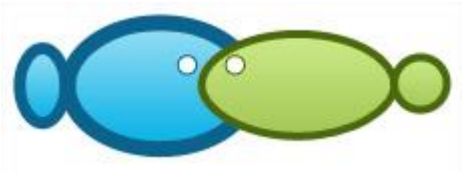

The effect of the probiotic *Saccharomyces cerevisiae* on feed efficiency, growth, digestive enzyme activity, and biochemical composition of striped catfish (*Pangasianodon hypophthalmus*)

[1]Diana Rachmawati, [2]Putut H. Riyadi, [1]Seto Windarto

[1] Department of Aquaculture, Faculty of Fisheries and Marine Sciences, University of Diponegoro, Semarang, , Central Java, Indonesia; [2] Department of Fishery Products Technology, Faculty of Fisheries and Marine Sciences, University of Diponegoro, Semarang, Central Java, Indonesia. Corresponding author: D. Rachmawati, dianarachmawati1964@gmail.com

Abstract. This study examined the effects of adding the probiotic *Saccharomyces cerevisiae* to feed on feed efficiency, growth performance, digestive enzyme activity, and body biochemical composition of striped catfish (*Pangasianodon hypophthalmus*). The test fish were striped catfish with an initial average weight of 20.36±0.22 g fish^{-1}. The test feed was a formulated pellet diet with *S. cerevisiae* probiotics added at different doses: T1, T2, T3, T4, and T5 (0, 1, 2, 3, and 4 g kg^{-1} feed, respectively). The test feed was administered using the *ad satiation* method thrice daily for 56 days. The results showed that adding *S. cerevisiae* probiotics to the feed significantly increased the feed efficiency, growth performance, digestive enzyme activity, and biochemical composition of striped catfish. Both feed efficiency and growth performance variables in striped catfish increased with increasing doses of *S. cerevisiae* probiotics. The same trend was observed for the digestive enzyme activity and biochemical composition of striped catfish. An additional 4 g kg^{-1} feed of probiotic *S. cerevisiae* was identified as the best dose for improving the productivity of striped catfish (*P. hypophthalmus*).
Keywords: aquaculture, ingredient, nutrient utilization, test fish.

Introduction. The success of striped catfish (*Pangasianodon hypophthalmus* (Sauvage, 1878)) farming is highly dependent on the availability of high-quality feed. Quality feed is a primary requirement for successful aquaculture. However, feed quality, palatability, and utilization have a significant impact on water quality, production, disease, and ultimately, the profitability and sustainability of the aquaculture industry (Daniel, 2018; Guo et al., 2020; Kong et al., 2020). The problem currently faced by fish farmers is the continuous rise in fish feed prices, resulting in feed costs accounting for approximately 60-70% of the total production costs per farming cycle (Pati et al., 2016; Dawood, 2021). The high cost of feed is due to suboptimal feed efficiency, which is caused by the presence of anti-nutritional factors in plant-based ingredients such as soybean meal, which is used as a plant protein source in fish feed. Antinutritional factors in soybean meal, such as protease inhibitors, soy agglutinin, and oligosaccharides, negatively affect protein digestibility and feed efficiency (El-Mokhlesany et al., 2023), growth and intestinal health (Bai et al., 2022), fish immunity (Buttle et al., 2001), and digestive enzyme activity (Dan et al., 2022). In this situation, probiotic supplementation through feed can be a nutritional approach that enhances aquaculture production by optimizing nutrient utilization and reducing production costs, thereby ensuring sustainability and profitability of the sector (Ramos et al., 2022).

Probiotics in aquaculture contribute to preventing pathogenic bacterial diseases and enhancing the proper utilization of nutrients by increasing digestive enzyme activity to ensure nutrient availability, improve water quality, and develop immune status and adaptability under adverse conditions in cultured fish species (Ibrahem, 2015; Banerjee

& Ray, 2017). Probiotics incorporated into feed can improve the growth, gut environment, and welfare of aquatic species (Ramos et al., 2017). One probiotic used in aquaculture is *Saccharomyces cerevisiae* (Nayak, 2010), which is one of the most commonly used probiotics in aquaculture feeds. It can improve feed utilization efficiency and increase fish production (Abdel-Tawwab et al., 2008), enhance growth, immunity, and disease resistance in various fish species (Hassaan et al., 2015), and improve feed utilization (Dawood et al., 2019). The addition of *S. cerevisiae* to feed can effectively reduce the need for animal protein sources (Sutthi et al., 2020).

