



The effect of phytase enzyme on feed digestibility, mineral digestibility, and growth of striped catfish (*Pangasianodon hypophthalmus*) fingerlings

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Abstract. Phytic acid forms insoluble phytate complexes that bind proteins and phosphorus, reducing protein digestibility and feed efficiency, thereby limiting the optimal growth of striped catfish (*Pangasianodon hypophthalmus*). This study aimed to investigate the impact of dietary phytase supplementation on nutrient digestibility, mineral digestibility, and growth performance in striped catfish fingerlings. The experiment followed a completely randomized design (CRD) with five treatments and three replications. The treatments consisted of different dietary phytase supplementation levels: 0, 250, 500, 750, and 1000 FTU kg⁻¹ feed (A, B, C, D, and E, respectively). Test striped catfish fingerlings had an average initial weight of 16.37±0.35 g fish⁻¹. The observed parameters included nutrient digestibility, feed utilization efficiency (FUE), feed conversion ratio (FCR), protein efficiency ratio (PER), relative growth rate (RGR), survival rate (SR), and mineral digestibility. The results showed that dietary phytase supplementation significantly improved ($p < 0.05$) nutrient digestibility, FUE, FCR, PER, RGR, and mineral digestibility but had no significant effect ($p > 0.05$) on SR. The optimal phytase dosage was 750 FTU kg⁻¹ feed, yielding the highest values in feed digestibility, mineral digestibility, and growth performance. Throughout the study, water quality parameters remained within the acceptable range for striped catfish fingerling culture, as referenced in aquaculture standards.

Key Words: diet, fish, growth rate, nutrient absorption, supplementation.

Introduction. The striped catfish (*Pangasianodon hypophthalmus*) is a freshwater fish species characterized by rapid growth rates, ranking second only to Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) in aquaculture production (Phan et al 2009; Lakra & Singh 2010). It is highly adaptable to farming conditions, exhibits strong disease resistance, and tolerates environmental fluctuations (Rachmawati et al 2025). The success of striped catfish farming largely depends on the availability of high-quality feed, which traditionally relies on fishmeal as its primary source of animal protein. However, due to limited supply, the price of fishmeal has surged alongside the rapid expansion of global aquaculture (FAO 2018). Rising costs, increasing demand, and unstable fishmeal supplies have driven researchers to seek alternative protein sources to meet the growing needs of the aquaculture feed industry (Hussain et al 2011; Shapawi et al 2013).

Plant-based ingredients are promising protein and energy sources for developing cost-effective and environmentally friendly aquaculture feeds (Hussain et al 2017). Nevertheless, these materials often contain high levels of anti-nutritional factors, particularly phytic acid (Rao et al 2009). Phytic acid, the primary organic form of phosphorus in plants, is abundant in oilseeds, cereals, and legumes. Approximately 80% of the total phosphorus in plant ingredients exists as phytate, which is largely unavailable to agastric or monogastric fish (NRC 2011). Phytic acid chelates essential minerals e.g: Ca, Mg, Fe, Zn, Cu, Mn (Hussain et al 2022), reducing their bioavailability (Papatryphon et al 1999). It also forms insoluble protein-phytate complexes with divalent and trivalent cations, further limiting nutrient absorption. These complexes diminish protein

digestibility and feed efficiency, ultimately impairing fish growth (Cao et al 2007). One effective strategy to mitigate these issues is dietary phytase supplementation.

