

## UTILIZATION OF SUCKERMOUTH CATFISH (*Pterygoplichthys pardalis*) AS A RAW MATERIAL OF PROTEIN IN ARTIFICIAL FEED TILAPIA

### PEMANFAATAN IKAN SAPU-SAPU (*Pterygoplichthys pardalis*) SEBAGAI BAHAN BAKU SUMBER PROTEIN DALAM PAKAN BUATAN IKAN NILA

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#### ABSTRACT

In aquaculture, feed constitutes approximately 60% of the total production cost. The feed efficiency can be enhanced by utilizing local ingredients, such as suckermouth catfish (*Pterygoplichthys pardalis*) meal, as an alternative to imported fish meal. This study aims to evaluate the effects of varying substitution levels between local fish meal and suckermouth catfish meal on the growth performance and digestive enzyme activity of Nile tilapia (*Oreochromis niloticus*). A Completely Randomized Design (CRD) was applied with five treatments and three replications: A (100% local fish meal:0% suckermouth catfish meal), B (75%:25%), C (50%:50%), D (25%:75%), and E (0%:100%), resulting in a total of 15 experimental units. Test fishes with an initial weight of 1.5 g/individual of fish were stocked as many as 20 individual of fish in a plastic bucket containing 85 L of air per unit. Fish were fed 6% of their body weight per day with two feedings in the morning and evening for 60 days. Variables were analyzed using analysis of variance (ANOVA), statistical tests were performed at a significance level of 5% ( $\alpha = 0.05$ ) with a 95% confidence interval. The results showed that treatment D (25% local fish meal: 75% suckermouth catfish meal) had the best significant effect ( $p = 0.004$ ) on weight gain of  $3.9 \pm 0.83$  g, treatments A, B, C and E were the same but different from treatment D, while for digestive enzyme activity, namely protease of 0.452 U/mL and amylase of 0.579 U/mL.

Keywords: amylase enzyme, growth, Nile tilapia, protease enzyme, suckermouth catfish

#### ABSTRAK

Dalam kegiatan budidaya, pakan menyumbang sekitar 60% dari total biaya produksi. Upaya efisiensi dapat dilakukan melalui pemanfaatan bahan baku lokal, seperti tepung ikan sapu-sapu, sebagai alternatif substitusi tepung ikan impor. Penelitian ini bertujuan untuk mengevaluasi pengaruh variasi tingkat substitusi antara tepung ikan lokal dan tepung ikan sapu-sapu terhadap pertumbuhan mutlak dan aktivitas enzim pencernaan ikan nila (*Oreochromis niloticus*). Penelitian menggunakan Rancangan Acak Lengkap (RAL) dengan lima perlakuan dan tiga ulangan, yaitu: A (100% tepung ikan lokal: 0% tepung ikan sapu-sapu), B (75%:25%), C (50%:50%), D (25%:75%), dan E (0%:100%), sehingga terdapat 15 unit percobaan. Ikan uji dengan bobot awal 1,5 g/ekor ditebar sebanyak 20 ekor dalam ember plastik berisi 85 L air per unit. Ikan diberi pakan sebanyak 6% dari bobot tubuh per hari dengan dua kali pemberian pagi dan sore selama 60 hari. Variabel dianalisis menggunakan analisis varians (ANOVA), uji statistik dilakukan pada tingkat signifikansi 5% ( $\alpha = 0,05$ ) dengan interval kepercayaan 95%. Hasil menunjukkan bahwa perlakuan D (25% tepung ikan lokal:75% tepung ikan sapu-sapu) memberikan pengaruh nyata terbaik ( $p = 0,004$ ) terhadap penambahan berat sebesar  $3,9 \pm 0,83$  g, perlakuan A, B, C, dan E sama tetapi berbeda dengan perlakuan D, sedangkan untuk aktivitas enzim pencernaan yaitu protease sebesar 0,452 U/mL dan amilase sebesar 0,579 U/mL.