S. cerevisiae contains substantial protein (approximately 40-55%) and a variety of bioactive components with potential as functional ingredients, such as α-glucan, β-glucan, α-mannan oligosaccharides, nucleic acids, and antioxidants, which can enhance fish growth performance, gut health, and immunity (Ayiku et al., 2020; Vidakovic et al., 2020). It contains essential amino acids, such as lysine and sulfur-containing amino acids, provides several important vitamins, such as B vitamins and folic acid (Huyben et al., 2018), and contains unsaturated fatty acids and linoleic and alpha-linolenic acids, which can also be synthesized by fatty acid desaturases (Vidakovic et al., 2020). It can also increase feed protein digestibility, impacting feed utilization efficiency and fish growth (Huyben et al., 2017), and produces several enzymes that can enhance nutrient digestion and significantly increase fish growth (Tewary & Patra, 2011). It also has an amino acid profile similar to that of fish (Rachmawati et al., 2022).

The addition of *S. cerevisiae* as a probiotic in feed has been widely proven to improve protein digestibility, feed utilization efficiency, growth, and disease resistance in several fish species, such as *Mystus cavasius* (Banu et al., 2020), *Oncorhynchus mykiss* (Adel et al., 2017), *Epinephelus coioides* (Chiu et al., 2010), *Oreochromis niloticus* (Opiyo et al., 2019), *Cyprinus carpio* (Sivani et al., 2016), *Clarias gariepinus* (El-Feky et al., 2017), and *Apostichopus japonicus* (Ma et al., 2019). This study aimed to examine the effect of adding *S. cerevisiae* probiotics to the feed on feed efficiency, growth performance, digestive enzyme activity, and biochemical body composition of striped catfish (*P. hypophthalmus*).

Material and Method

Preparation of test fish. The test fish used were striped catfish with an average weight of 20.36±0.22 g fish^{-1}, totaling 750 fish, which were obtained from the Sawangan Freshwater Fish Seed Center, Magelang, Central Java, Indonesia. The fish were acclimated to the environment and fed for one week, during which they were fed commercial fish feed that did not contain the probiotic *S. cerevisiae*. Next, the test fish were selected based on uniform weight and size, active swimming behavior, no deformities, and healthy conditions (Rachmawati et al., 2023). After acclimation, the test fish with known initial average body weights were randomly placed in the research tanks. The research tanks were fiber tanks measuring 1 × 1 × 1 m^3 with a water volume of 300 liters and were equipped with a recirculation system. A total of 15 fiber tanks were used, each loaded with 50 test fish at a stocking density of 1 fish/6 liters, and then, 3 fiber tanks served as replicates for each treatment.

Research design and preparation of test feed. This study was conducted for 56 days from May to July 2026, at the Wet Laboratory of the Sawangan Freshwater Fish Hatchery, Magelang, Central Java, Indonesia. The research employed an experimental method, using a completely randomized design (CRD) with five different probiotic dosage treatments in the feed, each with three replicates. The test feed consisted of a formulated feed with 31% protein content (Rachmawati et al., 2025) with the addition of the probiotic *S. cerevisiae* according to treatment, namely T1 (0 g kg^{-1} feed), T2 (1 g kg^{-1} feed), T3 (2 g kg^{-1} feed), T4 (3 g kg^{-1} feed), and T5 (4 g kg^{-1} feed). The *S. cerevisiae* used was Ragi Beta Glucan Powder (Avena Sativa L, Bioway, China) at a concentration of 10^{10} CFU g^{-1}. Before mixing with the feed ingredients, *S. cerevisiae* was activated by adding 1% liquid molasses and warm water at 15°C, as described by Zhang et al., (2022). The process of preparing the test feed began with the proximate analysis of the

feed ingredients and formulation of the test feed (Table 1), followed by weighing the raw materials according to the feed formulation and mixing the feed components from the smallest to largest quantity. The mixture was stirred evenly using a mixer until the test feed dough became homogeneous. In the final stage, fish oil, corn oil, and water (200 mL kg^{-1} feed) were added to the feed dough and mixed until it was homogeneous. After the test feed dough became homogeneous, the dough was molded into floating fish feed using an extruder (LX-75, China) with a 2 mm diameter. After extrusion, the test feed was dried at room temperature (approximately 26°C), packed in airtight plastic containers, and stored until use.