Phytase is widely recognized as an efficient and practical method to enhance mineral digestibility in monogastric or agastric fish, which lack endogenous phytase production and cannot hydrolyze phytic acid (Kemigabo et al 2018). By breaking down phytate, phytase liberates bound proteins and phosphorus, improving nutrient bioavailability (Cao et al 2007). Hydrolysis of phytic acid through phytase supplementation in plant-based ingredients can liberate protein and phosphorus from phytate complexes. Phytase supplementation enhances overall fish growth performance (Kemigabo et al 2018), increases mineral bioavailability, reduces feed costs, and supports sustainable aquaculture practices (Baruah et al 2007; Hussain et al 2022), improving protein digestibility and feed efficiency (Hussain et al 2020; Rachmawati et al 2023a). Many studies have evaluated phytase enzymes in feed that can improve protein digestibility, feed utilization efficiency, and growth of several fish species such as *Marsupenaeus japonicus* (Bulbul et al 2015), *Psetta maxima* (von Danwitz et al 2015), *Cirrhinus mrigala* (Naz et al 2023), *Sparus aurata* (Salem et al 2022), *Cyprinus carpio* (Rachmawati et al 2023b), *Labeo rohita* (Hussain et al 2016), *Oreochromis niloticus* (Rachmawati et al 2024). However, limited information exists on the effects of phytase enzymes on striped catfish fingerlings. This study aims to evaluate the impact of dietary phytase supplementation on nutrient digestibility, mineral digestibility, and growth performance in striped catfish fingerlings.

Material and Method

Test fish preparation and research design. This study was conducted on April-June 2025 at the Wet Laboratory of the Aquaculture Department, Faculty of Fisheries and Marine Science, Diponegoro University, Semarang, Central Java, Indonesia. The experiment employed a completely randomized design with five treatments and three replications. A total of 500 striped catfish fingerlings with an average initial weight of 16.37 ± 0.35 g fish⁻¹ were obtained from the Sido Makmur fish farmers group in Tambaksari village, Rowosari District, Kendal Regency. Before the experiment, the fish underwent a one-week acclimation period to adapt to the rearing conditions and experimental diet. During this period, the fish were fed a control diet (without phytase supplementation) at satiation three times daily (morning, noon, and evening). Healthy, uniformly sized fish showing active swimming behavior were selected for the experiment. Fish were fasted for 24 hours before trial commencement to clear their digestive systems. From 500 fish used in this study, 375 were used to monitor growth and feed utilization in each treatment (25 fish per treatment), while 125 were used to observe the digestibility of feed protein.

Preparation of test feed. The test feed used was artificial feed in the form of pellets containing 31% protein and isoenergetic 252 kcal g⁻¹ (Rachmawati et al 2023c) plus Cr₂O₃ at 1% as an indicator of protein digestibility (Watanabe 1995) and phytase enzyme according to the treatment. The treatment in this study was phytase enzyme supplementation in feed with different doses, namely: A (0 FTU kg⁻¹ feed), B (250 FTU kg⁻¹ feed), C (500 FTU kg⁻¹ feed), D (750 FTU kg⁻¹ feed) and E (1000 FTU kg⁻¹ feed). The phytase enzyme used in this study was Nathupos*E 10000 G brand produced by BASF SE, Ludwigshafen, Germany, which is a phytase enzyme that has higher enzyme activity, is more resistant to acidic pH, and temperatures up to 95°C (Bavaresco et al 2020). The test feed formulation is presented in Table 1.

Table 1
Formulation of test feed used in the study (1000 g) and proximate analysis results

Ingredients (g)	Test feed				
	A	B	C	D	E
Fish meal	345.00	345.00	345.00	345.00	345.00
Soybean meal	240.00	240.00	240.00	240.00	240.00
Corn flour	150.00	150.00	150.00	150.00	150.00
Bran	145.00	145.00	145.00	145.00	145.00
Tapioca flour	80.00	80.00	80.00	80.00	80.00
Fish oil	10.00	10.00	10.00	10.00	10.00
Corn oil	10.00	10.00	10.00	10.00	10.00
Mineral vitamin mix ¹	10.00	10.00	10.00	10.00	10.00
Cr ₂ O ₃	10.00	10.00	10.00	10.00	10.00
Total	1.000	1.000	1.000	1.000	1.000
Phytase levels (FTU kg ⁻¹ diet)	0	250	500	750	1000
<i>Proximate composition</i>					
Dry matter*	980.0	980.0	980.0	980.0	980.0
Crude protein*	311.15	311.8	311.0	311.2	311.0
Ether extract*	88.7	88.5	88.9	88.6	88.7
Carbohydrate*	202.0	202.3	202.2	202.1	202.0
Ash*	74.4	74.5	74.4	74.3	74.4
Crude fiber*	120.3	120.2	120.4	120.4	120.2
Analysed phytase (FTU kg ⁻¹ diet)*	79.8	238	475	746	998
Energy (kcal) ²	2623.4	2628.2	2628.6	2629.8	2629.9
Ratio of energy/protein (E/P) (cal g ⁻¹) ³	8.43	8.43	8.45	8.45	8.45