Kata kunci: enzim amilase, enzim protease, ikan nila, ikan sapu-sapu, pertumbuhan

## INTRODUCTION

Enhancing Nile tilapia (*Oreochromis niloticus*) production can be achieved through the adoption of intensive aquaculture systems, which are characterized by high stocking densities, rigorous water quality management, and the use of high-quality feed. Within these systems, the availability of nutritionally balanced feed is a primary determinant of growth efficiency and productivity (Suryahman *et al.* 2023; Rieuwpassa *et al.* 2020). Nevertheless, intensification also presents challenges, particularly in ensuring the sustainability of feed supply. Feed represents the largest cost component in aquaculture, often exceeding 60% of total production expenses (Surianti *et al.* 2021a). Dependence on imported raw materials such as fish meal and soybean meal is a major driver of high feed costs. Global market fluctuations and exchange rate instability have further contributed to rising feed prices, ultimately threatening supply stability and the long-term viability of aquaculture enterprises (Putra 2010).

Feed serves not only as a source of energy and nutrients but also directly influences the physiological performance of fish. Feed efficiency is typically reflected in biological parameters such as feed conversion ratio (FCR), specific growth rate (SGR), survival rate (SR), and final biomass (Darman *et al.* 2015). Moreover, undigested feed residues may contribute to water pollution, underscoring the importance of selecting feed ingredients that are both efficient and environmentally sustainable (Devani and Basriati 2015).

One strategic approach to reducing reliance on imports is the optimization of local feed resources. Currently, Indonesia imports approximately 120,000 tons of fish meal annually, valued at over USD 200 million, primarily from Peru and Vietnam. Soybean meal imports are also substantial, reaching 4.6 million tons in 2022 (BPS 2023). Such dependency highlights the urgency of developing alternative local feed ingredients to strengthen national feed self-sufficiency. Locally available raw materials should meet key criteria, including high nutritional value, abundance, non-toxicity, cost-effectiveness, and non-competition with human food requirements.

Suckermouth catfish (*Pterygoplichthys* sp.) is an invasive species widely distributed in freshwater ecosystems such as Lake

Tempe and Lake Sidenreng. Its population is abundant yet underutilized, and it is often regarded as a pest that disrupts aquatic ecosystems (Hasrianti *et al.* 2022). According to a report from the Inland Waters Fisheries Research and Extension Agency (2020), daily catches of suckermouth catfish in Lake Tempe range from 8–12 kg per fisher during the dry season and can reach 15–20 kg in the rainy season. Similarly, monitoring data from the Marine Affairs and Fisheries Service of Sidenreng Rappang Regency (2021) indicate a relatively stable supply of suckermouth catfish in Lake Sidenreng throughout the year, making it a promising and sustainable feed resource.

Beyond its availability, the suckermouth catfish also possesses high nutritional value. Sumaidi *et al.* (2023) reported that suckermouth catfish meal contains 91.11% crude protein, significantly higher than that of catfish meal, which contains only 18.14% protein (Romadhon *et al.* 2013). This high protein content demonstrates the potential of suckermouth catfish as a valuable protein source in aquafeed formulation. With appropriate formulation, its use could substantially reduce feed costs without compromising Nile tilapia growth performance. Consequently, further research is warranted to evaluate its potential as a substitute for local fish meal in order to support feed efficiency in intensive Nile tilapia culture. This study therefore aimed to examine the effects of different substitution levels between local fish meal and suckermouth catfish meal on the growth performance and digestive enzyme activity of Nile tilapia.

## METHODS

### Research site

This study was conducted from March to May 2024 in Bojo Village, Barru Regency, South Sulawesi Province, Indonesia.

### Experimental fish

The experimental fishes were monosex Nile tilapia fingerlings with an average initial weight of 1.5 g, obtained from the Sidrap Fish Hatchery Center (FHC Pangkajene Sidrap). A total of 240 fingerlings were used and stocked into 12 containers, with a stocking density of 20 fish/m<sup>2</sup>.