Table 1

Composition of test feed ingredients and proximate analysis results

Feed ingredients (g)	*Test feed*				
	T1	*T2*	*T3*	*T4*	*T5*
Fish meal	340	340	340	340	340
Soybean meal	340	340	340	340	340
Ground yellow corn	70	70	70	70	70
Bran	50	49	48	47	46
Wheat flour	100	100	100	100	100
Tapioca flour	40	40	40	40	40
Fish oil	20	20	20	20	20
Vegetable oil	20	20	20	20	20
Vit Min Mix[1)]	10	10	10	10	10
Cr_2O_3	10	10	10	10	10
Probiotic *S. cerevisiae*	0	1	2	3	4
Total	1000	1000	1000	1000	1000
Proximate analysis (%)					
Dry matter*	14.13	14.20	14.22	14.28	14.29
Crude protein*	31.0	31.2	31.2	31.0	31.1
Crude fat*	7.45	7.38	7.40	7.37	7.30
Ash*	8.46	8.30	8.25	8.27	8.30
Fiber*	5.20	4.88	4.37	4.53	4.63
NFE[2)]	26.48	26.37	26.46	26.39	26.40
GE (MJ/Kg)[3)]	18.64	18.70	18.68	18.79	18.80

Notes : [1)] Vitamin and mineral mixture each 1 kg of the mixture contains 2400 IU cholecalciferol (Vitamin D), 40 g of Vitamin E, 8 g of Vitamin K, 4.0 g of Vitamin B12, 4.0 g of Vitamin B2, 6 mg pyridoxine HCl; 7.2 mg riboflavin; 1.2 mg thiamine HCl; 3077 mg sodium chloride (NaCl, 39% Na, 61% Cl); 6 g Vitamin B6, 4.0 g pantothenic acid, 4800 IU Vitamin A, 8.0 g nicotinic acid, 400 mg folic acid, 20 mg biotin, 26 mg D-calcium pantothenate; 65 mg ferrous sulphate ($FeSO_4$. $7H_2O$, 20% Fe), 89 mg manganese sulfate ($MnSO_4$, 36% Mn), and 150 mg zinc sulfate ($ZnSO_4$. $7H_2O$, 40% Zn), 200 g choline, 4 g copper, 1.2 mg folic acid, 12 mg niacin, 28 mg copper sulphate ($CuSO_4$. $5H_2O$, 25% Cu), 11 mg potassium iodide (KI, 24% K, 76% I), 0.4 g iodine, 12 g iron, 22 g manganese, 22 g zinc, 0.04 g selenium, and 1000 mg Celite AW521 (acid-washed diatomaceous earth silica). w% on a dry matter (DM) basis. [*)]Proximate analysis results of the Laboratory of Nutrition and Feed Science, Faculty of Animal and Agricultural Sciences, Diponegoro University, (2026). [2)] Nitrogen-Free Extract (calculated by difference) = 100 – (protein + lipid + ash + fiber). [3)] Gross energy was calculated using the following factors: protein, 23 MJ kg^{-1}; lipid, 35 MJ kg^{-1}; and carbohydrates, 15 MJ kg^{-1} (Molina-Poveda et al., 2013).

Proximate composition of test fish. The proximate composition of fish from each treatment was determined according to the procedures described by the AOAC, (2005). Protein content was measured via nitrogen estimation (N × 6.25) using the Kjeldahl method. Total lipids were measured via ether extraction with a Soxhlet apparatus. To determine the fish moisture content, the samples were dried at 105°C. The ash content was determined by dry ashing in a porcelain crucible in a muffle furnace at 550°C for 5 h.