Notes: ¹ Vitamin and mineral mix kg⁻¹: Vit. B6 46 mg, potassium (K) 150 mg, calcium (Ca) 219 mg, copper (Cu) 9 mg, iron (Fe) 90 mg, Vit. C (coated) 68,800 mg activity, selenium (Se) 150 mg, Vit. B1 52 mg, magnesium (Mg) 1.900 mg, Vit. B2 97 mg, Vit. A 36,000 I.U., Vit. D3 9,000 I.U., manganese (Mn) 105 mg, zinc (Zn) 90 mg, iodine (I) 1.8 mg, cobalt (Co) 450 mg, Vit. B12 60 mg, sodium (Na) 117 mg, pantothenic acid 93 mg, inositol 225 mg, biotin 450 mg, Vit. E 187 mg, Vit. K3 19 mg, niacin 130 mg, folic acid 10 mg; ² Calculated based on digestible energy according to NRC (2011): 1 g protein = 3.5 kcal g⁻¹, 1 g fat = 8.1 kcal g⁻¹, and 1 g carbohydrate = 2.5 kcal g⁻¹; ³ According to NRC (2011) the E/P value for optimal growth of fish ranges from 8 to 12 kcal g⁻¹; *Proximate analysis results of Animal Food Science Laboratory, Faculty of Animal Husbandry and Agriculture, Diponegoro University (2025).

Research container. Fifteen 1 m³ fiberglass tanks (water depth maintained at 80 cm) equipped with a recirculating system were used to maintain optimal water quality parameters. Fish were stocked at a density of 25 fish tank⁻¹. The experimental diets were administered at satiation three times daily (06:00, 12:00, and 18:00) for 56 days. Weekly sampling was conducted to monitor weight gain using a digital balance (YATT I-2000). Daily maintenance included siphoning out 10% of the water to remove uneaten feed and fecal matter (Rachmawati et al 2023c).

Feed digestibility determination. Feed digestibility (protein, energy, and total digestibility) for the five experimental diets was determined indirectly using 1% Cr₂O₃ as an inert marker. Five additional fiberglass tanks with flow-through water systems and aeration were used for digestibility trials, stocked with 20 fish tank⁻¹ (average weight 16.37±0.35 g fish⁻¹). Following a one-week adaptation period to the experimental diets, feces were collected immediately after excretion using pipettes or siphons. Collected feces were oven-dried at 70°C and stored frozen until analysis. Chromium concentrations in feed and feces were analyzed following the procedure described by Takeuchi (1988).

Mineral digestibility analysis. The apparent digestibility coefficients of minerals (Ca, P, Mg, Na, K, Fe, Cu, Zn, and Mn) were determined indirectly using Cr₂O₃ (1% inclusion) as an inert marker. Following the 56-day feeding trial, feed and fecal samples were collected for analysis. Chromium concentration was quantified using a UV-VIS 2001 spectrophotometer (CITEX SP-DUV560 China) (absorption wavelength: 370 nm) after

oxidation with molybdate reagent (Divakaran et al 2002). The mineral digestibility coefficient of the test feed was calculated using the NRC (2011) method.

Water quality parameters. The water quality parameters (temperature, dissolved oxygen, and pH) refer to the APHA (1992) method.

