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Optimizing Growth and Survival of *Oreochromis niloticus* Using Varying Levels of Kepok Banana (*Musa balbisiana*) Peel Powder in Feed

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Abstract: This study aimed to evaluate the effects of different dietary inclusion levels of kepok banana (*Musa paradisiaca*) peel powder on the growth performance, survival, and feed efficiency of GIFT tilapia (*Oreochromis niloticus*) fry. A completely randomized design was used, consisting of four treatments: A = 0%, B = 10%, C = 15%, and D = 20% banana peel powder, with four replicates per treatment. A total of 160 fingerlings measuring 3–5 cm were reared in 16 aerated buckets for 30 days. The observed parameters included survival rate, absolute weight gain, absolute length gain, feed conversion ratio (FCR), and water quality. The FCR was calculated for each bucket using the formula: FCR = total feed consumed / total weight gain. The results showed that Treatment B, with 10% banana peel powder inclusion, produced the highest survival rate (85 ± 5.77%), absolute weight gain (2.92 ± 0.13 g), and absolute length gain (2.40 ± 0.08 cm), as well as the lowest FCR (1.63 ± 0.29). This treatment significantly outperformed the other treatments based on ANOVA analysis ($p < 0.05$). Water quality remained within optimal ranges throughout the study, with temperature ranging from 28.12 to 28.19°C, pH from 7.19 to 7.36, and dissolved oxygen from 6.13 to 6.28 ml/L. These findings indicate that 10% dietary inclusion of banana peel powder can optimize growth performance and feed efficiency without compromising survival, thereby providing a locally available alternative feed ingredient for tilapia fry.
Keywords: Dose; growth; *Musa paradisiaca*; *Oreochromis* sp.; survival rate

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INTRODUCTION

GIFT tilapia is a strain of Nile tilapia (*Oreochromis niloticus*) that has been genetically improved through selective breeding to achieve faster growth and greater adaptability in aquaculture systems (Abaho et al., 2025). According to WorldFish, GIFT tilapia was developed beginning in 1988 as an *Oreochromis niloticus* strain suitable for both small-scale and commercial aquaculture, with the primary objective of improving growth performance (Eknath & Acosta, 1998). In Indonesia, tilapia is recognized as one of the strategic commodities in aquaculture. Data from KKP (2023) indicate that national tilapia production in 2022 reached 1,421,597 tons, with an estimated value of approximately Rp36.85 trillion, positioning Indonesia as the world's second-largest tilapia producer after China. Market trends also suggest strong prospects, as global tilapia imports in 2022 were valued at USD 1.64 billion, with the highest demand recorded for frozen fillet products. These conditions indicate that improving the efficiency of tilapia farming, including GIFT tilapia culture, is directly relevant to increasing productivity and strengthening the competitiveness of the aquaculture sector.

A major constraint in tilapia farming is the high cost of feed. Sinaga et al. (2021) and Benzie and Vandeputte (2017) reported that, in intensive farming systems, commercial feed may account for approximately 60–70% of total production costs; therefore, fluctuations in feed prices can substantially affect farmers' profit margins.

Similarly, studies on tilapia aquaculture by Magondu et al. (2025) and Omasaki et al. (2017) showed that feed purchases can absorb around 70% of production costs. At the same time, the supply of feed raw materials remains highly dependent on imports, contributing to the continued increase in commercial feed prices. This dependence represents a serious challenge because production efficiency is determined not only by fish growth performance, but also by farmers' ability to access feed ingredients that are affordable, locally available, and nutritionally adequate.

