative vegetable materials such as soybean are needed to promote sustainable aquaculture development. However, phytate in soybean could interfere with the protein digestion of the fish body. This study examines the effectiveness of phytate enzymes in enhancing protein digestibility, growth performance, mineral digestion, and body chemical composition of Sangkuriang catfish (*Clarias gariepinus* var. Sangkuriang) juveniles. The study was completely randomized design with 4 treatments and 3 repetitions. One hundred thirteen Sangkuriang catfish juveniles (7.65 ± 0.14 g) were used for each repetition. The fish were fed with an experimental diet supplemented with various doses of phytase enzyme: 0 (A), 500 (B), 1,000 (C), and 1,500 (D) FTU/kg of feed. The mineral digestibility, protein digestibility, protein efficiency ratio (PER), feed conversion ratio (FCR), the efficiency of feed utilization (EFU), apparent digestibility coefficients (ADCp), relative growth rate (RGR), and survival rate (SR) were observed. Data were analyzed using analysis of variance followed by Duncan's multiple range test. The results showed that adding 1,000 FTU/kg of phytase enzyme (C) exhibited the highest PER, FCR, EFU, ADCp, and RGR

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value of Sangkuriang catfish juveniles compared to other treatments. All treatment groups (B-C) had the same SR value (100%) and had the highest crude protein and ash content compared to the A group. All group treatments also exhibited a higher phosphorus, calcium, potassium, magnesium, iron, zinc, manganese, copper, and cobalt. Therefore, phytase enzyme supplementation could improve protein digestibility, mineral digestibility, growth performance, and body chemical composition of Sangkuriang catfish juveniles.

Keywords: Mineral, phytase enzyme, phytic acid, protein, Sangkuriang catfist

INTRODUCTION

The Sangkuriang catfish (*Clarias gariepinus* var. Sangkuriang) is a popular and frequently consumed freshwater fish in Indonesia. The Ministry of Maritime Affairs and Fisheries Indonesia noted that catfish production in Indonesia reached 1.06 million tonnes in 2021. The catfish production increased by 2.95% compared to the previous year, which amounted to 1.03 million tonnes (Widi, 2022). This fish is commonly consumed due to its relative ease of preparation, affordability, and high protein content. In addition, this fish is also cultivated due to its relatively rapid growth rate and increased customer demand, which drives catfish farmers to engage in intensive cultivation (Rachmawati et al., 2022). Artificial feed is fish culture feed made from various materials that have good nutritional content according to the needs of fish and is manufactured with careful consideration for the nature and size of the fish. Artificial feed has a significant role in determining the success of intensive Sangkuriang catfish cultivation. Fish meal represents up to 50% of the animal protein in artificial feed, making it the most expensive protein element (Tacon & Metian, 2008). Protein, essential amino acids, vital fatty acids, cholesterol, vitamins, and mineral attractants are abundant in fish feed, making it the primary dietary source (National Research Council [NRC], 2011). With the development of fish farming activities, the demand for fish feed increases, resulting in a restricted supply of fish feed and an increase in the rate of unsustainable overfishing in natural environments (Tacon & Metian, 2008).

Alternative vegetable materials are needed to promote the development of environmentally friendly and sustainable aquaculture (Shapawi et al., 2013). Soy flour is one of the vegetable ingredients used as a source of protein due to its availability, relative affordability, and balanced profile of key amino acids (Akiyama & Dominy, 1989; Tacon & Metian, 2008). However, the fish feed cannot contain soy flour due to anti-nutritional factors (ANF) in phytic acid. Phytic acid can generate phytate-protein and phytate-mineral-protein complexes, reducing protein digestion and utilization by inhibiting protein digestion (Cao et al., 2007). The phytate protein complex cannot be digested by proteolytic enzymes (Ravindran et al., 1995), and phytic acid inhibits the activity of certain proteolytic enzymes, including pepsin, amyloperoxidase, and amylase (Cao et al., 2007). Additionally, phytic acid chelates minerals such as calcium, magnesium, zinc, iron, and copper to create insoluble complexes, limiting the absorption and bioavailability of macro and micro elements required by fish (Papatryphon et al., 1999).