Digestive enzyme activity analysis. Protease enzyme activity was analyzed using the method of Bradford, (1976), as described below. The procedure involves preparing protein standard solutions (typically Bovine Serum Albumin/BSA) at various concentrations, followed by the addition of Bradford reagent to both the enzyme extract samples and the standard solutions. The mixtures were incubated at room temperature for 10-60 min to allow full color development, after which the absorbance was measured

at λ = 595 nm. The protein content of the samples was calculated using a linear regression equation (y = ax + b) derived from a standard curve. Finally, protease activity was determined by incorporating the protein content obtained using the Bradford method into the specific activity formula, as follows:

$$\text{Specific activity} = \frac{\text{Enzyme activity (unit mL}^{-1})}{\text{Protein content (mg mL}^{-1})}$$

Amylase activity was determined using the method described by Rick & Stegbauer, (1974). The substrate, in the form of a starch solution with varying concentrations of 10 mg mL^{-1} and 20 mg mL^{-1}, 5 mL each, was dissolved in 5 mL of phosphate buffer. Then, 1 mL of α-amylase Liquozyme supra enzyme was added to the 7 mL mixture. The solution was then incubated at 37°C for 30 min. The reaction was stopped by adding 1 mL of 1 N HCl to the mixture. The remaining starch concentration in the solution was measured indirectly by measuring the absorbance of the solution mixed with 1 mL iodine solution. The iodine solution was prepared by dissolving 5 g of KI and 500 mg of I in 100 mL of water and diluting it 100-fold. The absorbance was measured at 620 nm using a UV-Vis spectrophotometer. The measured concentration was determined using the absorbance value obtained from the calibration curve. If the absorbance value was not detected on the calibration curve, the sample was diluted until the absorbance was detected on the calibration curve.

Lipase activity was measured according to Cherry & Crandell, (1932). The basic measurement procedure involves incubating a mixture of the lipase enzyme with the substrate (olive oil emulsion and buffer solution) at a specific temperature and pH (usually 37°C) for a defined period. Next, a reaction-stopping solution (a mixture of acetone and ethanol) was added to halt enzyme activity. The free fatty acids formed were then titrated using a standard base solution, such as (NaOH), with a phenolphthalein (pp) indicator until the titration endpoint was reached. One unit of lipase enzyme is generally defined as the amount of enzyme capable of releasing 1 µmol of free fatty acid per milliliter (or per gram) of the sample per minute.

Water quality analysis. The observed water quality parameters referring to Boyd & Tucker (2012). Water temperature (Water quality checker), DO (Jenway 970), and pH (Jenway 3510), were monitored daily in all the fiber tanks, whereas ammonia (HANNA: HI. 8633), was monitored at the beginning, middle, and end of the experiment. Siphoning was also performed daily, approximately 2 h after feeding, to remove feces and feed residues and maintain the quality of the aquaculture medium.

Growth, feed utilization and survival rate parameters. The study began with randomly placing the test fish, previously weighed for initial average body weight, into fiber tanks at a stocking density of one fish/6 L. Test feed was provided *ad satiation* with a feeding frequency of three times daily at 07.00, 13.00, and 18.00. To assess weight gain, the test fish were weighed weekly for 56-day study. The parameters observed included the feed conversion ratio (FCR), protein efficiency ratio (PER), relative growth rate (RGR), survival rate (SR), and apparent digestibility coefficient of protein utilization (ADCp), according to the NRC, (2011). The calculation formulas are as follows:

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

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

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

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

$$\text{ADCp (\%)} = 100 - \{100 \times Cr_2O_3 \text{ in the feed} / \%\ Cr_2O_3 \text{ in the feces} \times \%\ \text{protein in the feces} / \%\ \text{protein in the feed}\}$$

Statistical analysis. Before statistical analysis, all data were tested for normality (Shapiro–Wilk test) and homogeneity of variance (Levene's test) at a 5% significance level. One-way analysis of variance (ANOVA) was performed to determine the statistical significance ($p < 0.05$) of the differences in the measured parameters among the various dietary levels of *S. cerevisiae* probiotics. If the ANOVA results were significant ($p < 0.05$) or highly significant ($p < 0.01$), Duncan's multiple range test was conducted to compare mean values among treatments at ($p < 0.05$) to identify the best treatment (Steel et al., 1997). All statistical analyses were performed using SPSS (Standard Version 22.0, SPSS Inc., Chicago, Illinois).