One promising approach to reducing feed costs is the utilization of agricultural waste as an alternative feed ingredient, including kepok banana peels. According to Ilmi (2021), kepok banana is taxonomically classified as *Musa balbisiana*. Kepok banana peels have potential as a raw material for fish pellet production because they contain carbohydrates, protein, vitamin C, and fat. Hasan et al. (2024) and Jeharu et al. (2015) reported that kepok banana peels contain 1.27% carbohydrates, 1.71% protein, 0.30% vitamin C, and 3.28% fat. However, this material also has several limitations, particularly its crude fiber content and antinutritional compounds, which may reduce digestibility when used at excessive levels. Therefore, its inclusion in fish feed must be evaluated at appropriate doses to prevent negative effects on feed intake, feed efficiency, growth, and survival.

Several previous studies have investigated the use of banana-based materials in fish feed. Hasan et al. (2024), in a study on *Oreochromis niloticus* fingerlings, showed that banana peel supplementation affected weight gain and feed conversion ratio, with a 2% inclusion level producing better feed conversion ratio and survival than several other treatments. Rahmatillah et al. (2026) examined kepok banana peel as a feed additive for tilapia fry and reported that the addition of kepok banana peel extract at 25% per kg of feed resulted in the highest weight gain, length growth, and survival rate. Fermented banana peel has also been evaluated as an alternative protein source in hybrid tilapia diets, with findings indicating that molasses-fermented banana peel can partially replace fish meal without impairing growth performance at low to moderate inclusion levels (Yusuf et al., 2022). Nevertheless, existing studies remain limited by differences in the form of test materials, such as extracts, flour, fruit waste, or fermented products; variation in fish species or strains; and the absence of consistent economic analyses linking biological performance with feed cost efficiency.

Based on these gaps, this study aimed to analyze the effects of different doses of kepok banana peel powder on the growth and survival of GIFT tilapia (*Oreochromis niloticus*). The study hypothesized that the inclusion of banana peel powder at low to moderate doses would improve or maintain the growth and survival performance of GIFT tilapia compared with the control, whereas excessive doses may reduce performance due to increased crude fiber content or reduced feed palatability. From a practical perspective, this study is expected to contribute to the development of alternative feeds derived from locally available agricultural waste.

METHOD

This study was a quantitative experimental study designed to evaluate the effect of different inclusion levels of kepok banana peel meal in feed on the growth performance and survival rate of GIFT tilapia (*Oreochromis niloticus*). The experiment was conducted using a non-factorial completely randomized design consisting of four dietary treatments and four replicates. The main treatment factor was the percentage of kepok banana peel meal added to the feed, namely 0%, 10%, 15%, and 20%. The observed responses included absolute weight gain, absolute length growth, survival rate, feed conversion ratio, and water quality parameters. This design was used to determine whether different doses of kepok banana peel meal produced significant differences in the biological performance of GIFT tilapia.

Time and Location

This study was conducted in November 2025 at Sinta Farm, Jl. Limau Mungkur, Dusun I, Bangun Rejo Village, Tanjung Morawa Subdistrict, Deli Serdang Regency, Indonesia.

Experimental Fish, Containers, and Materials

A total of 160 GIFT tilapia fingerlings, with an initial length of 3–5 cm, were used in this study. The fish were randomly distributed into 16 plastic buckets, each containing 20 L of water, at a stocking density of 10 fish per bucket. Each bucket was equipped with an aeration system and was considered one experimental unit (Tahya et al., 2025).

The equipment used in this study included a ruler, digital scale, aerator, air hose, air stone, thermometer, pH meter, dissolved oxygen (DO) meter, and feed-making equipment. The feed ingredients consisted of kepok banana peel meal, soybean meal, wheat flour, fish meal, maize flour, fine rice bran, and water.

Experimental Design

This study employed a non-factorial completely randomized design consisting of four treatments and four replicates (Aisyah & Gustiningrum, 2021; Manullang, 2020). Each bucket served as one experimental unit, resulting in a total of 16 experimental units. The treatments were arranged as follows:

- Treatment A: 0% kepok banana peel meal
- Treatment B: 10% kepok banana peel meal
- Treatment C: 15% kepok banana peel meal
- Treatment D: 20% kepok banana peel meal

The positions of the buckets were randomized to minimize positional bias caused by differences in light exposure, aeration distribution, or surrounding environmental conditions. The layout of the experimental units is presented in Figure 1.