## Experimental diets

Experimental diets were prepared by weighing all ingredients according to the formulation for each treatment (A–E), as presented in Table 1. Dry ingredients such as fish meal, suckermouth catfish meal, shrimp head meal, soybean meal, cornmeal, carboxymethyl cellulose (CMC), vitamins, and minerals were thoroughly mixed for approximately 10 minutes until homogeneous. Fish oil was then added while mixing, followed by the gradual addition of water until the dough achieved a plastic consistency suitable for pelletizing.

The dough was extruded into pellets using a pelletizer. Fresh pellets were dried in an oven at 40–50°C for 12–24 hours or sun-dried until the moisture content fell below 10%. The dry pellets were stored in airtight containers and kept in a cool, dry environment to maintain quality and prevent mold growth or nutrient loss. The proximate

composition of the experimental diets is presented in Table 2.

## Experimental design

A completely randomized design (CRD) was applied, consisting of five treatments and three replicates, yielding 15 experimental units in total. The treatments included varying substitution levels between local fish meal (LFM) and suckermouth catfish meal (SCFM) as follows:

- A: 100% local fish meal, 0% suckermouth catfish meal
- B: 75% local fish meal, 25% suckermouth catfish meal
- C: 50% local fish meal, 50% suckermouth catfish meal
- D: 25% local fish meal, 75% suckermouth catfish meal
- E: 0% local fish meal, 100% suckermouth catfish meal

Table 1. Composition of feed raw materials with substitution of fish meal by catfish meal in each treatment (%) (Pertiwi *et al.* 2021).

Raw Material	Percentage				
	A	B	C	D	E
Fish meal	30	22.5	15	7.5	0
Suckermouth catfish meal	0	7.5	15	22.5	30
Shrimp head meal	19	19	19	19	19
Soybean meal	22	22	22	22	22
Cornmeal	10	10	10	10	10
Carboxymethyl cellulose (CMC)	10	10	10	10	10
Fish oil	4	4	4	4	4
Vitamins and minerals	5	5	5	5	5
<b>Total</b>	100	100	100	100	100

Table 2. Analysis of feed nutritional content based on the treatment of substitution of fish meal with catfish meal.

Treatment	Water (%)	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)	BETN (%)	Ash (%)
A	27.29	30.51	21.85	7.90	10.80	28.94
B	29.87	30.96	21.46	8.92	10.48	28.18
C	27.64	31.06	22.24	7.23	12.97	26.50
D	28.08	32.60	23.91	6.47	12.51	24.51
E	28	32.81	23.65	6.51	12.73	24.3

Note: Proximate analysis of feed was conducted in the Feed Chemistry Laboratory, Faculty of Animal Husbandry, Hasanuddin University. A (100% local fish meal and 0% janitor fish meal), B (75% local fish meal and 25% janitor fish meal), C (50% local fish meal and 50% janitor fish meal), D (25% local fish meal and 75% janitor fish meal), E (0% local fish meal and 100% janitor fish meal).

## Feeding and rearing management

Nile tilapia were stocked in the experimental containers following a 1–2 day acclimatization period. Fish were uniform in size, healthy, and stocked at a density of 15 fish per container. During the 60-day trial, fish were fed experimental diets at 6% of total biomass per day, divided into two equal meals (07:00 and 16:00). Biomass sampling was performed every 10 days to adjust feed quantity according to updated fish weight.

Freshwater was used as the rearing medium, and water quality was maintained by replacing 30–50% of the volume weekly or when water quality declined. Parameters such as temperature, pH, dissolved oxygen (DO), and ammonia were monitored periodically to ensure they remained within the optimal range for Nile tilapia growth. Uneaten feed and feces were removed regularly to minimize organic accumulation and maintain water quality.

