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EFFECT OF DIFFERENT FEEDING RATES OF CORN COB FLOUR SUPPLEMENTED-FEED ON THE GROWTH OF FARMED *Osphronemus gouramy*

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ABSTRACT

The rapid growth of aquaculture industry and the limited availability of conventional fish feed have driven the need for alternative feed sources, particularly in intensive fish farming systems. This study, conducted from May 15 to July 5, 2017, in Bengkulu, aimed to determine the optimal feeding rate for gourami (*Osphronemus goramy*) using artificial fish pellets. A completely randomized design was applied, testing four feeding rates based on fish biomass: D1 (2%), D2 (3%), D3 (4%), and D4 (5%) per day. Gouramis (3.2–3.3 g, 1.1–1.3 cm) were reared in 24 plastic containers (50×30×27 cm^3) under controlled water quality conditions. The results showed that a 5% feeding rate (D4) yielded the best outcomes in absolute length (1.97 ± 0.13 cm), specific growth rate (2.78 ± 0.17% day^{-1}), feed conversion ratio (3.72 ± 0.11), feed efficiency (26.85 ± 0.30%), and survival rate (88.89%). Statistical analysis revealed that different feeding rates significantly influenced absolute length, specific growth rate, and feed conversion ratio, while feed efficiency and survival rate remained unaffected. Despite the promising growth performance at higher feeding rates, the high feed conversion ratio and low feed efficiency highlight the need for improved feed formulations. Future research should focus on optimizing corn cobs as a complementary ingredient to enhance feed efficiency, minimize waste, and contribute to sustainable aquaculture. Incorporating corn cob-based feeds could improve waste management and provide economic benefits to fish farmers.

KEYWORDS*:* corn cob flour; feeding rate; fish feed; gourami; growth.

ABSTRAK:* *Pengaruh Tingkat Pemberian Pakan Berbeda yang Disuplementasi Tepung Tongkol Jagung terhadap Pertumbuhan* Osphronemus gouramy *Hasil Budidaya

*Pesatnya pertumbuhan industri akuakultur dan keterbatasan ketersediaan pakan ikan konvensional mendorong perlunya sumber pakan alternatif, terutama dalam sistem budidaya ikan intensif. Penelitian ini, yang dilaksanakan pada tanggal 15 Mei hingga 5 Juli 2017 di Bengkulu, bertujuan untuk menentukan tingkat pemberian pakan optimal bagi ikan gurami (**Osphronemus goramy**) menggunakan pakan buatan ikan. Rancangan acak lengkap diterapkan dengan menguji empat tingkat pemberian pakan berdasarkan biomassa ikan: D1 (2%), D2 (3%), D3 (4%), dan D4 (5%) per hari. Ikan gurami (3,2–3,3 g, 1,1–1,3 cm) dipelihara dalam 24 wadah plastik (50×30×27 cm^3) dengan kualitas air yang terkontrol. Hasil penelitian menunjukkan bahwa tingkat pemberian pakan 5% (D4) memberikan hasil terbaik*

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dalam hal panjang mutlak (1,97 ± 0,13 cm), laju pertumbuhan spesifik (2,78 ± 0,17% hari^{-1}), rasio konversi pakan (3,72 ± 0,11), efisiensi pakan (26,85 ± 0,30%), dan tingkat kelangsungan hidup (88,89%). Analisis statistik menunjukkan bahwa tingkat pemberian pakan yang berbeda berpengaruh signifikan terhadap panjang mutlak, laju pertumbuhan spesifik, dan rasio konversi pakan, sedangkan efisiensi pakan dan tingkat kelangsungan hidup tidak terpengaruh. Meskipun tingkat pemberian pakan yang lebih tinggi menghasilkan pertumbuhan yang lebih baik, tingginya rasio konversi pakan dan rendahnya efisiensi pakan menunjukkan perlunya perbaikan formulasi pakan. Penelitian lebih lanjut perlu difokuskan pada optimalisasi tongkol jagung sebagai bahan tambahan pakan untuk meningkatkan efisiensi pakan, mengurangi limbah, dan mendukung kegiatan akuakultur berkelanjutan. Penggunaan pakan berbasis tongkol jagung juga dapat membantu pengelolaan limbah serta memberikan manfaat ekonomi bagi pembudidaya ikan.