A1	B2	C2	A3
C4	D4	B4	B3
B1	C3	A4	D2
D3	A2	D1	C1

Figure 1. Layout of the experimental setup

Pellet Formulation

The feed used in this study was formulated from a mixture of raw materials, including kepok banana peel meal, fish meal, rice bran, maize flour, and wheat flour. Feed formulation was designed to produce pellets containing approximately 28–30% protein, with different inclusion levels of kepok banana peel meal according to the assigned treatments. The amount of kepok banana peel meal required for each 1 kg feed formulation was calculated as follows:

- 10% kepok banana peel meal = 10/100 × 1 kg = 0.10 kg = 100 g
- 15% kepok banana peel meal = 15/100 × 1 kg = 0.15 kg = 150 g
- 20% kepok banana peel meal = 20/100 × 1 kg = 0.20 kg = 200 g

To prepare the experimental feeds, the raw materials were weighed according to the kepok banana peel meal inclusion level in each treatment, while water was added as needed during the pelleting process.

For the feed containing 10% kepok banana peel meal, the formulation consisted of:

- Kepok banana peel meal: 0.10 kg
- Fish meal : 0.24 kg
- Rice bran : 0.17 kg
- Maize flour : 0.17 kg
- Wheat flour: 0.17 kg

For the feed containing 15% kepok banana peel meal, the formulation consisted of:

- Kepok banana peel meal: 0.15 kg
- Fish meal : 0.24 kg
- Rice bran : 0.17 kg
- Maize flour : 0.17 kg
- Wheat flour: 0.17 kg

For the feed containing 20% kepok banana peel meal, the formulation consisted of:

- Kepok banana peel meal: 0.20 kg
- Fish meal : 0.24 kg
- Rice bran : 0.17 kg
- Maize flour : 0.17 kg
- Wheat flour: 0.17 kg

Observed Parameters

The parameters observed in this study included absolute weight gain, absolute length growth, survival rate, feed conversion ratio, and water quality. Fish weight and length were measured every seven days. Water quality parameters, including temperature, pH, and dissolved oxygen, were measured weekly in the morning at approximately 09:00 (Manullang, 2020). All measuring instruments were calibrated before use to ensure measurement accuracy.

Absolute weight gain was calculated using the following formula:

$$W = W_t - W_0$$

Note:
W : absolute weight gain
Wt : final body weight
W0 : initial body weight.

Absolute length growth was calculated using the following formula:

$$L = L_t - L_0$$

Note:
L : absolute length growth
Lt : final body length
L0 : initial body length.

Survival rate was calculated using the following formula:

$$SR = \frac{Nt}{N0} X\ 100\%$$

Note:
SR : survival rate
Nt : the number of fish at the end of the experiment
N0 : the number of fish at the beginning of the experiment.

Feed conversion ratio was calculated using the following formula:

$$FCR = \frac{Total\ feed\ consumed}{Total\ biomass\ gain}$$

If mortality occurred, the biomass of dead fish was included in the biomass gain calculation when available. The feed conversion ratio was calculated separately for each experimental unit, rather than only once for each treatment, to allow appropriate statistical analysis (Melanie et al., 2024).

Data Analysis

The experimental unit for statistical analysis was the bucket rather than the individual fish. Accordingly, all data on growth performance, survival, and feed conversion ratio (FCR) were first aggregated at the bucket level. The results are presented as mean ± standard deviation. Prior to statistical analysis, the assumptions of normality and homogeneity of variance were evaluated. Normality was assessed using the Shapiro–Wilk test, whereas homogeneity of variance was examined using Levene's test or Bartlett's test, as appropriate.