Research parameters observed. Research parameters observed included feed digestibility (apparent digestibility coefficient / ADC) referring to Takeuchi (1988), feed utilization efficiency (EFU), feed conversion ratio (FCR), protein efficiency ratio (PER), relative growth rate (RGR), survival rate (SR) referring to NRC (2011), proximate test feed and test fish carcass referring to AOAC (2005) method, mineral digestibility referring to NRC (2011), each calculated based on the following formulae:

$$\text{ADC (\%)} = 100 - \left\{ 100 \times \frac{\text{Cr}_2\text{O}_3 \text{ in the feed}}{\% \text{ Cr}_2\text{O}_3 \text{ in the feces}} \times \frac{\% \text{ nutrient in the feces}}{\% \text{ nutrient in the feed}} \right\}$$

$$\text{EFU (\%)} = \frac{\text{final weight (g)} - \text{initial weight (g)}}{\text{the weight of feed consumed (g)}} \times 100$$

$$\text{FCR} = \frac{\text{feed intake (g)}}{\text{body weight gain (g)}}$$

$$\text{PER} = 100 \times \frac{\text{final weight (g)} - \text{initial weight (g)}}{\text{the amount of diet consumed (g)} \times \text{protein content of diet (\%)}}$$

$$\text{RGR (\% day}^{-1}\text{)} = 100 \times \frac{\text{final weight (g)} - \text{initial weight (g)}}{(\text{times of experiment (day)} \times \text{initial weight (g)})}$$

$$\text{SR (\%)} = 100 \times \frac{\text{final count}}{\text{initial count}}$$

Statistical analysis. Data on parameter observations were analyzed using variance analysis (ANOVA) to determine the effect of treatment. If the ANOVA results had a significant effect ($p < 0.05$) or a very significant effect ($p < 0.01$), Duncan's multiple area test was conducted to determine the difference in the mean values between treatments to determine the best treatment (Steel et al 1997).

Results. Feed digestibility (protein digestibility, energy digestibility, and total digestibility) increased significantly ($p < 0.05$) with different doses of phytase enzyme supplementation in the test feed (Table 2). Test diets with phytase enzyme supplementation (test diets B, C, D, and E) had higher values of protein digestibility, energy digestibility, and total digestibility compared to those without phytase enzyme. The test feed with phytase enzyme supplementation of 750 FTU kg^{-1} feed (test feed D) had the highest value of protein digestibility, energy digestibility, and total digestibility compared to other treatment feeds.

Table 2
Protein digestibility, energy digestibility, and total digestibility values of the test feed with different doses of phytase enzyme supplementation

Parameter (%)	Test feed				
	A	B	C	D	E
Protein digestibility	68.52±0.21 ^e	75.17±0.22 ^d	78.65±0.15 ^b	88.22±0.01 ^a	82.42±0.01 ^b
Energy digestibility	52.37±0.22 ^e	57.18±0.21 ^d	62.46±0.20 ^c	72.64±0.16 ^a	68.82±0.15 ^b
Total digestibility	60.42±0.25 ^e	68.29±0.16 ^d	73.02±0.12 ^c	80.58±0.21 ^a	75.24±0.14 ^b

Note: Means in the same column with different superscripts indicate significant differences ($p < 0.05$).

The results in Table 3 show that striped catfish fingerlings fed with test feeds with phytase enzyme supplementation (test feeds B, C, D and E) have higher growth performance (RGR) and feed efficiency (EFU, PER, and FCR) compared to those without phytase enzyme. Supplementation of phytase enzyme in feed did not significantly ($p > 0.05$) affect the survival of striped catfish fingerlings. The striped catfish fingerlings fed feed with the addition of phytase enzyme 750 FTU kg^{-1} feed (test feed D) have the

highest PER, EFU, RGR values and the lowest FCR value compared to other feed treatments.