KATA KUNCI: ***ikan gurami; pakan ikan; pertumbuhan; tepung tongkol jagung; tingkat pemberian pakan***

INTRODUCTION

Gourami (*Osphronemus gouramy*) is an endemic fish in Indonesia with high nutritional value and is suitable for human growth. Studies by Hidayatulah *et al.* (2022) found that gouramis are high in protein content and low in cholesterol (55 mg per 100 g). Sadya and Bayu (2022) stated that Indonesia's gourami production in 2021 was 176,113.78 tons, equivalent to IDR 6.21 trillion. Cahyono (2001) found that intensive gourami cultivation requires feed containing protein comprising at least 3% of their biomass. Furthermore, in the aquaculture business, feed accounts for 50–70% of production costs, and feed efficiency is directly related to profitability. The sustainability of high-protein feed for the aquaculture sector faces challenges such as high costs, nutritional value, and sustainable resource availability (FAO, 2024).

Corncobs, considered agricultural waste and nearly worthless, are widely used in ruminant feed (Jannathulla *et al.*, 2018; Rostika & Safitri, 2012; Tangendjaja & Wina, 2007; Umiyasih & Wina, 2008; Zaenuri *et al.*, 2014) and have long been an alternative animal feed source that is readily available in Indonesia. A study by Van Doan *et al.* (2018) found that corncobs can be processed into a feed source that enhances livestock growth. Several studies (Novrianto *et al.*, 2019; Yulfiperius *et al.*, 2020; Zimbardi *et al.*, 2013) have found that their nutritional content is promising enough to be used as part of a feed combination for gourami cultivation. Although corncobs contain crude protein, cellulose, hemicellulose, non-nitrogen extracts, lignin, and water, their crude fiber content is relatively high (± 40%). Moreover, they have low palatability. Therefore, feed materials with high fiber content, such as corncobs, require further processing by adding other elements that can substitute and complement the overall feed composition to meet nutritional needs.

Napolitano *et al.* (2022) stated that alternatives for fish feed are worth exploring to replace the currently formulated feeds, which are generally costly and difficult to obtain. Furthermore, corncob flour, which contains high fiber, can be used effectively to reduce production costs for aquaculture communities. According to Aragão *et al.* (2022), protein plays a crucial role in influencing fish growth. Additionally, Xing *et al.* (2024) found that juvenile fish require ten essential/indispensable amino acids (EAA/IAA), including crude protein, arginine, histidine, isoleucine, leucine, valine, lysine, sulfur amino acids, threonine, and tryptophan. Innovators in aquaculture must prioritize cost-effective and environmentally friendly feed alternatives to ensure more sustainable fisheries cultivation (Nunes *et al.*, 2022). For this reason, various aquaculture feed products with unique formulations have incorporated additional protein sources such as fish meal, soybean meal, and corncobs (Ali & Kaviraj, 2018; Dawood & Koshio, 2020; Hamidoghli *et al.*, 2020; Jannathulla *et al.*, 2018; Rostika & Safitri, 2012).

A study by Rahmadika (2019) found that tilapia grew well with a combination of corncob flour and commercial feed containing crude protein. Similar results were observed by Novrianto *et al.* (2019), where the Java barb exhibited good growth when fed a combination of fish meal and corncob flour. Various studies have demonstrated that feeding rates that optimize growth parameters vary among fish species: *Lates calcarifer* at 6% of biomass per day (Hassan *et al.*, 2021), *Sander lucioperca* at 3.0-4.5% of body weight per day (Kozłowski & Piotrowska, 2024), *Acipenser medirostris* at 5.3% of body weight per day (Zheng *et al.*, 2015), and *Siniperca scherzeri* up to 2.5% of body weight per day (Kim *et al.*, 2021). Therefore, feeding levels of 3–6% of body weight per day significantly impact length increase, energy requirements, and specific growth rate.

A study by Cadorin *et al.* (2022) on *Oreochromis niloticus* found that fish fed up to apparent satiation showed the best daily weight gain and growth rate compared to fish on a restricted feeding regimen. Feed intake influences changes in body composition, bone structure, and soft tissue mass. Furthermore, fish subjected to restricted feeding experience reduced muscle mass (Bureau *et al.*, 2006). Therefore, studies on appropriate feeding rates for satisfactory weight gain and overall fish health deserve robust and diverse research. By employing a completely randomized design and using feed composed of two main ingredients (corncob flour and fish meal), the present study aims to determine the effect of different feeding rates (2%, 3%, 4%, and 5% of biomass) on the growth of gourami.