Data that satisfied these assumptions were analyzed using one-way analysis of variance (ANOVA) at a 5% significance level. The ANOVA results were reported in standard statistical format, including the F-value, degrees of freedom, and p-value. When ANOVA indicated a significant treatment effect, mean comparisons were performed using the Least Significant Difference test at $p < 0.05$. Significant differences among treatments were denoted by different superscript letters in the table, whereas treatments sharing the same superscript letter were considered not significantly different. Statistical decisions were based on the p-value rather than the criterion "F-value < 0.05." The null hypothesis was rejected when $p < 0.05$ (Yusuf et al., 2022; Aisyah & Gustiningrum, 2021; Hossain & Shefat, 2021).

RESULTS AND DISCUSSION

Growth Performance

Based on data analysis, the mean, standard deviation, and ANOVA results for survival rate and growth performance were obtained. The complete results are presented in Table 1.

Table 1. Statistical test results for survival rate and growth performance of tilapia

Parameter	A (0%) Mean ± SD	B (10%) Mean ± SD	C (15%) Mean ± SD	D (20%) Mean ± SD	Sig.
Survival rate (%)	67.50 ± 5.00	85 ± 5.77	72.50 ± 5	65 ± 5.77	0.001
Absolute weight gain (g)	2.51 ± 0.19	2.92 ± 0.13	2.85 ± 0.15	2.49 ± 0.17	0.005
Absolute length growth (cm)	2.25 ± 0.17	2.40 ± 0.08	2.35 ± 0.06	1.95 ± 0.21	0.004

The statistical analysis showed that Treatment B, which contained 10% Kepok banana peel flour, produced the best overall performance across the three main parameters: survival rate, absolute weight gain, and absolute length gain. This treatment resulted in the highest survival rate, reaching 85.00 ± 5.77%, as well as the greatest absolute weight gain of 2.92 ± 0.13 g and absolute length gain of 2.40 ± 0.08 cm. Treatment B differed significantly from the other treatments in terms of survival rate and weight gain. For length gain, Treatment B was not significantly different from Treatments A and C, but it differed significantly from Treatment D.

These findings indicate that the inclusion of 10% Kepok banana peel flour represents the optimal dose for supporting the survival and growth performance of tilapia fry. This inclusion level likely provided a suitable balance between the nutritional contribution of Kepok banana peel flour and the ability of the fish to consume and utilize the feed efficiently. At this level, the additive may not have substantially reduced feed palatability, increased crude fiber beyond an acceptable threshold, or impaired nutrient utilization. In contrast, the decline in performance observed at the 20% inclusion level suggests that excessive substitution may reduce diet quality, particularly in terms of digestibility and the balance between dietary energy and protein.

Biologically, the improved performance at the 10% inclusion level may be explained by several factors. First, Kepok banana peel flour may contribute carbohydrates as an energy source, thereby allowing a greater proportion of dietary protein to be used for growth rather than energy metabolism. Second, excessive inclusion may increase dietary crude fiber, which can reduce digestibility and feed intake. Third, vitamins and bioactive compounds present in banana-based ingredients may support the physiological condition of fish. However, this interpretation should be made cautiously because proximate composition and digestibility data were not available in the present study.

These results are consistent with previous studies on the use of banana peel flour or banana-based ingredients as alternative feed components to improve growth performance and survival in various fish species. Jeharu et al. (2015) reported that the use of Kepok banana peel flour in tilapia feed formulations produced favorable results at a 20% inclusion level, with a weight gain of 2.93 g, followed closely by the 10% inclusion level, with a weight gain of 2.90 g. Other studies have also shown that local banana-based substitute ingredients can support fish growth and survival, although their effectiveness depends strongly on maintaining appropriate inclusion levels (Tahya et al., 2025; Mulyani et al., 2023; Yusuf et al., 2022). Similarly, Melanie et al. (2024) reported that the 10% banana peel flour treatment produced the best growth and survival performance in carp.