Table 3

Average values of initial fish weight, final fish weight, weight gain (WG), feed utilization efficiency (EFU), protein efficiency ratio (PER), feed conversion ratio (FCR), relative growth rate (RGR), and survival rate (SR) of catfish fed test feed with different doses of phytase enzyme supplementation

Parameters	Test feed				
	A	B	C	D	E
Initial body weight (g)	16.34±0.36	16.38±0.34	16.40±0.36	16.34±0.35	16.38±0.34
Final bodyweight (g)	69.02±0.28 ^e	82.19±0.22 ^d	90.36±0.22 ^c	110.70±0.22 ^a	97.36±0.20 ^b
WG (g fish ⁻¹)	52.68±0.24 ^e	65.81±0.23 ^d	73.96±0.24 ^c	94.36±0.24 ^a	80.98±0.22 ^b
EFU (%)	56.27±0.22 ^e	64.52±0.19 ^d	71.32±0.16 ^c	84.72±0.23 ^a	78.65±0.14 ^b
PER	1.56±0.20 ^e	2.24±0.18 ^d	2.79±0.21 ^c	3.92±0.14 ^a	3.35±0.12 ^b
FCR	1.94±0.10 ^e	1.68±0.16 ^d	1.45±0.14 ^c	1.02±0.12 ^a	1.22±0.13 ^b
RGR (% day ⁻¹)	2.24±0.15 ^e	2.89±0.12 ^d	3.42±0.10 ^c	4.37±0.11 ^a	3.94±0.13 ^b
SR (%)	100±0.0 ^a	100±0.0 ^a	100±0.0 ^a	100±0.0 ^a	100±0.0 ^a

Notes: Means in the same column with different superscripts indicate significant differences (p < 0.05).

The mineral digestibility composition of striped catfish fingerlings feces presented in Table 4 shows that phytase enzyme supplementation plays a very important role in improving mineral digestibility and the minimum amount of minerals excreted at the level of 750 FTU kg⁻¹ feed which indicates that at this level more minerals are available to striped catfish fingerlings compared to other test diets.

Table 4

Fecal mineral digestibility composition of striped catfish fingerlings fed feed with different doses of phytase enzyme supplementation

Parameter (%)	Test feed				
	A	B	C	D	E
Ca	0.145±0.02 ^e	0.135±0.01 ^d	0.130±0.01 ^c	0.080±0.01 ^a	0.100±0.02 ^b
P	1.71±0.02 ^e	1.52±0.02 ^d	1.36±0.02 ^c	0.85±0.01 ^a	1.16±0.01 ^b
Mg	0.063±0.01 ^e	0.054±0.01 ^d	0.042±0.01 ^c	0.029±0.01 ^a	0.039±0.01 ^b
Na	0.56±0.01 ^e	0.45±0.01 ^d	0.43±0.01 ^c	0.29±0.01 ^a	0.38±0.01 ^b
K	0.62±0.02 ^e	0.59±0.01 ^d	0.49±0.01 ^c	0.30±0.01 ^a	0.40±0.01 ^b
Fe	0.562±0.01 ^e	0.049±0.01 ^d	0.043±0.01 ^c	0.028±0.01 ^a	0.034±0.01 ^b
Cu	0.053±0.01 ^e	0.042±0.01 ^d	0.036±0.01 ^c	0.014±0.01 ^a	0.028±0.01 ^b
Zn	0.062±0.01 ^e	0.053±0.01 ^d	0.044±0.01 ^c	0.028±0.01 ^a	0.036±0.01 ^b
Mn	0.055±0.01 ^e	0.043±0.01 ^d	0.036±0.01 ^c	0.018±0.01 ^a	0.028±0.01 ^b

Notes: Means in the same column with different superscripts indicate significant differences (p < 0.05).

The results of the measurement of water quality parameters during the study (Table 5), show that the value of water quality parameters during the study after being compared with the value of water quality parameters according to the reference is still in a feasible condition suitable to be used as a medium for cultivating striped catfish fingerlings.