MATERIALS AND METHODS

The study was conducted from May 15 to July 5, 2017, at Forestry Complex Block D No. 18, Air Sebakul, Bengkulu. The Research Ethics Committee, through the Institute for Research and Community Service at the University of Prof. Dr. Hazairin, SH, approved this research based on the regulations outlined in the university's 2021–2025 Research Strategic Plan. The approval covers the collection, maintenance, and necessary actions for handling *O. gouramy* in the Sebakul Bengkulu Water Block Forestry Housing.

This research does not involve any intentional actions that cause suffering to the research subjects. Upon completion of the study, *O. gouramy* was returned to the fisheries development pond at the Faculty of Agriculture, Aquaculture Study Program, University of Prof. Dr. Hazairin, SH. Furthermore, according to Minister of Maritime Affairs and Fisheries Regulation Number 10 of 2021, concerning Standards for Business Activities and Products in the Implementation of Risk-Based Business Licensing in the Maritime and Fisheries Sector, gourami is not classified as an endangered species.

Feed Formulation

Corncobs obtained from local farmers were dried at 60°C for two days. The flour was then produced by crushing and filtering it through a 100-mesh sieve. The feed was formulated with the following composition: fish meal (65.23%), corncob flour (17.70%), corn oil (4.69%), mixed vitamins (4.63%), mixed minerals (5.15%), and carboxymethyl cellulose (2.60%). All ingredients were placed in a basin and mixed with 100 mL of hot water. Once the ingredients were evenly mixed, the dough was molded using a pellet molding machine. The molded pellets were then air-dried using a fan until completely dry. The dried pellets contained 23% protein, 11.19% fat, 10.18% nitrogen-free extract, 18.78% dietary fiber, 5.66% crude fiber, and 31.19% ash. The pellets were placed in an airtight container and stored at 4°C until further use.

Experimental Design

The study used a completely randomized design with four treatments and six repetitions. The different feed rate configurations were as follows:
D1: Feed given at 2% of the fish biomass
D2: Feed given at 3% of the fish biomass
D3: Feed given at 4% of the fish biomass
D4: Feed given at 5% of the fish biomass

Object Preparation

Six gourami fingerlings measuring 1.1–1.3 cm were stocked in a container with dimensions of 50 × 30 × 27 cm^3 for each treatment. The initial average weight (W_0) of the fish in the experiment was as follows: D1 treatment (3.2 ± 0.31 g), D2 treatment (3.4 ± 0.50 g), D3 treatment (3.2 ± 0.11 g), and D4 treatment (3.3 ± 0.40 g). Since there were four treatments with six repetitions, the study used a total of 144 fish and 24 containers.

The fish were distributed in the afternoon. Measurements were taken using a scale and a ruler to assess length and weight differences throughout the experiment. Before the experiment began, the fish were confirmed to be healthy, agile, unblemished, and exhibiting bright body colors. Afterward, they were placed in plastic containers for maintenance.

Feeding

The feed, formed into pellets, was adjusted to match the size of the gourami fingerlings' mouth opening. Feeding was conducted three times daily at 09:00 am, 12:00 pm, and 04:00 pm, with rates of 2%, 3%, 4%, and 5% of the fish biomass.

Maintenance

The siphoning method was used to remove leftover feed to prevent a decline in water quality. Water changes were conducted regularly to maintain water quality. The water was sourced from a well and had been pre-settled in a reservoir.

Growth Measurement

Fish length and weight were measured after the adaptation period as part of the initial observations. Subsequently, measurements were taken every 15 days until day 60 for all treatments. Length was measured from the tip of the snout to the tip of the tail, while weight was determined by individually weighing each fish.

Absolute length (L_m) was calculated using the formula (1) (Quinn II & Deriso, 1999):

$$L_m = L_t - L_0 \quad \text{.....(1)}$$

Where is the absolute length (cm), is the final length (cm), and is the initial length (cm).

Specific growth rate (SGR) was calculated using the formula (2) (Quinn II & Deriso, 1999):

$$SGR = (Ln(Wt) - Ln(Wo)) * 100/t(d) \quad \text{.....(2)}$$

Where W_0 is the initial weight (g), Wt is the final weight (g), t is the period expressed in the number of days (d), and Ln is the natural logarithm.