Applying phytase enzyme in feed can hydrolyze phytate into penta-, tetra-, tri-, di-, and monophosphate myoinositol and neutralize the detrimental effect of phytic acid on protein and other nutrients in feed. Furthermore, the presence of phytase enzymes in feed can enhance the bioavailability of phosphorus and nitrogen bound to phytate, hence limiting the release of phosphorus (P) and nitrogen (N) into the aquatic environment (Cao et al., 2007). Phytase enzyme enrichment in feed has boosted growth, feed conversion ratio, and protein and mineral digestibility in some fish, such as *Pangasius pangasius* (Debnath et al., 2005), *Ephinephelus fuscoguttatus* (Shapawi et al., 2013), *Marsupenaeus japonicas* (Bulbul et al., 2015), *Psetta maxima* (von Danwitz et al., 2016), *Cirrhinus mrigala* (Hussain et al., 2020), *Sparus aurata* (Salem et al., 2022), *Oreochromis niloticus* (Shahzad et al., 2022), *Cyprinus carpio* (Shahzad et al., 2021), *Carassius auratus* (Nie at al., 2017), and *Labeo rohita* (Hussain et al., 2017).

There is little information regarding the phytase enzyme enrichment in Sangkuriang catfish juvenile feed; therefore, further research is required. This study aimed to examine the effectiveness of phytate enzymes in enhancing protein digestibility, growth performance, mineral digestion, and body chemical composition of Sangkuriang catfish (*Clarias gariepinus* var. Sangkuriang) juveniles.

MATERIALS AND METHODS

Animal Preparation and Research Design

This study was conducted in Balai Budidaya Ikan Air Tawar (BBIAT), Muntilan, Jawa Tengah, Indonesia. The current research used a completely randomized design (CRD), 4 treatments of phytase supplementation at different doses, and each treatment was repeated three times. The stocking density of fish was 113 fish/research container fiber for each repetition. The fish used was Sangkuriang catfish (*Clarias gariepinus* var. Sangkuriang) juveniles procured from BBIAT, weighing an average of 7.65 ± 0.14 g/head and rearing for 56 days. Juvenile Sangkuriang catfish were selected before a treatment based on their uniform size and weight, absence of deformity, active swimming, and good health (Rachmawati et al., 2017). During 1 week of acclimatization, fish were fed with commercial fish feed that did not contain phytase enzyme. Fish were not fed the day before receiving treatment to remove residual food from initial feedings.

Experimental Feed Preparation

The experimental fish feed was artificial pellets which contained 32% protein, isoenergy (301 kcal) (Rachmawati et al., 2022), 1% chromium (III) oxide (Cr_2O_3) as a protein digestibility indicator (NRC, 2011), phytase enzymes at different doses: 0 (A), 500 (B), 1,000 (C), and 1,500 (D) FTU/kg feed (Table 1). The phytase enzyme (Nathupos®E 10,000 G, BASF SE, Germany) was made of light brown granules.

Feed preparation begins with weighing the raw materials according to the feed formulation, mixing the feed ingredients from tiny to large quantities, using a mixer machine, and adding fish oil (Ultra Omega 3-D™, NOW Foods, USA), corn oil (Mazola®, Saudi Arabia), and water to taste. Furthermore, the dough was placed within the extruder floating pellet molding machine. After stamping, the feed was air-dried at room temperature (around 26°C), then packaged and stored in airtight plastic.

Table 1

Feed formulation (1,000 g)

Material (g)	Treatment			
	A	B	C	D
Fish flour	345.00	345.00	345.00	345.00
Soybean	240.00	240.00	240.00	240.00
Corn flour	150.00	150.00	150.00	150.00
Bran	145.00	144.95	144.90	144.85
Tapioca flour	80.00	80.00	80.00	80.00
Fish oil	10.00	10.00	10.00	10.00
Corn oil	10.00	10.00	10.00	10.00
Mineral and vitamin mix[1]	10.00	10.00	10.00	10.00
Phytase enzyme (FTU)	0	0.05	0.1	0.15
Chromium (III) oxide (Cr_2O_3)	10.00	10.00	10.00	10.00
Total	1,000	1,000	1,000	1,000
	Proximate analysis results			
Protein (%)*	30.21	31.19	32.20	30.20
Fat (%)*	7.87	8.40	8.99	8.73
Nitrogen Free Extract/NFE (%)*	35.22	35.36	34.8	32.73
Energy (kcal)[2]	301.34	301.82	301.19	301.98
Ratio of energy/protein (E/P) (cal/g)[3]	9.98	9.97	9.97	9.90

Note.