Feed Conversion Ratio

The feed conversion ratio (FCR) was lowest in Treatment B, indicating better feed efficiency compared with the other treatments. FCR is an important indicator of feed utilization efficiency because it reflects the amount of feed required to produce a unit increase in fish biomass. Therefore, a lower FCR indicates more efficient feed conversion (Muarif et al., 2021). The FCR values for each replicate are presented in Table 2.

Table 2. FCR of GIFT tilapia fry under different Kepok banana peel flour treatments

Reflication	Treatment			
	A (0%)	B (10%)	C (15%)	D (20%)
1	2.35	1.92	1.57	2.11
2	2.15	1.36	2.06	3.17

Reflication	Treatment			
	A (0%)	**B (10%)**	**C (15%)**	**D (20%)**
3	3.21	1.41	2.14	2.57
4	2.67	1.83	1.96	3.25
Mean ±SD	2.60 ± 0.46	1.63 ± 0.29	1.93 ± 0.25	2.78 ± 0.54

Treatment A, which served as the control, had an average FCR of 2.60 ± 0.46, indicating that 2.60 g of feed was required to produce 1 g of body weight gain. In Treatment B, the FCR decreased markedly to 1.63 ± 0.29, representing the lowest value among all treatments. This result suggests that the inclusion of 10% Kepok banana peel flour produced the most efficient feed utilization.

Table 3. Analysis of variance for FCR

Source of Variation	Sum of Squares	df	Mean Square	F-value	F-table	
					5 %	**1%**
Treatment	3.51	3	1.17	7.22**	3.49	5.95
Error	1.94	12	0.16			
Total	5.45	15	1.33			

The ANOVA results showed that different levels of Kepok banana peel flour had a highly significant effect on the FCR of tilapia. The calculated F-value of 7.22 was higher than the F-table values at both the 5% level (3.49) and the 1% level (5.95), indicating that the null hypothesis was rejected. This finding supports previous studies showing that banana peel-based feed ingredients can affect feed efficiency, growth performance, and survival in tilapia when incorporated at appropriate levels (Gonzales-Plasus et al., 2022; Rahmatillah et al., 2026). Similarly, Intharathat et al. (2024) reported that fermented banana peel meal could be included in tilapia diets at suitable levels without adverse effects on growth or feed utilization. In the present study, the treatment mean square value of 1.17 was higher than the error mean square of 0.16, indicating that variation in FCR was more strongly influenced by treatment than by random error.

Treatment C, containing 15% Kepok banana peel flour, produced an FCR of 1.93 ± 0.25. This value was still better than that of the control but was less efficient than Treatment B. In contrast, Treatment D, containing 20% Kepok banana peel flour, produced the highest FCR value of 2.78 ± 0.54, indicating the lowest feed efficiency. Biologically, this decrease in efficiency may have occurred because excessive banana peel flour inclusion can increase dietary crude fiber and reduce digestibility or palatability. Previous digestibility studies on banana peel in GIFT Nile tilapia have also indicated that banana peel has nutritional potential, but its use must be carefully managed because digestibility and feed utilization depend on the inclusion level and processing method (Yossa et al., 2021). Therefore, the present findings suggest that 10% Kepok banana peel flour is the most efficient inclusion level for improving FCR, whereas excessive inclusion may reduce feed utilization efficiency.

Water Quality Monitoring

The complete data on water quality parameters, including temperature, pH, and dissolved oxygen, observed during the study period are presented in Table 4.