Feed conversion (FC) ratio was calculated using the formula (3) (Boyd & McNevin, 2022):

$$FC = \frac{F}{(B_t + B_d) - B_0} \quad \text{.....(3)}$$

Where is feed conversion, is the final weight (g), is the initial weight (g), is the weight of deceased fish (g), and is the amount of feed consumed during the experiment (g).

Feed efficiency (FE) was calculated using the formula (4) (Jobling, 1993):

$$FE = \frac{(B_t + B_d) - B_0}{F} \quad \text{.....(4)}$$

Where is feed efficiency (%), is the final weight (g), is the initial weight (g), is the amount of feed given (g), and is the weight of fish that died during rearing period (g).

Survival rate (SR) calculation was done

using the formula (5) (Nohrman, 1953):

$$SR = \frac{Nt}{No} \times 100 \quad ....(5)$$

Where is the number of live fish at the end of the rearing period (individual), is the number of live fish at the beginning of rearing period (individual), and is the survival rate (%).

Water Quality Measurement

Water quality parameters were observed on the 1st, 15th, 30th, 45th, and 60th days. These parameters included temperature (measured with a thermometer), pH (measured with a pH meter), and dissolved oxygen (measured with a DO meter).

Statistical Analysis

The effect of different feeding rates, based on fish biomass, on length, specific growth rate, feed conversion, and feed efficiency was analyzed using analysis of variance (ANOVA) at a 5% significance level with SPSS 16. Additionally, the least significant difference (LSD) method was used to determine the optimal feeding rate at a 5% significance level. Water quality data were analyzed descriptively.

RESULTS AND DISCUSSIONS

Growth Performance

Feed is a crucial factor in promoting fish growth and development (Aragão *et al.*, 2022; McClements & Grossmann, 2021; Novrianto *et al.*, 2019; Yulfiperius *et al.*, 2020). Therefore, feed quality plays a key role in determining the overall characteristics of fish. The experiment results over 60 days, using different feeding rates (2%, 3%, 4%, and 5%) based on fish biomass, were analyzed with ANOVA to determine statistical significance at a 5% level. Significant differences in several biological developments were observed, as presented in Table 1.

Different feeding rates were found to affect growth, with the highest absolute length observed in the D4 treatment (5% feed of fish biomass). Since the ANOVA test revealed a significant difference in absolute length, the analysis was further extended using LSD to identify the optimal feeding rate for gourami growth. The LSD analysis confirmed that feeding at 5% of fish biomass (D4) significantly differed from the other treatments: 2% (D1), 3% (D2), and 4% (D3).

Although Gamboa-Delgado *et al.* (2013) stated that plant-based protein derivatives are generally low in methionine and not cost-effective, a cellular-level study by Walton *et al.* (1984) found that the high lysine content in fish meal plays a role in regulating carnitine synthesis, which is directly related to the transportation of long-chain fatty acids into the mitochondria. Additionally, Hamid *et al.* (2016) stated that lysine is responsible for maintaining acid-base balance and nitrogen content in fish tissues. The stability provided by lysine helps reduce body fat levels and regulate osmoregulation (Chiu *et al.*, 1988), thereby promoting rapid muscle growth in fish. As a result, well-developed muscle fibers contribute to an overall increase in fish body weight (Michelato *et al.*, 2016; Nguyen & Davis, 2016).

In this study, corncob flour constituted the second-largest component of the pellets (17.70%), after fish meal (65.23%). Therefore, the protein from fish meal could compensate for the typically low methionine content in plant-based protein derivatives, supporting fish growth (Gamboa-Delgado *et al.*, 2013). The ability of fish to efficiently convert feed into body weight gain is a primary goal in aquaculture systems. Furthermore, the feed conversion ratio is influenced by protein quality, which depends on the amino acid composition.