[1]Mineral and vitamin mix/kg: Sodium (Na) 117 mg, selenium (Se) 150 mg, vitamin B1 52 mg, magnesium (Mg) 1,900 mg, vitamin B2 97 mg, vitamin B6 46 mg, potassium (K) 150 mg, calcium (Ca) 219 mg, copper (Cu) 9 mg, iron (Fe) 90 mg, vitamin C (coated) 68,800 mg activity, zinc (Zn) 90 mg, iodine (KI) 1.8 mg, cobalt (Co) 450 mg, vitamin B12 60 mg, vitamin A 36.000 I.U., vitamin D3 9.000 I.U., manganese (Mn) 105 mg, panthothenic acid 93 mg, inositol 225 mg, biotin 450 mg, vitamin E 187 mg, vitamin K3 19 mg, niacin 130 mg, and folic acid 10 mg

[2]Determined based on Digestible Energy (NRC, 2011), for 1 g of protein equal to 3.5 kcal/g, 1 g of fat equal to 1 kcal/g, and 1 g of carbohydrate equal to 2.5 kcal/g

[3]Based on NRC (2011), the E/P value for the optimum growth of fish ranges from 8–12 kcal/g

*Proximate analysis results from Laboratorium Ilmu Makanan Ternak, Fakultas Peternakan dan Pertanian, Universitas Diponegoro in the year 2022

Container Preparation

The study used a container fiber tub of 1.5 m x 1.5 m x 1 m with up to 12 units supplied with a recirculation system to maintain water quality within the optimal range. The maintenance media contained mountain water deposited in a reservoir. The study was initiated by placing 113 test fish with a known average initial weight into each of the 113 research containers. Determining fish density refers to Rachmawati et al. (2022), in which 50 fish were stocked per square meter. The feed was administered three times daily, at 06.00 a.m., 12.00 p.m., and 6.00 p.m., according to the *at-satiation* method. During the study, the weight gain of the test fish was monitored weekly using digital scales. Two hours after feeding, excrement, and feed residues were sucked up using a siphon to keep them clean and suitable for fish life.

Proximate Analysis

Based on Jayant et al. (2018), proximate analysis was conducted to assess the test feed and fish carcasses. A semi-automatic Kjeltec™ 2300 Analyzer Unit (FOSS Analytical, Denmark) was used to determine protein content. The fat content was evaluated using an ether extraction method based on the Soxhlet technique using Soxtec™ 2043 Fat Extraction System (FOSS Analytical, Denmark). Test feed samples and fish were burned in a furnace at 550°C for 24 hr to assess their ash content.

Protein Digestibility Analysis

According to Pérez-Jiménez et al. (2009), protein digestibility is determined using the indirect approach by adding 1% Cr_2O_3 to indicate protein digestibility to the test feed. During the 56-day study, fish feces were collected every morning, afternoon, and evening after the fish were fed. Feces are collected using a short plastic tube whose end is connected to a wooden stick to make it easier to maneuver while collecting feces, and the collected feces are then placed in a bucket. Feces were filtered using a plankton cloth net, and the filtrate is placed in small plastic bottles and refrigerated at 4°C. The feces were dried in a gravity oven (Fisherbrand™, Fisher Scientific, Belgium) at 6°C for 24 hr before analysis. The protein and Cr_2O_3 content in the feces were then measured using atomic absorption spectrophotometry (AAS) with a wavelength of 350 nm.

Mineral Content Analysis. At the end of the test, the mineral content of the fish was determined by randomly selecting twelve fish from each treatment (1 fish per replication). After drying each fish sample in an electric oven at 70–80°C until it attained a constant weight, approximately 2 g of each sample was weighed. Afterward, the sample was dissolved with strong nitric acid. The estimation of fish body minerals was performed with an atomic absorption spectrophotometer following the Association of Official Analytical Chemists (AOAC) (2019) guidelines.