Results. The addition of *S. cerevisiae* probiotics to the test diets (T2, T3, T4, and T5) significantly improved the growth performance and feed utilization efficiency of striped catfish compared with the diet without supplementation (T1). The detailed data are listed in Table 2. The growth performance parameters showed a significant increase ($p < 0.05$) in the RGR with increasing doses of *S. cerevisiae* in the diet, up to 4 g kg^{-1} feed. No significant differences were observed in the survival rates among the test diet treatments. The feed efficiency parameters (PER, and ADCp) and growth parameter (RGR) showed significant increases ($p < 0.05$) with the addition of *S. cerevisiae* probiotic to the feed, with the highest values observed in the group fed diets supplemented with *S. cerevisiae* probiotic at 4 g/kg (D). A significant decrease ($P < 0.05$) in feed conversion ratio (FCR) was observed with increasing doses of *S. cerevisiae* probiotics in the diet.

Table 2

Growth performance and feed utilization of striped catfish with the addition of *S. cerevisiae* probiotic in the diet during the study

Parameters	*Test feed*				
	T1	*T2*	*T3*	*T4*	*T5*
Initial weight (g)	20.36±0.24^{a}	20.36±0.22^{a}	20.38±0.24^{a}	20.36±0.22^{a}	20.38±0.26^{a}
Final weight (g)	47.64±0.14^{e}	56.60±0.10^{d}	69.90±0.12^{c}	76. 96±0.15^{b}	88.04±0.13^{a}
Weight gain (g)	27.28±0.19^{e}	36.24±0.16^{d}	49.52±0.16^{c}	56.60±0.18^{b}	67.66±0.19^{a}
Feed intake (g feed/fish)	204.64±0.15^{e}	223.12±0.18^{d}	260.48±0.32^{c}	285.24±0.23^{b}	310.53±0.48^{a}
FCR	1.75±0.12^{e}	1.68±0.12^{d}	1.62±0.13^{c}	1.50±0.12^{b}	1.32±0.10^{a}
PER	1.48±0.02^{e}	2.01±0.03^{b}	2.47±0.02^{c}	2.78±0.01^{b}	3.10±0.02^{a}
ADCp (%)	52.26±0.14^{e}	64.12±0.17^{d}	68.10±0.13^{c}	73.18±0.15^{b}	79.24±0.14^{a}
RGR (% day^{-1})	2.34±0.10^{e}	2.78±0.12^{d}	3.43±0.13^{c}	3.78±0.10^{b}	4.30±0.01^{a}
SR (%)	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}

Note: Means with the same letter in the same row are not significantly different at $p < 0.05$.

The results showed a significant difference ($p < 0.05$) in the intestinal amylase, protease, and lipase activities of striped catfish fed diets supplemented with the probiotic *S. cerevisiae*. Higher intestinal amylase, protease, and lipase activities were observed in striped catfish fed diets with 4 g kg^{-1} feed *of S. cerevisiae* probiotic than in the others. Table 3 shows the digestive enzyme activity of striped catfish fed diets with different *S. cerevisiae* probiotic doses.

Table 3

Digestive enzyme activity in striped catfish fed diets with different doses of *S. cerevisiae* probiotic

Digestive enzymes (U mg^{-1} protein)	*Test feed*				
	T1	*T2*	*T3*	*T4*	*T5*
Amylase	4.75±0.12^{e}	5.10±0.10^{d}	5.68±0.14^{c}	5.82±0.13^{b}	6.34±0.23^{a}
Protease	32.26±0.32^{e}	32.84±0.13^{d}	33.72±0.52^{c}	34.26±0.31^{b}	36.18±0.20^{a}
Lipase	33.14±0.18^{e}	33.62±0.14^{d}	33.89±0.16^{c}	34.13±0.10^{b}	34.62±0.11^{a}

Note: Means the same letter in the same row are not significantly different at $p < 0.05$.

The results showed that the addition of *S. cerevisiae probiotics* to the feed had a significant effect on the crude protein, crude lipid, and carbohydrate contents of striped catfish (Table 4). The highest crude protein value was recorded in T5 (14.98±0.20%), whereas the lowest value was recorded in T1 (13.68±0.25%). The highest crude lipid content was found in T5 (2.86±0.34%) and the lowest in T1 (2.14±0.22%). The highest carbohydrate content was observed in T5 (1.54±0.04%), and the lowest was in T1 (1.14±0.02%). The proximate composition of the striped catfish is shown in Table 4.