Li *et al.* (2021) highlighted the importance of amino acid balance in fish feed, stating that both essential and nonessential amino acids must be considered when formulating diets to achieve optimal growth. Additionally, lysine deficiency (ideally required at around 3–6%) can hinder fish growth and cause dorsal fin erosion (Li *et al.*, 2009). Xing *et al.* (2024)

Table 1. Growth performance of gourami after 60 days of rearing and feeding at different rates of corn cob-based feed

Parameters	Feeding rate (%)			
	2 (D1)	**3 (D2)**	**4 (D3)**	**5 (D4)**
L (cm)	1.55 ± 0.26[a]	1.81 ± 0.20[b]	1.78 ± 0.24[b]	1.97 ± 0.13[c]
SGR (% day^{-1})	2.52 ± 0.14[a]	2.71 ± 0.19[b]	2.66 ± 0.41[b]	2.78 ± 0.17[c]
W_0 (g)	3.2 ± 0.31	3.4 ± 0.50	3.2 ± 0.11	3.3 ± 0.40
Wt (g)	5.7 ± 0.18	6.3 ± 0.13	6.1 ± 0.16	6.5 ± 0.27
FC	4.34 ± 0.05[b]	4.57 ± 0.03[b]	6.50 ± 0.04[b]	3.72 ± 0.11[a]
FE (%)	23.03 ± 0.64[a]	21.86 ± 0.81[a]	15.37 ± 0.20[a]	26.85 ± 0.30[a]
SR (%)	86.11[a]	86.11[a]	83.34[a]	88.89[a]

Note: Absolute length (L); specific growth rate (SGR); initial weight (W_0); final weight (Wt); feed conversion (FC); feed efficiency (FE); survival rate (SR); D1: Feed given at 2% of the fish biomass; D2: Feed given at 3% of the fish biomass; D3: Feed given at 4% of the fish biomass; D4: Feed given at 5% of the fish biomass. Values with different superscripts in the same rows show significant differences ($P<0.05$).

also emphasized that juvenile fish require ten essential amino acids, including lysine. Given that fish growth is influenced by feed quality (Kong *et al.*, 2020), the higher protein content in D4, due to the increased feed percentage, positively impacted fish growth. However, if not properly processed, even high-quality feed may not significantly enhance growth.

Several studies (McClements & Grossmann, 2021; Possidônio *et al.*, 2021) have indicated that while well-balanced nutrition is essential, overprocessing feed can diminish its nutritional benefits by increasing saturated fat content. In this study, the pellet formation process, incorporating corncobs, was not overprocessed. As a result, fish length continuously increased, and feeding rate differences were significantly associated with length growth.

The growth rate of gouramis from the beginning to the end of the study consistently increased, with the highest SGR observed in treatment D4 (2.78% day^{-1}). Weight gain is significantly influenced by protein content and the feed energy ratio. Since protein requirements vary based on species, age, and biomass (Hepher, 1989), growth can be optimized when energy intake and amino acids from feed are appropriately adjusted. Analyses of feed impact on the digestive system and fish growth must consider multiple parameters, including feeding schemes, dosage, nutrition, fermentation processes, microbiota roles, and species differences. Previous studies have shown that increased growth correlates with the ability of fish to absorb amino acids (Debnath & Saikia, 2021; Kari *et al.*, 2022; Li *et al.*, 2021; Xing *et al.*, 2024).

Sufficient protein in fish feed enhances feed utilization efficiency (Luthada-Raswiswi *et al.*, 2021), digestive enzyme activity (Kari *et al.*, 2022), growth optimization, and regulation of lipids, blood triglycerides, and liver glycogen (Basto-Silva *et al.*, 2022; Budi *et al.*, 2015). Additionally, digestive enzyme activity is closely linked to hormone function in promoting healthy growth (Devlin *et al.*, 2004; Kobayashi *et al.*, 2007; Nam *et al.*, 2001). Therefore, feed innovations that positively influence digestive enzyme activity should be implemented (Hamidoghli *et al.*, 2020), as protein adequacy is directly linked to growth parameters.

The results of this study demonstrated that the highest protein intake, represented by the 5% feeding rate (D4), resulted in the best SGR (2.78 ± 0.17% day^{-1}). These findings align with previous research indicating that *Chanos chanos* exhibited significant growth when fed at 5% of their biomass (Islamiyah *et al.*, 2017; Mutiasari *et al.*, 2017). Similarly, Kamble *et al.* (2024) found that Nile tilapia fed at 4% of their body weight exhibited optimal growth when supplemented with guava and star gooseberry leaf extracts. Lower feeding rates, such as 3%, have also been reported to support optimal growth, particularly when using commercial feed rich in protein (Fahrurrozi *et al.*, 2023; Aryani *et al.*, 2020). Novodworski *et al.* (2024) emphasized that both feed composition and protein content significantly influence fish growth.