## Research parameters

### Absolute growth

$$W = W_t - W_0$$

Where:

W = Absolute growth (g/fish)

W<sub>t</sub> = Average fish weight at the end of maintenance (g/fish)

W<sub>0</sub> = Average fish weight at the beginning of maintenance (g/fish)

### Digestive enzyme activity

Amylase and protease enzymes were extracted from the digestive tract of Nile tilapia, specifically from the small intestine, which is the primary site of digestive enzyme activity. Each replicate consisted of three Nile tilapia of uniform size. Approximately 1 g of intestinal tissue was weighed, homogenized with 10 mL of phosphate buffer (pH 7.0), and centrifuged at 10,000 rpm for 15 minutes at 4°C. The supernatant was collected and used as the crude enzyme extract. Amylase activity was determined using the DNS (3,5-dinitrosalicylic) method with 1% starch solution as the substrate, incubated for 15 minutes at 37°C, and measured at an absorbance of 540 nm. Protease activity was measured using 1% casein solution as the

substrate, incubated for 10 minutes at 37°C, followed by termination with 10% TCA, and the absorbance was read at 280 nm.

Protease enzyme activity was calculated using the equation described by Bergmeyer and Grassl (1983) as follows:

$$U = (Act - Abl)/(Ast - Abl) \times PT$$

The unit of protease enzyme activity is expressed as U, while Act refers to the absorbance reading obtained from the test sample. Abl denotes the absorbance value of the blank solution used as the control without enzyme, and Ast represents the absorbance of the standard solution containing the reference enzyme. P indicates the dilution factor applied to the sample, and T is the incubation time expressed in minutes.

Amylase enzyme activity was calculated using the equation of Bergmeyer and Grassl (1983) as follows:

$$U = (Ass - Abl)/(Ast - Abl) \times PT$$

The unit of amylase enzyme activity is expressed as U. Ass denotes the absorbance value of the tested sample, while Abl represents the absorbance of the blank solution serving as a control without enzymatic activity. Ast indicates the absorbance of the standard solution used as a reference. P represents the dilution volume in milliliters (mL), and T refers to the incubation duration, expressed in minutes.

### Water Quality

Water quality parameters, including temperature and pH, were measured daily for sixty days to monitor the rearing conditions of Nile tilapia. Temperature was recorded using a digital thermometer immersed directly in the water during both morning and afternoon observations, while pH was determined using a calibrated pH meter prior to use. Dissolved oxygen (DO) levels were measured weekly with a portable DO meter. In addition, ammonia concentration was measured at the beginning and end of the experiment using the spectrophotometric method with specific reagents for ammonia detection. The types of water quality parameters and the respective measuring instruments are presented in Table 3.

Table 3. Types of water quality parameters and their measurement instruments.

Parameters	Tools used
Temperature (°C)	Thermometer digital
pH	pH meter
Dissolved oxygen (mg/L)	DO meter portable
Ammonia (mg/L)	Spectrophotometry

### Statistical analysis

Absolute growth variables were analyzed using analysis of variance (ANOVA) with the aid of SPSS software version 22. The statistically tested values included fish growth parameters. The analysis was performed to determine whether significant differences existed among treatments. Statistical tests were conducted at a 5% significance level ( $\alpha = 0.05$ ) with a 95% confidence interval. When ANOVA results indicated a significant effect, a post hoc W-Tukey test was applied to identify specific differences among treatments. Enzyme activity data and water quality parameters obtained during the experiment were further compared with findings from previous studies on Nile tilapia to ensure that the environmental conditions during the rearing period remained within the optimal range.

## RESULTS AND DISCUSSION

### Growth

The growth rate of Nile tilapia after 60 days of feeding trials is presented in Table 4. Meanwhile, the activities of protease and amylase enzymes during the rearing period are illustrated in Figures 1 and 2. The results of variance analysis indicated that feed type had a significant effect ( $P < 0.05$ ) on the

absolute growth rate of Nile tilapia. Further analysis using the W-Tukey test revealed that the highest growth rate was observed in treatment D (25% local meal and 75% suckermouth catfish meal), reaching 3.90%. In contrast, treatments A (100% local meal and 0% suckermouth catfish meal, 2.90%), B (75% local meal and 25% suckermouth catfish meal, 2.90%), C (50% local meal and 50% suckermouth catfish meal, 2.80%), and E (100% local meal and 0% suckermouth catfish meal, 3.10%) showed no significant differences among treatments ( $P = 0.004$ ).