Table 4

The proximate composition of whole body (% dry matter basis) of striped catfish fed with probiotic *S. cerevisiae* in the diet during the study

Proximate composition (%)	*Test feed*				
	T1	*T2*	*T3*	*T4*	*T5*
Moisture	77.99±1.20^{a}	77.30±1.09^{a}	77.35±1.30^{a}	77.32±1.30^{a}	77.12±0.46^{a}
Crude protein	13.68±0.25^{e}	14.03±1.02^{d}	14.50±0.13^{c}	14.52±0.42^{b}	14.98±0.20^{a}
Crude lipid	2.14±0.22^{e}	2.50±0.56^{d}	2.61±0.27^{c}	2.60±0.24^{b}	2.86±0.34^{a}
Carbohydrate	1.14±0.22^{d}	1.26±0.04^{d}	1.34±0.02^{c}	1.42±0.04^{b}	1.54±0.04^{a}
Ash	5.64±2.15^{a}	5.64±1.23^{a}	5.62±0.56^{a}	5.62±0.60^{a}	5.63±0.26^{a}

Note: Means with the same letter in the same row are not significantly different at $p < 0.05$.

The results of the water quality parameter observations during the study are presented in Table 5. Measurements indicated that the values for temperature, pH, DO, and ammonia remained within a suitable range for striped catfish, based on the literature regarding optimal water quality conditions for the species.

Table 5

Results of water quality parameter measurements in the rearing media Java barb during the study

Water quality parameters	*Test feed*					*References*
	T1	*T2*	*T3*	*T4*	*T5*	
Temperature (°C)	25-30	26-29	26-30	25-29	26-30	25-30*
pH	6.5-8.0	6.5-7.6	6.5-7.5	6.5-8.0	6.5-7.5	6.5-8.6*
DO (mg L^{-1})	5.0-7.2	5.3-7.5	5.0-7.6	5.4-7.2	5.2-7.3	≥3*
Ammonia (mg L^{-1})	<0.0028	<0.0029	<0.0038	<0.0025	<0.0249	<0.01*

Note: * Boyd & Tucker, (2012).

Discussion. This study showed that increasing the dosage of *S. cerevisiae* as a probiotic in the feed improved feed efficiency and growth performance in striped catfish. This proves that *S. cerevisiae* as a probiotic plays a role in enhancing the feed efficiency and growth performance of striped catfish. The improvement in fish growth performance can be associated with the role of feed containing the probiotic *S. cerevisiae* in enhancing the digestion process and absorption of various nutrients by stimulating the secretion and activity of digestive enzymes involved in nutrient digestion (Dawood et al., 2019). *S. cerevisiae* can be effectively applied as a probiotic to enhance aquaculture production (Abdel-Tawwab et al., 2008; Chiu et al., 2010). The use of *S. cerevisiae* as a probiotic in the aquaculture feed industry continues to increase because of its capacity to boost the immune response (Li & Gatlin III, 2004) and potential impact on the host gut microbial community (Tovar et al., 2002). Several studies have shown that feed containing *S. cerevisiae* as a probiotic increases protein digestibility, growth, feed utilization efficiency, and the immune system of fish, as reported by El-Feky et al., (2017), Ma et al., (2019), Opiyo et al., (2019), and Banu et al., (2020).

The administration of test feed supplemented with the probiotic *S. cerevisiae* showed beneficial effects in terms of increased body weight of fish, RGR, and decreased FCR compared to the test feed without supplementation. Similarly, PER was significantly higher ($p < 0.05$) in fish fed *S. cerevisiae* probiotic-added feed than in those without the probiotic. Similar results have been reported for *Clarias gariepinus* (El-Feky et al., 2017), *Labeo rohita* (Saini et al., 2014), and *Sparus aurata* (Carnevali et al., 2004). Striped catfish fed the T2, T3, and T4 diets showed increased growth and feed utilization

efficiency compared with those fed the T1 diet. This increase in growth and feed utilization efficiency can be partially attributed to *S. cerevisiae*, which is rich in nutrients such as proteins, carbohydrates, nucleic acids, and vitamins and can serve as a nutritional enhancer for animals (Adel et al., 2017). Furthermore, the increase in feed intake in diets supplemented with *S. cerevisiae* probiotics (1-4 g kg^{-1} feed) is believed to be due to the increased appetite of fish, resulting in higher feed intake and improved growth. El-Bab et al., (2022) found that the addition of *S. cerevisiae* enhanced protein digestibility, which can explain the better growth and feed efficiency observed in the present study. *S. cerevisiae* added to feed can improve production, enhance growth, increase immunity, and improve feed efficiency in fish (Islam et al., 2021). A study on the growth performance of *Oreochromis mossambicus* treated with *S. cerevisiae* probiotics showed a significantly higher effect ($p < 0.05$) on specific growth rate and reduced FCR than that of fish fed without *S. cerevisiae probiotics* (Owatari et al., 2022).