Azrita *et al.* (2021) reported that formulated feed with high nutritional content directly correlates with increased fish weight, reinforcing Effendie's (1979) assertion that energy requirements must be precisely calculated for optimal growth. A lack of energy leads to protein oxidation as an energy source (Page & Andrews, 1973), which is detrimental since protein is essential for fish development (Hastings & Dickie, 1972). The proximate test in this study revealed that the feed contained 28.66% protein, which falls short of the 32% required for gouramis of 3–4 cm in size (Sahwan, 2002). Despite this, treatment D4 still produced significantly higher growth rates than the other treatments, indicating that protein, fat, and carbohydrates were effectively utilized (Bardach *et al.*, 1972)

The feed conversion ratio (FCR) is an essential indicator of feed efficiency. Treatment D4 exhibited the lowest FCR (3.72 ± 0.11), suggesting the best feed utilization. However, all treatments showed relatively high FCR values, indicating suboptimal feed quality. A high FCR suggests that excess feed remains uneaten, leading to inefficiencies (Djajasewaka, 1985). Conversely, a lower FCR signifies better feed quality and efficiency. Enhancing the ability of fish to convert feed intake into biomass is crucial for reducing production costs and improving sustainability (De Verdal *et al.*, 2018). Protein content and amino acid balance significantly influence the FCR. Feeds derived from plant-based proteins often suffer from imbalanced essential amino acid compositions, negatively affecting feed conversion efficiency (Hossain *et al.*, 2003; Olvera-Novoa *et al.*, 2002). Furthermore, high fiber content in plant-based feed can reduce palatability and digestive efficiency (Mugo-Bundi *et al.*, 2015; Refstie *et al.*, 2000).

Several factors affect the FCR, including nutritional content, feed quality, palatability, and environmental conditions (Abidi & Khan, 2014; Kasumyan *et al.*, 2022). High-quality feed should be rich in amino acids such as glycine, alanine, and betaine while maintaining structural integrity and water stability (Samuelsen *et al.*, 2013). The high FCR in this study was likely due to the corncob flour used in the feed formulation, which may not have been efficiently digested by gouramis. Azrita *et al.* (2021) found that feeds with higher fiber content resulted in higher FCR values. Therefore, improving feed composition by optimizing fiber content and amino acid balance can enhance feed efficiency (De Verdal *et al.*, 2018).

Despite the highest feed efficiency being observed in treatment D4, ANOVA results did not show a significant effect of different feeding rates on feed efficiency. This was likely due to the corncobs used in the feed, which may have lost some nutritional value during processing. Additionally, since the pellets used were sinking-type, they may not have been ideally suited for gouramis, which prefer surface feeding. The quality of plant-based feed is highly dependent on processing methods. Improper processing can lead to oxidation, reducing nutritional benefits (Hemler & Hu, 2019; Possidónio *et al.*, 2021). McClements & Grossmann (2021) emphasized that fresh vegetable-based feed offers superior nutrition, whereas highly processed feeds often contain excess saturated fats with diminished quality.

The highest survival rate was observed in treatment D4 (88.89%). However, different feeding rates did not significantly impact survival, likely because the fish were maintained in optimal environmental conditions. Kordi (2009) highlighted that poor nutrition is a leading factor in reduced survival rates, while excessive fat in feed can impair liver function and overall fish health. The formulated pellets in this study contained 23% protein, 11.19% fat, and 10.18% nitrogen-free extract. The relatively high fat content (11.19%) contributed to the high survival rate observed, as fat plays a role in enhancing feed palatability. Additionally, methionine from corncob flour supports metabolic activities necessary for fish health (Gamboa-Delgado *et al.*, 2013).

Amino acids and their metabolites are crucial for metabolism and immune function in fish (Li *et al.*, 2009; Smedley *et al.*, 2016). Watford (2015) noted the increasing importance of amino acid research in optimizing fish nutrition. Since fish cannot synthesize essential amino acids, high-quality protein sources must be incorporated into their diets. Although fishmeal is the preferred protein source, concerns regarding sustainability have led researchers to explore plant-based alternatives (Luthada-Raswiswi *et al.*, 2021). While plant-based proteins can complement fishmeal, their effectiveness depends on amino acid composition and digestibility.