Table 5

Fecal mineral digestibility composition of striped catfish fingerlings fed feed with different doses of phytase enzyme supplementation

Parameter (%)	Test feed					References
	A	B	C	D	E	
Temperature (°C)	27-30	27-30	28-30	27-30	28-29	25-30°C*
pH	6.8-7.8	6.7-7.5	6.8-8.0	6.9-8.1	6.7-7.8	6.5-8.6*
Dissolved oxygen (mg L ⁻¹)	5.4-7.5	6.2-7.3	5.8-7.5	5.8-7.5	5.6-7.7	> 3*

Notes: *Boyd (2003).

Discussion. Feed digestibility (protein digestibility, energy digestibility, and total feed digestibility) increased with the addition of phytase enzyme. This is because phytic acid in the feed has been hydrolyzed by the phytase enzyme so that the protein in the phytate complex compound is freed. Phytase enzyme supplementation in feed can increase protein digestibility (Hussain et al 2020). This result follows the statement of Baruah et al (2007) which stated that the addition of 750 FTU kg⁻¹ feed can increase the value of protein digestibility, energy digestibility and total feed digestibility in *L. rohita*. Orisasona et al (2017) stated that the addition of 750 FTU kg⁻¹ feed can increase the value of protein digestibility, energy digestibility and total feed digestibility in *Clarias gariepinus*.

The addition of phytase enzymes in feed can increase phytic acid hydrolysis so that nutrients bound by phytic acid can be absorbed by the intestinal system and increase protein digestibility (Salem et al 2022). Cao et al (2007) stated that phytic acid breakdown can increase nutrient absorption because the hydrolysis reaction by the phytase enzyme can reduce phytic acid and release protein and mineral bonds. Adeoye et al (2016) stated that the addition of phytase helps hydrolyze phytate, thereby improving nutrient digestion in fish. Wang et al (2009) suggested that breaking the complex bonds of protein phytate can increase the activity of trypsinogen and trypsin enzymes that break down proteins into amino acids. An increase in protein digestibility means an increase in amino acid digestibility. The increase in total feed digestibility value indicates that with the addition of phytase enzyme, the digestibility of nutrients as energy sources (fat and carbohydrates) also increases (Kumar et al 2012). This is evidenced by the results of this study that the increasing digestibility of feed increased with the addition of phytase enzyme in feed.

The results of this study indicate that supplementation of phytase enzyme in feed can improve growth performance (RGR) and feed efficiency (EFU, PER, FCR) of striped catfish fingerlings. The value of growth performance and feed efficiency obtained by striped catfish fingerlings fed with phytase enzyme supplementation (250, 500, 750 and 1000 FTU kg⁻¹ feed) was higher than without phytase enzyme (0 FTU kg⁻¹ feed). Phytase enzyme supplementation in feed resulted in increased phosphorus utilization and bioavailability of nutrients by fish (Kemigabo et al 2018). Phytase enzyme supplementation in feed can improve protein digestibility, feed utilization efficiency and fish growth (Chen et al 2018; Naz et al 2023; Rachmawati et al 2023a). The improvement in growth performance and feed efficiency was significant with increasing phytase enzyme up to a dose of 750 FTU kg⁻¹ diet, after which it decreased. This indicates that the test diet with phytase enzyme supplementation dose of 750 FTU kg⁻¹ is the best dose suitable for increasing the bioavailability of nutrients for striped catfish fingerlings growth. This statement is in accordance with the opinion of Cao et al (2007) who stated that the addition of phytase enzyme in fish feed is in the range of 750-1000 FTU kg⁻¹ feed. However, it has been observed that higher doses can inhibit fish growth and may result in competitive inhibition of essential minerals such as magnesium (Mg), zinc (Zn), iron (Fe), and cations during the assimilation process (Xu et al 2021). The best dosage of phytase enzyme in feed may vary depending on the specific fish species, different sources and products, feed formulation (especially substrate), and other response parameters (Naz et al 2023). The results of this study are similar to the results reported by Nie et al (2017), Hussain et al (2020), Shahzad et al (2021), and Rachmawati et al (2023a, b). Several previous studies have reported different phytase enzyme doses for various fish species, such as 750 FTU kg⁻¹ feed for *L. rohita* (Hussain et al 2016) and *C. mrigala* (Naz et al 2023); 1000 FTU kg⁻¹ for *C. carpio* (Rachmawati et al 2023b), and *Morone saxatilis* (Papatryphon et al 1999). The survival rate of striped catfish fingerlings in our study was found to be 100%, which is consistent with the findings of previous studies conducted by Adeoye et al (2016), Maas et al (2021), and Rachmawati et al (2023a, b; 2024).