Observed Parameters. The observed parameters consist of protein efficiency ratio (PER), feed conversion ratio (FCR), the efficiency of feed utilization (EFU), apparent digestibility coefficients (ADCp) (Pérez-Jiménez et al., 2009), relative growth rate (RGR), and survival rate (SR) (NRC, 2011); where each parameter was calculated using the following formulas:

$$ADCp\ (\%) = 100 - \left\{\frac{100 \times Cr_2O_3\ in\ the\ feed}{\%\ Cr_2O_3\ in\ the\ feces} \times \frac{\%\ protein\ in\ the\ feces}{\%\ protein\ in\ the\ feed}\right\} \tag{1}$$

$$EFU\ (\%) = \frac{Final\ weight - Initial\ weight}{Weight\ of\ diet\ consumed} \times 100 \tag{2}$$

$$RGR\ (\%) = 100 \times \frac{(Final\ weight - Initial\ weight)}{(Times\ of\ experiment \times Initial\ weight)} \tag{3}$$

$$FCR = \frac{Feed\ intake\ (g)}{Body\ weight\ gain\ (g)} \tag{4}$$

$$PER = 100 \times \frac{(Final\ weight - Initial\ weight)}{The\ amount\ of\ diet\ consumed \times Protein\ content\ of\ diet} \tag{5}$$

$$SR\ (\%) = 100 \times \left(\frac{Final\ count}{Initial\ count}\right) \tag{6}$$

Statistical Analysis. Data were analyzed using analysis of variance (ANOVA) using SPSS ver. 19.0 (USA). If the ANOVA results had a significant effect ($p<0.05$) or had a highly significant effect ($p<0.01$), Duncan's multiple range test was conducted to determine the difference in the mean values between treatments (Steel et al., 1997).

RESULTS

The addition of phytase enzyme to the feed significantly ($p<0.05$) increased PER, FCR, EFU, ADCp, and RGR, but not ($p>0.05$) in SR parameters (Table 2). The PER, FCR, EFU, ADCp, and RGR values of juvenile Sangkuriang catfish supplemented with phytase enzyme were greater than in the absence of supplementation. Based on the highest PER, FCR, EFU, and RGR values, adding 1,000 FTU/kg of feed phytase enzyme was the optimal dose for juvenile Sangkuriang catfish.

Table 3 shows the influence of phytase enzyme supplementation on the chemical composition of juvenile Sangkuriang catfish. Sangkuriang catfish juveniles fed with phytase enzyme had the highest crude protein content and ash content compared to those fed without phytase enzyme. There was no significant ($p>0.05$) difference between treatments regarding lipid and dry matter.

Table 2

Data of protein efficiency ratio (PER), feed conversion ratio (FCR), the efficiency of feed utilization (EFU), apparent digestibility coefficients (ADCp), relative growth rate (RGR), and survival rate (SR) of juvenile's Sangkuriang catfish

Parameter	Treatment			
	A	B	C	D
PER	1.63 ± 0.12^{d}	2.84 ± 0.18^{b}	3.49 ± 0.10^{a}	2.42 ± 0.13^{c}
FCR	1.82 ± 0.10^{d}	1.43 ± 0.14^{b}	1.02 ± 0.11^{a}	1.65 ± 0.17^{c}
EFU (%)	57.45 ± 0.22^{d}	69.28 ± 0.15^{b}	78.30 ± 0.18^{a}	65.29 ± 0.16^{c}
ADCp (%)	68.32 ± 0.25^{d}	75.46 ± 0.27^{b}	80.15 ± 0.23^{a}	72.52 ± 0.29^{c}
RGR (%/day)	2.10 ± 0.18^{d}	2.98 ± 0.12^{b}	3.27 ± 0.17^{a}	2.62 ± 0.19^{c}
SR (%)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}

Note. The alphabetical superscript indicates significant differences between treatments. The juvenile Sangkuriang catfish were fed with an experimental diet supplemented with various doses of phytase enzyme: (A) 0, (B) 500, (C) 1,000, and (D) 1,500 FTU/kg of feed