Growth rate refers to the increase in body weight or length of fish over a certain period. In addition to aquatic environmental conditions, feed is one of the main external factors that plays a crucial role in fish growth (Rambo *et al.* 2018). The quality and nutrient composition of feed are essential, not only as a source of energy and growth support but also in tissue formation, organ maintenance, repair of damaged tissues, and sustaining metabolic processes (Surianti *et al.* 2021b). Feed quality is therefore a key determinant of success in aquaculture. High-quality feed can improve fish health, accelerate growth, and ultimately enhance production yield. Optimal growth occurs when the nutrients consumed and absorbed by the fish exceed the basic requirements for maintaining physiological functions (Rosyidah *et al.* 2024).

Table 4. Average growth rate of Nile tilapia during maintenance.

Treatment	Value±SD
	Growth Rate (%/day)
A	2.9±0.26 <sup>a</sup>
B	2.9±0.11 <sup>a</sup>
C	2.8±0.20 <sup>a</sup>
D	3.9±0.83 <sup>b</sup>
E	3.1±0.26 <sup>a</sup>

Note: Different superscript in the same column indicate significant differences between treatments ( $P < 0.05$ ).

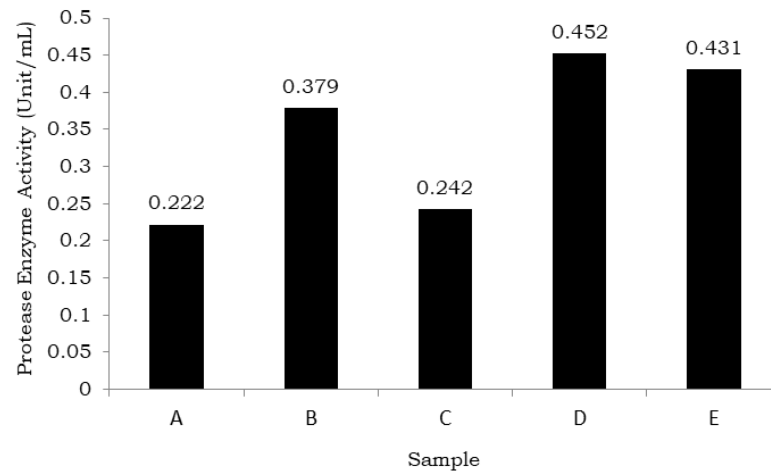


Figure 1. Protease enzyme activity of Nile tilapia measured over a 60-day period under five different dietary treatments.

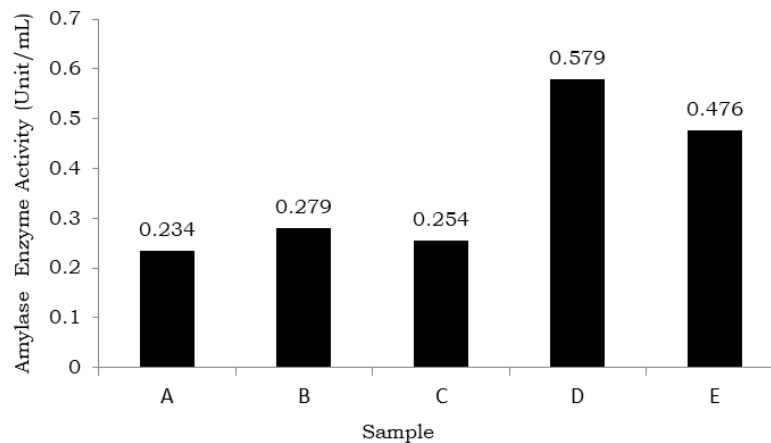


Figure 2. Amylase enzyme activity in Nile tilapia measured over a 60-day period under five different dietary treatments.