The survival rate in this study was high, suggesting that proper feed formulation and environmental management contributed to fish health. Werna (2008) reported that fish survival rates can reach 100% when environmental conditions are optimized, and nutritional requirements are met.

Water Quality

Scientifically, the water quality during the experiment for each treatment and repetition is presented in Table 2. Oktavianto *et al.* (2014) found that temperatures below or above the normal range (25–30°C) can cause fish to lose their appetite, which, in turn, weakens the immune system and increases mortality. Therefore, the osmoregulation response of fish to environmental pressures, such as changes in physical parameters, must be anticipated, considering that environmental factors significantly affect growth and survival. A study by Nirmala & Rasmawan (2010) found that gouramis possess labyrinth organs in their gills, allowing them to take oxygen directly from the air. This ability enables gouramis to survive even when dissolved oxygen concentrations are suboptimal.

Measurements of physical parameters confirmed that the water quality in this study met the standards set by the National Standardization Council of the Republic of Indonesia (Regulation No. 4 of 2022, amending Regulation No. 4 of 2021) concerning conformity assessment schemes for Indonesian National Standards in the agriculture, plantation, livestock, and fisheries sectors for gourami cultivation. Specifically, temperatures ranged from 25–30°C, pH levels ranged from 6.5–7.4, and DO levels ranged from 4.3–5.27 mg L^{-1}.

Optimal conditions for gourami cultivation were maintained by rejuvenating the water every 15 days. Additionally, siphoning was carried out to prevent the accumulation of uneaten food, which could otherwise degrade water quality. Water quality is a critical determinant of fish growth and survival, even when optimal feeding configurations are implemented. According to Volkoff & Rønnestad (2020), temperature and pH are the primary factors influencing feed consumption and metabolic rate in fish. A low pH can cause mucus to accumulate on the gills, eventually leading to lethargy. In such cases, the energy obtained from food is primarily used to maintain metabolism rather than support growth. Therefore, poor water quality can result in mass fish mortality over time. Moreover, dissolved oxygen plays a vital role in the respiratory system of fish.

Overall, the water quality parameters measured in this study—temperature, pH, and dissolved oxygen—were within safe limits for fish growth, as evidenced by the high survival rate (88.9%) and progressive increases in length and weight. Thus, the maintained water quality in this study contributed to the survival of gouramis, even though the feed conversion ratio was high (indicating significant feed waste) and feed efficiency was low (suggesting suboptimal feed consumption).

Table 2. Water quality of rearing water during feeding experiment on gourami using different feeding rates of corn cob-based feed

Treatment	Temperature (°C)	pH	Dissolved (mg L^{-1})
D1	26.0-27.8	6.6-7.9	4.2-6.16
D2	26.0-27.0	6.9-7.3	4.0-5.67
D3	26.0-27.6	6.9-7.8	4.1-5.27
D4	26.0-27.8	6.5-7.4	4.3-5.05

Note: D1: Feed given at 2% of the fish biomass; D2: Feed given at 3% of the fish biomass; D3: Feed given at 4% of the fish biomass; D4: Feed given at 5% of the fish biomass.

CONCLUSION

This study found that a feeding rate of 5% of fish biomass (D4) resulted in the best outcomes for absolute length, specific growth rate, and feed conversion ratio. Different feeding rates significantly influenced these parameters, while feed efficiency and survival rate remained unaffected. However, the high feed conversion ratio and low feed efficiency observed highlight the need for improved feed formulation and utilization strategies. While incorporating fish meal with alternative ingredients shows potential for feed diversification, further research is required to optimize corn cobs as a complementary feed ingredient. Future studies should focus on enhancing feed efficiency, minimizing waste, and refining feed formulations to support sustainable aquaculture. Optimizing corn cob-based feed could also contribute to waste reduction and provide economic benefits to fish farmers, promoting both environmental and financial sustainability.

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AUTHOR CONTRIBUTION

Y: conceptualization, methodology, data curation, formal analysis, investigation, writing original draft, supervision, validation, review, and editing; F: visualization, supervision, software, project administration, review, and editing; SH: investigation, project administration, supervision, review, and editing.

DECLARATION OF COMPETING INTEREST AND USE GENERATIVE AI

We declare that we have no known competing financial interests or personal relationships. No generative AI was also employed.

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