Table 3

The body chemical composition (%) of juvenile Sangkuriang catfish

Treatment	Dry matter	Protein	Lipid	Ash
A	24.38 ± 0.57^{a}	53.42 ± 0.13^{b}	24.60 ± 0.52^{a}	17.39 ± 0.25^{b}
B	23.67 ± 0.48^{a}	55.26 ± 0.54^{a}	23.65 ± 0.49^{a}	19.83 ± 0.62^{a}
C	23.54 ± 0.76^{a}	55.48 ± 0.29^{a}	23.57 ± 0.62^{a}	19.24 ± 0.28^{a}
D	24.73 ± 0.35^{a}	56.19 ± 0.32^{a}	24.22 ± 0.70^{a}	18.57 ± 0.59^{a}

Note. The alphabetical superscript indicates a significant difference between treatments. The juvenile Sangkuriang catfish were fed with an experimental diet supplemented with various doses of phytase enzyme: (A) 0, (B) 500, (C) 1,000, and (D) 1,500 FTU/kg of feed

The influence of feeding with phytase enzyme supplementation on the macro and micro mineral composition of juvenile Sangkuriang catfish is presented in Figures 1 (a–d) and 2 (a–e). The highest phosphorus value was obtained in juvenile Sangkuriang catfish, which was given treatment C (phytase enzyme 1,000 FTU/kg feed), followed by treatment D (phytase enzyme 1,500 FTU/kg feed), treatment B (phytase enzyme 500 FTU/kg feed), and the lowest phosphorus value was found in treatment A (phytase enzyme 0/kg feed) (Figure 1a). Juvenile Sangkuriang catfish fed with phytase enzyme supplementation had higher calcium and magnesium values than those without supplementation (Figures 1b and 1d). The potassium value showed no significant difference between juvenile Sangkuriang catfish fed with phytase enzyme supplementation and without supplementation (Figure 1c).