Caption for Figures 1 and 2: The baseline value represents the enzyme activity in Nile tilapia prior to the administration of experimental diets. Diet A: 100% local fish meal and 0% suckermouth catfish meal; Diet B: 75% local fish meal and 25% suckermouth catfish meal; Diet C: 50% local fish meal and 50% suckermouth catfish meal; Diet D: 25% local fish meal and 75% suckermouth catfish meal; Diet E: 0% local fish meal and 100% suckermouth catfish meal.

The analysis of the absolute length growth of Nile tilapia revealed a significant effect resulting from differences in feed composition. The best performance was observed in the treatment combining 25% local fish meal (LFM) and 75% suckermouth catfish meal (SCFM), with an absolute length growth of  $3.9 \pm 0.83$  cm. These findings demonstrate that a higher proportion of suckermouth catfish meal in the diet can exert a positive impact on the length growth of Nile tilapia.

The relevance between the use of suckermouth catfish meal and the length growth of Nile tilapia is closely associated with its nutritional composition, particularly

its protein content. Based on proximate analysis in the present study, local fish meal contained 40% protein, whereas suckermouth catfish meal contained 44.07%. Furthermore, Cano-Salgado *et al.* (2022) reported that the crude protein content of suckermouth catfish meal can reach as high as 62.18%, considerably greater than the 56.99% protein content commonly found in local fish meal. A high protein level in the diet contributes directly to body tissue synthesis, including the length growth of fish.

However, elevated protein and lipid contents do not necessarily guarantee efficient growth, especially

when suckermouth catfish meal is used exclusively without blending with other feed ingredients. The reduction in growth rate observed under the 100% SCFM diet may be attributed to protein quality, essential amino acid balance, feed digestibility, or the presence of anti-nutritional factors and heavy metal contaminants that may be present in suckermouth catfish, particularly when sourced from polluted waters. As highlighted by Furuya *et al.* (2020) and Jobling (2016), the effectiveness of dietary protein in promoting fish growth depends not only on the total protein content but also on a balanced amino acid profile and nutrient bioavailability.

Adequate nutrient availability in feed not only provides an energy source but also supports the physiological requirements and morphological growth of Nile tilapia (Ali *et al.* 2015). Length growth occurs when the nutrients digested and absorbed by the fish, particularly proteins and essential amino acids, exceed the basic requirements for body maintenance (Yolanda *et al.* 2013). Accordingly, the higher the protein content and nutritional quality of feed ingredients, such as suckermouth catfish meal, the more optimal the length growth that can be achieved. The use of suckermouth catfish meal as a feed substitute offers an efficient, low-cost, and locally available alternative, while also demonstrating a significant positive effect on fish growth performance.

Treatment D (25% local fish meal and 75% suckermouth catfish meal) is considered the optimal level of substitution, as it provides a balance between high-quality animal protein and feed acceptability for fish. At 100% substitution with suckermouth catfish meal, despite its high protein content, growth performance may decline due to reduced palatability and digestibility in the absence of other ingredients with stronger aroma profiles that enhance feed intake. Conversely, when the proportion of suckermouth catfish meal is too low, the overall protein content decreases and may no longer be sufficient to support optimal growth. This finding is consistent with Ali *et al.* (2015) and Yolanda *et al.* (2013), who emphasized that maximum structural growth in fish occurs when dietary protein and essential amino acid requirements for maintenance are met, and the surplus can be allocated to body growth.

Therefore, the inclusion of suckermouth catfish meal as a feed substitute not only exerts a positive effect

on length growth in Nile tilapia but also represents a cost-effective, locally available alternative that promotes feed self-sufficiency at the national level. A substitution rate of 75% suckermouth catfish meal has been scientifically demonstrated as the optimal composition, successfully combining high nutritional value with significant growth efficiency in Nile tilapia.