Fish growth and performance are closely related to the function of digestive enzymes (Liu et al., 2022). The results of this study indicate that the addition of *S. cerevisiae* to the feed increases amylase, protease, and lipase at various doses of *S. cerevisiae* in the feed. Darafsh et al., (2020) reported that the addition of *S. cerevisiae* to fish feed can increase protease, lipase, and amylase enzymes, thereby enhancing the growth rate in fish. *S. cerevisiae* releases various digestive enzymes following cell lysis in the fish digestive tract, which can effectively improve nutrient absorption in the digestive tract, thus increasing the growth rate and improving feed efficiency (Hao et al., 2022). *S. cerevisiae*, as an immunostimulant, has beneficial effects on fish digestive enzymes (Qu et al., 2019). The addition of *S. cerevisiae* to feed as a probiotic has been reported to enhance digestive enzyme activity in *O. mykiss* (Adel et al., 2017), *A. japonicus* (Yang et al., 2014; Wang et al., 2015), and *O. niloticus* (Rachmawati et al., 2025).

The results of the proximate analysis showed that the addition of *S. cerevisiae* probiotics to the feed had a significant effect on the crude protein, crude fat, and carbohydrate contents of striped catfish (Table 4). The addition of *S. cerevisiae* probiotics to feed was proven to be effective in increasing the digestibility of nutrients, such as crude protein, fat, and carbohydrates. *S. cerevisiae* produces digestive enzymes, such as proteases, lipases, and amylases, which help break down complex proteins, fats, and carbohydrates into simpler forms that are more easily absorbed by the fish intestines. *S. cerevisiae*, as a probiotic, creates a healthy intestinal environment and increases the metabolic rate and protein retention. *S. cerevisiae* improves intestinal microflora and promotes more efficient body metabolism to store energy reserves in the form of fat. In addition, *S. cerevisiae* in the feed functions as a probiotic to improve the fish digestive system and support optimal nutrient absorption, resulting in an overall increase in energy availability, including carbohydrate (glycogen) reserves in the fish body. Similar research results were reported by Sharawy et al., (2016), Abu-Elala et al., (2018), and Ayiku et al., (2020).

Conclusions. The addition of *Saccharomyces cerevisiae* probiotics to feed can improve feed efficiency, growth performance, digestive enzyme activity, and biochemical composition in striped catfish (*Pangasianodon hypophthalmus*). The addition of *S. cerevisiae* probiotics at a dose of 4 g kg^{-1} feed was the best method for enhancing striped catfish productivity. The addition of *S. cerevisiae* as a probiotic in feed can increase the nutritional content of fish feed to support improved aquaculture production through optimal nutrient utilization and reduced production costs, which will ensure the sustainability and profitability of aquaculture.

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Authors Contributions. DR: Originator of the idea or principal conceptor of the research, data analysis and interpretation, as well as drafting the initial manuscript, revising, improving, and refining the writing prior to publication; PHR: Refinement of

methodology, conducting experiments/field observations, and preparation of data visualizations/graphics; SW: Supervisor or overseer who monitored the research process and conducted a critical review of the manuscript.

Conflicts of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Authors:
Diana Rachmawati (DR), Department of Aquaculture, Faculty of Fisheries and Marine Sciences, University of Diponegoro, 50275 Semarang, Central Java, Indonesia, e-mail: dianarachmawati1964@gmail.com
Putut Har Riyadi (PHR), Department of Fishery Products Technology, Faculty of Fisheries and Marine Sciences, University of Diponegoro, Semarang, Central Java, Indonesia, e-mail: putut.riyadi@live.undip.ac.id
Seto Windarto (SW), Department of Aquaculture, Faculty of Fisheries and Marine Sciences, University of Diponegoro, 50275 Semarang, Central Java, Indonesia, e-mail: setosidhartawan@gmail.com

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