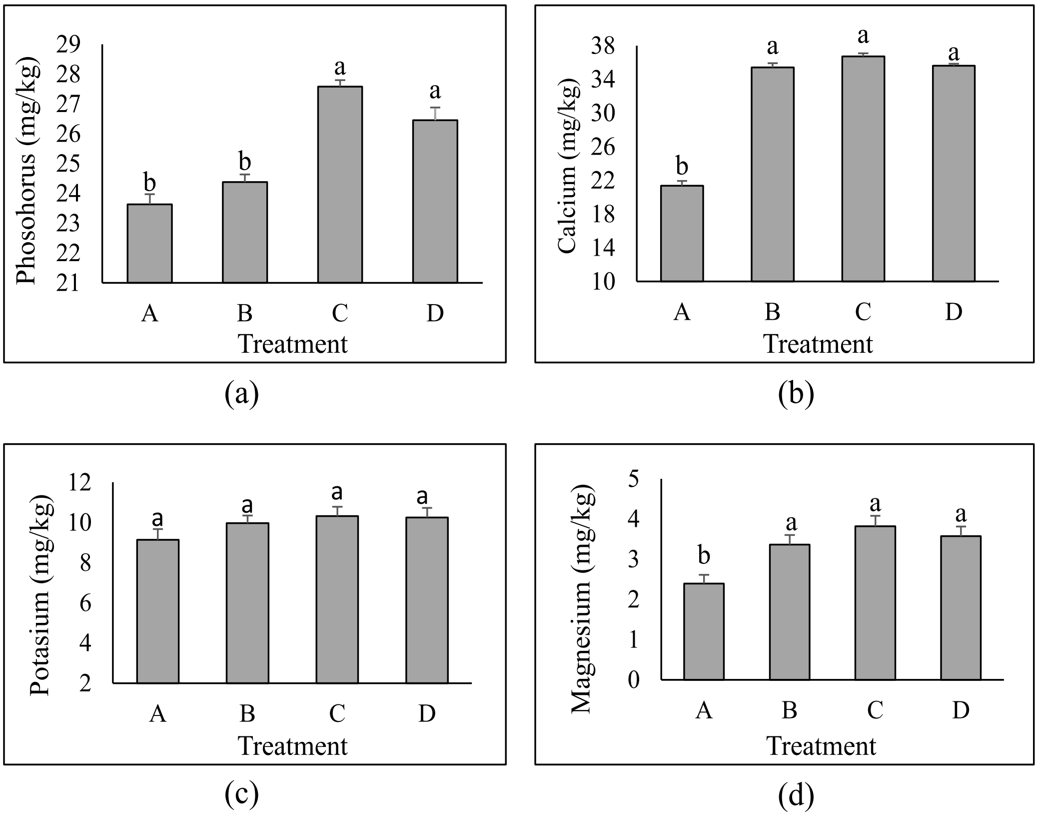

Figure 1. The macro-mineral composition including (a) phosphorus, (b) calcium, (c) potassium, and (d) magnesium of juvenile Sangkuriang catfish after fed with an experimental diet supplemented with various doses of phytase enzyme: (A) 0, (B) 500, (C) 1,000, and (D) 1,500 FTU/kg of feed

Note. The alphabetical superscript indicates a significant difference between treatments

The iron value of juvenile Sangkuriang catfish fed with phytase enzyme supplementation was higher than without phytase enzyme (Figure 2a). Juvenile Sangkuriang catfish fed with phytase enzyme supplementation also had higher zinc, manganese, and copper values than those without supplementation (Figures 2b, c, and d). The highest cobalt value gave the highest yield in juvenile Sangkuriang catfish that was given treatment C (phytase enzyme 1,000 FTU/kg feed), followed by treatment D (phytase enzyme 1,500 FTU/kg feed), treatment B (phytase enzyme 500 FTU/kg feed), and the lowest in treatment A (phytase enzyme 0 FTU/kg feed) (Figure 2e).

DISCUSSION

The phytase enzyme supplementation in the feed was substantially different ($p<0.05$) in the PER, FCR, EFU, ADCp, and RGR parameters but not in the SR parameter ($p>0.05$) (Table 2). It demonstrates that adding phytase enzyme to fish feed can hydrolyze protein phytate complex