### **Enzyme activity**

The results showed that both protease and amylase activities increased towards the end of the rearing period after the fish were fed diets with different substitution levels of local fish meal and suckermouth catfish meal. The activities of protease and amylase varied depending on the proportion of feed ingredients used. In the treatment containing 25% local fish meal and 75% suckermouth catfish meal, protease activity reached 0.452 U/mL, while amylase activity was 0.579 U/mL. These values were higher compared with those observed in other treatments, such as the diet composed of 100% local fish meal without suckermouth catfish meal, where protease and amylase activities were recorded at 0.222 U/mL and 0.234 U/mL, respectively.

The differences in enzyme activity indicate that variations in feed composition influence the ability of fish to digest nutrients. Higher protease and amylase activities in treatments containing greater proportions of suckermouth catfish meal reflect improved digestive efficiency for protein and carbohydrate utilization. This finding suggests that Nile tilapia were able to absorb and metabolize nutrients from the diet more effectively, which was positively correlated with the absolute growth observed during the rearing period.

Protease is an enzyme responsible for hydrolyzing proteins into amino acids, thereby facilitating the digestive process (Sudiartha *et al.* 2014). In this study, protease activity varied markedly among treatments, with the highest value recorded in Diet D (0.452 U/mL) and the lowest in Diet A (0.222 U/mL). This variation reflects differences in protein digestion efficiency among the dietary treatments. According to Moeis *et al.* (2020a), protease activity serves as a key indicator of the ability of fish to digest and utilize dietary protein. The protease activity observed in this experiment also demonstrated better performance compared with the findings of Latifah (2017), who

reported protease activity of 0.50  $\mu\text{mol}$  tyrosine/g/min in catfish supplemented with probiotics at 10 mL/kg of feed.

The enhancement of proteolytic enzyme activity in certain treatments is closely linked to the nutritional quality of the feed ingredients, particularly suckermouth catfish meal. This ingredient is known to contain a relatively high protein level (approximately 54%), a complete profile of essential amino acids, and important minerals such as calcium, phosphorus, magnesium, and zinc. These nutrients are thought to stimulate the secretion of digestive hormones, such as cholecystokinin, which in turn triggers the release of pancreatic proenzymes, thereby supporting the optimal production and activity of protease.

In addition to protease, amylase activity exhibited a similar trend. An increase in amylase activity was observed in treatments combining local feed ingredients with suckermouth catfish meal, reflecting improved efficiency in carbohydrate utilization from the diet. This enzymatic activity indicates the capacity of the fish digestive system to hydrolyze starch into glucose, which is subsequently used for energy supply and growth. According to Fitriyani (2018), amylase activity in the digestive tract of fish typically ranges between 0.0758 and 0.2148 U/mL/min, serving as a reference for assessing the effectiveness of carbohydrate utilization in fish.

In general, the increase in digestive enzyme activities, both protease and amylase, observed in the treatment with 25% local fish meal and 75% suckermouth catfish meal indicates a positive correlation with nutrient availability in the diet and the growth of Nile tilapia. These findings suggest that a feed formulation combining two different protein sources in a proportional manner can enhance the efficiency of digestive enzyme activity, thereby contributing to improved growth performance in fish (Moeis *et al.* 2020b).

The increase in digestive enzyme activity was closely related to the availability

of optimal nutrient substrates in the diet, particularly easily digestible proteins and carbohydrates. Adequate substrate availability can stimulate enzyme secretion by the pancreas and digestive tract through hormonal activation, such as the release of cholecystokinin and gastrin, which play important roles in regulating enzymatic functions (Jobling, 2016). Therefore, a balanced combination of feed ingredients has the potential to enhance digestibility and improve nutrient metabolic efficiency in fish. Conversely, in the treatment with 100% local fish meal without the inclusion of suckermouth catfish meal, digestive enzyme activity tended to be lower. This may be attributed to limitations in protein quality or imbalances in the essential amino acid profile, which reduced nutrient intake and utilization efficiency, ultimately exerting a negative impact on fish growth.