Phytase enzyme supplementation in feed can reduce the phytate content of plant-based diets, improving mineral bioavailability for striped catfish fingerlings. As shown in Table 4, mineral digestibility values increased with phytase supplementation, as a result of which fish excreted less minerals through feces into the aquatic environment. The amount of minerals excreted through the feces of fish fed the test diet with phytase

enzyme supplementation was higher than fish fed the test diet without phytase enzyme supplementation. This decrease in mineral excretion with phytase supplementation in this study attests to the fact that mineral digestibility increases with phytase supplementation. Similar research results were reported by Nwanna & Schwarz (2007), that most of the action of phytase is focused on phytate degradation, resulting in the release of more minerals, thereby increasing mineral digestibility. The results of this study showed that the maximum mineral digestibility was obtained by striped catfish fingerlings fed with phytase enzyme supplementation at a dose of 750 FTU kg⁻¹ feed, this is supported by the opinion of Hussain et al (2011) which stated that the maximum mineral digestibility of phytase supplementation in feed was at a dose of 750 FTU kg⁻¹ feed. Phytase supplementation in feed is likely to break down phytic acid that will free more mineral chelates so that mineral utilization increases (Kumar et al 2012; Orisasona et al 2017; Qiu & Davis 2017). Similar research results were reported by Hussain et al (2016) on *L. rohita*, Orisasona et al (2017) on *C. gariepinus*, and Rachmawati et al (2023b) on *C. carpio*.

Mineral digestibility of striped catfish fingerlings fed without phytase enzyme supplementation (0 FTU kg⁻¹ feed) was lower than that of test fish fed with phytase enzyme supplementation. When the digestibility of phosphorus (P) was increased, the digestibility of minerals such as Ca, Mg, Na, K, Fe, Cu, Zn, and Mn also increased. The positive role of phytase enzyme in the liberation of phosphorus and other minerals for different fish species has been reported by Kumar et al (2012), Hussain et al (2016), Orisasona et al (2017), and Rachmawati et al (2023b). Adeshina et al (2023) stated that phytase enzyme supplementation in feed can reduce phosphorus excretion into the aquatic environment. Nwanna & Schwarz (2007) suggested that higher phosphorus digestibility resulted in reduced phosphorus excretion in all fish groups fed with phytase enzyme supplementation compared to fish fed without phytase enzyme supplementation. Phytase supplementation in feed is very useful in developing environmentally friendly fish feed by increasing nutrient digestibility and reducing nutrient excretion into the aquatic environment, and is expected to help reduce water pollution (Hussain et al 2016; Orisasona et al 2017; Rachmawati et al 2023b).

Table 5 showed that the values of water quality parameters during the study after being compared with the values of water quality parameters according to the references were still in a feasible condition suitable to be used as a medium for cultivating striped catfish fingerlings. This had an effect on the survival of striped catfish fingerlings during the study which was 100%.

Conclusions. This study provides the evidence that feed with phytase enzyme supplementation can improve nutrient digestibility, feed digestibility, and growth of striped catfish fingerlings. Phytase enzyme supplementation of 750 FTU kg⁻¹ feed is the best dose that produces the highest value of nutrient digestibility, feed digestibility, and growth of catfish compared to other doses of phytase enzyme. Phytase enzyme supplementation in feed can hydrolyze phytic acid, therefore further research is needed on phytase enzyme supplementation in feed in other fish species.

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Conflict of interest. The authors declare that there is no conflict of interest.

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