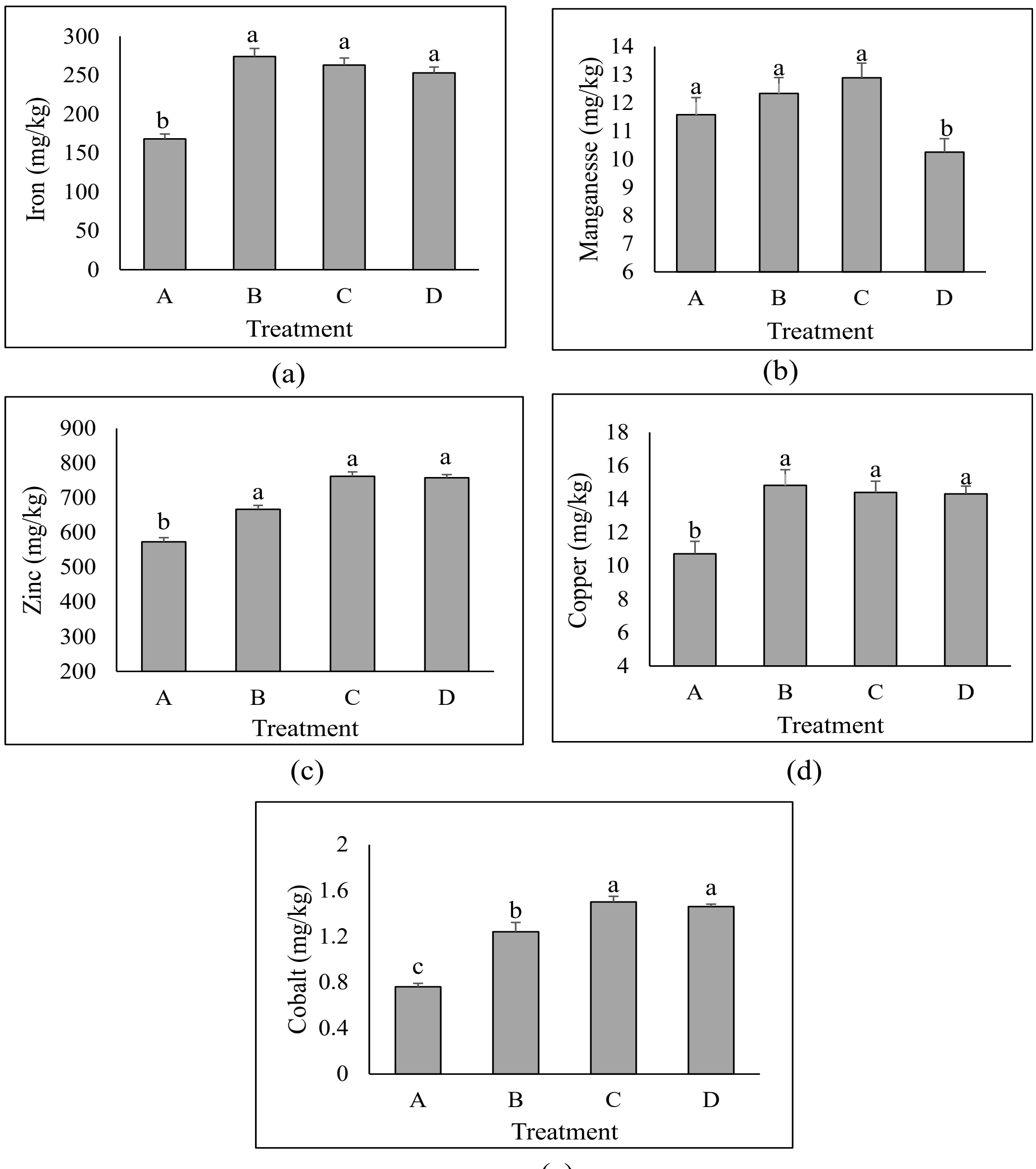

Figure 2. The micro-mineral composition including (a) iron, (b) manganese, (c) zinc, (d) copper, and (e) cobalt of juvenile Sangkuriang catfish after fed with an experimental diet supplemented with various doses of phytase enzyme: (A) 0, (B) 500, (C) 1,000, and (D) 1,500 FTU/kg of feed

Note. The alphabetical superscript indicates a significant difference between treatments

compounds into easily digestible amino acids for fish growth (Haghbayan & Mehrgan, 2015).

Spinelli et al. (1983) found that feed containing 0.5 % phytic acid had a negative effect on rainbow trout growth due to a decrease in protein availability in the feed. Phytic acid functions as a chelator to produce protein phytate complex molecules, influencing proteins and minerals' bioavailability (NRC, 2011). The results of a similar study were reported by Debnath et al. (2005), Hussain et al. (2017), Salem et al. (2022), Shapawi et al. (2013), and von Danwitz et al. (2016), who reported that the addition of phytase enzymes to feed had a significant effect in the PER, FCR, EFU, ADCp, and RGR parameters but had no significant effect on SR.

The PER, FCR, EFU, ADCp, and RGR parameters of juvenile Sangkuriang catfish fed with phytase enzyme supplementation at 1,000 FTU/kg of feed were the highest compared to other treated feeds. The 1,000 FTU/kg feed of phytase enzyme is believed to be effective at hydrolyzing antinutrient factors (phytic acid) in feed (Cao et al., 2007). The highest PER, FCR, EFU, ADCp, and RGR values after 1,000 FTU/kg feed of phytase enzyme supplementation were also reported in striped bass (Papatryphon et al., 1999), rainbow trout (Vielma et al., 2000), Atlantic salmon (Sajjadi & Carter, 2004), *Sparus aurata* (Salem et al., 2022), and *Cirrhinus mrigala* (Hussain et al., 2017).

The results showed that the supplementation of phytase enzyme in the feed caused the FCR value to decrease. Phytase enzymes in the feed are believed to hydrolyze phytate, thereby breaking the complex bond between phytate and protein and minerals. It has a beneficial effect on converting trypsinogen to trypsin enzymes, which can break down protein into its constituent amino acids (Hussain et al., 2017). Thus, feed consumption efficiency is maximized, lowering the feed conversion ratio. Administration of phytase enzymes in feed can improve FCR, as it was reported in rainbow trout (Wang et al., 2009), *Labeo rohita* (Baruah et al., 2007), *Marsupenaeus japonicas* (Bulbul et al., 2015), *Cirrhinus mrigala* (Hussain et al., 2017), and *Oreochromis niloticus* (Shahzad et al., 2022).