Previous studies support these findings. Cano-Salgado *et al.* (2022) reported that suckermouth catfish meal can be used as a substitute for commercial fish meal without compromising fish growth performance. The presence of high-quality animal protein, essential amino acids, and key minerals in suckermouth catfish meal is believed to contribute to improved digestive efficiency. Accordingly, the nutrients in suckermouth catfish meal act synergistically to enhance digestive enzyme activity, increase feed digestibility, and support the overall growth of Nile tilapia. Furthermore, its use as a locally available feed ingredient provides an environmentally friendly and cost-effective alternative for advancing the aquaculture feed industry.

### Water quality

Measurements of dissolved oxygen (DO), temperature, salinity, pH, and ammonia represent crucial aspects in assessing water health and overall environmental quality. The results of water quality parameter measurements are presented in Table 5.

Table 5. Results of water quality parameter measurements during the experimental period.

Parameters	Observed Ranges	Optimal Range for Nile Tilapia
Temperature ( $^{\circ}\text{C}$ )	26–31	20–30 $^{\circ}\text{C}$ (FAO 2011)
pH	6.72–8.09	6.5–9.0 (Makori <i>et al.</i> 2017)
Dissolved oxygen (mg/L)	6.5–7.2	$\geq 5.0$ mg/L (Abaho <i>et al.</i> 2017)
Ammonia (mg/L)	0.020–1.033	<0.1–0.2 mg/L (Svobodová <i>et al.</i> 1993)

The optimization of Nile tilapia production requires effective aquaculture management, particularly in maintaining water quality as the primary medium for aquatic organisms (Andriani *et al.* 2018). Based on the measurements obtained, the water quality parameters during the rearing period remained within a tolerable range for Nile tilapia culture. Water temperature was recorded between 26–31°C, which is consistent with the findings of Indriati and Hafiludin (2022), who reported a range of 27–28°C, and is considered suitable to support Nile tilapia growth. Dissolved oxygen (DO) levels ranged from 6.5–7.2 mg/L, aligning with Pramleonita *et al.* (2018), who stated that optimal DO levels for Nile tilapia culture are between 6.1–14.5 mg/L. Furthermore, according to the Decree of the Minister of Marine Affairs and Fisheries No. 52 of 2020, Nile tilapia can survive at DO concentrations above 2 mg/L. The pH values during the experimental period ranged from 6.72 to 8.09, which remains within the optimal range for Nile tilapia growth, as suggested by Azhari and Tomaso (2018), i.e., between 6.5 and 9.

Ammonia concentrations measured during the rearing period ranged from 0.020 to 0.093 mg/L, which remained within the tolerable limits for Nile tilapia growth. According to Safsafubun *et al.* (2023), ammonia in aquatic environments exists in equilibrium between free ammonia (NH<sub>3</sub>), which is toxic, and ammonium ions (NH<sub>4</sub><sup>+</sup>), which are non-toxic and can still be utilized in growth processes. Effendi (2003) noted that ammonia concentrations in natural waters generally remain below 0.1 mg/L. However, Crab (2010) emphasized that ammonia-N may become harmful to cultured fish when levels exceed 1.5 mg/L.

## CONCLUSION

This study demonstrated that varying substitution levels between local fish meal and suckermouth catfish meal significantly affected the growth rate and digestive enzyme activities (protease and amylase) of Nile tilapia. The diet containing 25% local fish meal and 75% suckermouth catfish meal yielded the best performance, producing the highest absolute growth as well as the greatest protease and amylase activities. These findings indicate that an appropriate combination of feed ingredients can enhance nutrient utilization efficiency

and improve the physiological performance of the digestive system in fish. Therefore, suckermouth catfish meal has strong potential as an effective and economical local feed ingredient to support the productivity of Nile tilapia aquaculture.

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