Table 4. Water quality parameters during the 30-day rearing period

Treatment	Temperature (°C) Mean ±SD	pH Mean ±SD	DO (ml/L) Mean ±SD
A (0 %)	28.13 ± 0.59	7.19 ± 0.50	6.13 ± 0.86
B (10 %)	28.19 ± 0.65	7.34 ± 0.46	6.14 ± 0.89

Treatment	Temperature (°C) Mean ±SD	pH Mean ±SD	DO (ml/L) Mean ±SD
C (15%)	28.12 ± 0.64	7.31 ± 0.37	6.24 ± 0.86
D (20 %)	28.19 ± 0.59	7.36 ± 0.39	6.28 ± 1.01

During the rearing period, water temperature remained relatively stable across all treatments, ranging from 28.12 ± 0.64°C to 28.19 ± 0.65°C. The pH values ranged from 7.19 ± 0.50 to 7.36 ± 0.39, while dissolved oxygen ranged from 6.13 ± 0.86 to 6.28 ± 1.01 mL/L. These results indicate that the rearing water conditions were generally stable and suitable for GIFT tilapia fingerlings. The recorded values were also consistent with the acceptable water quality ranges for tilapia culture reported in previous studies, namely temperatures of approximately 24–30°C, pH values of approximately 6.5–8.5, and dissolved oxygen levels above the minimum threshold required for normal fish growth and survival (Nurwahida et al., 2024; Lutviana et al., 2020).

Water quality is an important external factor that affects feed intake, metabolism, growth, and survival in cultured fish. In the present study, temperature, pH, and dissolved oxygen were relatively similar among treatments, suggesting that environmental conditions were not the main source of variation in fish performance. The mean temperature of approximately 28°C was within the optimum range for tilapia fry growth. Leonard and Skov (2022) reported that tilapia fry perform well within an optimum temperature range of 22–30°C, while Khallaf et al. (2021) emphasized that temperature affects growth performance, feed intake, and feed conversion in *Oreochromis niloticus*. These findings indicate that the temperature conditions in the present study were adequate to support normal metabolic activity and feed utilization.

The pH values observed in this study were also within a suitable range for tilapia culture. The mean pH values ranged from 7.19 to 7.36, indicating neutral to slightly alkaline water conditions. This range is appropriate for tilapia fingerlings because pH values of approximately 6.5–8.5 are generally considered suitable for growth and survival. Nurwahida et al. (2024) stated that unsuitable pH conditions can inhibit fish growth; however, the values recorded in the present study did not indicate acidic or highly alkaline stress. Therefore, pH was unlikely to be a limiting factor affecting growth, survival, or feed conversion.

Dissolved oxygen also remained at acceptable levels in all treatments, with mean values ranging from 6.13 to 6.28 mL/L. These values were above the minimum level commonly required for tilapia fingerlings. Lutviana et al. (2020) reported that dissolved oxygen levels above 3.5 mg/L can support fish growth and survival, particularly when aeration is provided. Thus, the DO values in the present study suggest that oxygen availability was sufficient to support respiration, metabolism, and feed utilization.

Overall, the water quality results strengthen the interpretation that the observed differences in growth performance and FCR were more likely related to feed formulation than to environmental stress. Because temperature, pH, and dissolved oxygen remained within acceptable ranges across all treatments, the superior performance observed in the 10% Kepok banana peel flour treatment can be more reasonably attributed to an appropriate balance in dietary composition, feed acceptability, and feed efficiency rather than to differences in water quality.

CONCLUSION

This study demonstrated that the inclusion of 10% kepok banana peel powder in the diet of tilapia fry optimized growth performance, survival, and feed efficiency. Treatment B produced the highest survival rate (85 ± 5.77%), weight gain (2.92 ± 0.13

g), and length gain (2.40 ± 0.08 cm), while also achieving the lowest feed conversion ratio (FCR) (1.63 ± 0.29). These results indicate more efficient feed utilization at this inclusion level. Water quality remained within suitable ranges across all treatments, suggesting that the observed differences in fish performance were primarily attributable to dietary composition rather than environmental variation. Moderate supplementation with kepok banana peel powder enhanced growth and feed efficiency, whereas excessive inclusion at 20% reduced performance, likely due to increased fiber content that may have lowered digestibility and feed palatability. Overall, these findings indicate that kepok banana peel powder has potential as a sustainable, locally available feed ingredient for tilapia aquaculture.

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