All aquatic organisms require minerals for vital physiological and biochemical activities, as well as for the maintenance of normal life processes. Fish need both macro-minerals (phosphorus, calcium, magnesium, and potassium) and micro-minerals (cobalt, copper, iron, manganese, and zinc) (NRC, 2011). The results (Figures 1 and 2) demonstrated that supplementing Sangkuriang catfish juvenile feeding with phytase enzyme improved the macro- and micro-mineral content of the fish body. Adding phytase enzymes to the diet enhances the availability of phosphorus in freshwater fish, as was reported in *Cirrhinus mrigala* (Hussain et al., 2017), *Sparus aurata* (Salem et al., 2022), *Oreochromis niloticus* (Shahzad et al., 2022), *Carassius auratus* (Nie et al., 2017), and *Cyprinus carpio* (Shahzad et al., 2021).

In addition, Cian et al. (2019) reported that feeding Pacu fish (*Piaractus mesopotamicus*) with phytase enzyme supplementation increased the availability of minerals in the fish body (phosphorus [P], zinc [Zn], and iron [Fe]) due to a decrease in gastrointestinal phytic acid and an increase in mineral bioavailability compared to fish fed without supplementation. Supplementation of the phytase enzyme considerably enhanced the content of minerals (phosphorus [P], calcium [Ca], magnesium [Mg], and zinc [Zn]) in the spine of juvenile red sea bream (*Pagrus major*) (Laining et al., 2012). Different amounts of phytase enzyme supplementation affected the consumption of phosphorus, minerals, and protein in rainbow trout (*Oncorhynchus mykiss*) (Sugiura et al., 2001). In addition, adding phytase enzymes to the feed can improve the fish's ability to digest minerals. Cheng and Hardy (2003) showed that adding phytase enzyme to the diet of rainbow trout increased the digestibility of Mg, Mn, Zn, and P, with P being more digestible than the other minerals.

As indicated in Table 3, adding phytase enzyme to the feed affects the protein content of juvenile Sangkuriang catfish. It may be noticed that the feed supplemented with phytase enzyme has a larger protein content than feed without the addition. It may be owing to the phytase enzyme's ability to enhance protein availability by completely hydrolyzing the phytate-protein complex in the fish intestine and negating the negative effect of phytate on protein (Liebert & Portz, 2005). This study's rise in PER supported the increase in juvenile Sangkuriang catfish protein content. According to Tables 2 and 3, adding phytase enzyme to the feed of juvenile Sangkuriang catfish enhanced the protein content of the fish body and the PER. In addition, the results revealed that juvenile Sangkuriang catfish fed with phytase enzyme supplementation at a dose of 1,000 FTU/kg feed (treatment C) had the highest increase in protein digestibility, which would result in the highest increase in feed utilization efficiency.

The addition of phytase enzymes in feed could increase protein digestibility and the efficiency of feed utilization in several fish (Biswas et al., 2019), including *Ephinephelus fuscoguttatus* (Shapawi et al., 2013), *Marsupenaeus japonicas* (Bulbul et al., 2015), *Sparus aurata* (Salem et al., 2022), *Carassius auratus* (Nie et al., 2017), and *Labeo rohita* (Hussain et al., 2017). The body ash content of juvenile Sangkuriang catfish that was given phytase enzyme supplementation was higher than that without supplementation. Bulbul et al. (2015) stated that adding phytase enzymes in feed can increase the concentration of bone ash and phosphorus in the body of *Marsupenaeus japonicas*. Liebert and Portz (2005) also reported that the ash content on the scales and spine of *Oreochromis niloticus* increased significantly after being fed a diet containing the phytase enzyme.

CONCLUSION

Adding 1,000 FTU/kg of phytase enzyme (C) exhibited the highest PER, FCR, EFU, ADCp, and RGR value of Sangkuriang catfish juvenile compared to other treatments. All treatment groups (B-C) had the same SR value (100%) and had the highest crude protein and ash content compared to the A group. All group treatments also exhibited a higher phosphorus, calcium, potassium, magnesium, iron, zinc, manganese, copper, and cobalt. Therefore, phytase enzyme supplementation could improve protein digestibility, mineral digestibility, growth performance, and body chemical composition of Sangkuriang catfish juveniles.

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