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Effect of Supplementing Feed with Kepok Banana Peel Extract (*Musa balbisiana* Colla) on the Growth and Survival Rate of Nile Tilapia (*Oreochromis niloticus*) Fry

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Abstract: This study aimed to analyze the effect of kepok banana peel extract (*Musa balbisiana* Colla) as a feed additive on the growth and survival of Nile tilapia (*Oreochromis niloticus*) fry, as well as to identify the optimum dosage. The study was motivated by the high cost of feed and the underutilization of agricultural waste as a functional feed ingredient. An experimental method employing a completely randomized design (CRD) was used, consisting of four treatments and three replicates: feed without extract (control) and feed supplemented with kepok banana peel extract at doses of 150, 200, and 250 g/kg feed. The experiment involved 12 experimental units stocked with Nile tilapia fry with an initial average size of ±3 cm and reared for 28 days. The observed parameters included absolute weight gain, absolute length gain, and survival rate. Data were analyzed using analysis of variance (ANOVA), followed by the least significant difference (LSD) test at the 5% significance level. The results showed that supplementation with kepok banana peel extract had a highly significant effect (P<0.01), indicating that the treatments produced statistically significant differences at a 99% confidence level. Further analysis revealed that each treatment differed significantly, with growth increasing in line with increasing extract dosage. The treatment at a dose of 25% per kg feed produced the highest growth, with an absolute weight gain of 5.43 g, an absolute length gain of 4.43 cm, and a survival rate of 86.6%. Water quality remained within the optimal range throughout the study. These findings indicate that kepok banana peel extract has potential as a natural feed additive that supports waste utilization and the sustainability of Nile tilapia aquaculture.
Keywords: *Oreochromis niloticus*; *Musa balbisiana*; feed additive; growth performance; survival rate

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INTRODUCTION

Tilapia (*Oreochromis niloticus*) is one of the leading commodities in freshwater aquaculture due to its high environmental adaptability, rapid growth rate, and substantial economic value. Consequently, tilapia is widely cultivated under both intensive and semi-intensive farming systems in many developing countries, including Indonesia. However, successful tilapia production is determined not only by genetic and environmental factors, but also by efficient and sustainable feed management.

In aquaculture practice, feed accounts for more than 50–70% of total production costs, making feed utilization efficiency a key factor in determining the profitability of farming operations (El-Sayed, 2020). During the seed stage, feed efficiency becomes even more critical because this phase is the most vulnerable to environmental stress and fluctuations in water quality, both of which can directly affect growth and survival. Inefficient conversion of feed into biomass often results in suboptimal growth and increased mortality, thereby reducing overall aquaculture productivity (Hasan et al., 2021). Therefore, innovations aimed at improving feed efficiency have become an urgent necessity in modern aquaculture systems.

One approach that has gained increasing attention in recent years is the use of natural feed additives. Natural additives, such as plant extracts, probiotics, and

agricultural waste-based materials, have been reported to enhance nutrient utilization efficiency, improve metabolism, and strengthen the immune system of fish (Dawood et al., 2018; Fitrianingrum, 2023). In addition, natural additives offer advantages over synthetic compounds because they are safer, more environmentally friendly, and do not leave harmful residues in fishery products (Reverter et al., 2014). Thus, the exploration of natural materials as feed additives represents a relevant strategy for supporting sustainable aquaculture.

One potentially valuable yet underutilized natural resource is kepok banana peel waste. Banana peels are known to contain various bioactive compounds, such as flavonoids, phenolic compounds, and fiber, which exhibit antioxidant activity and may improve the metabolic efficiency of aquatic organisms (Someya et al., 2002; Zalukhu et al., 2023). Flavonoids and phenolic compounds play an important role in reducing oxidative stress, thereby allowing energy derived from feed to be allocated more efficiently toward growth. Meanwhile, fiber content at appropriate levels may support digestion and nutrient absorption.

Nevertheless, most previous studies have utilized banana peels in fermented form or as a direct supplementary feed ingredient, rather than as an extract enriched with active compounds. An extraction-based approach has the potential to increase the availability and concentration of bioactive compounds, thereby optimizing their physiological effects on fish. However, studies on the use of kepok banana peel extract as a feed additive for tilapia seed, particularly regarding dose effectiveness on growth and survival, remain very limited.

This research gap highlights the need for a more specific and measurable investigation into the use of kepok banana peel extract in tilapia feed. Therefore, this study offers a novel approach by applying kepok banana peel extract directly into feed as a source of bioactive compounds at controlled dosage levels. This approach is expected to improve nutrient utilization efficiency, enhance growth performance, and increase the survival of tilapia seed.

This study aims to analyze the effects and evaluate the effectiveness of kepok banana peel extract supplementation in feed on the growth and survival of tilapia seed, as well as to determine the optimum dose that yields the best results. Growth performance was assessed based on absolute weight gain and absolute length gain, while survival was evaluated using the survival rate. The findings of this study are expected not only to provide a theoretical contribution to the development of functional feeds based on agricultural waste, but also to offer practical benefits in improving feed cost efficiency and the sustainability of tilapia farming systems (Saputra et al., 2024).

METHOD

This study employed an experimental method using a Completely Randomized Design (CRD) consisting of four treatments and three replicates. The experimental fish were Nile tilapia (*Oreochromis niloticus*) fingerlings with an average initial size of approximately ± 3 cm. A total of 12 experimental units were used, each stocked with Nile tilapia fingerlings and maintained for 28 days. The treatments were as follows:

P0: feed without extract supplementation (control)
P1: feed supplemented with kepok banana peel extract at 150 g/kg feed
P2: feed supplemented with kepok banana peel extract at 200 g/kg feed
P3: feed supplemented with kepok banana peel extract at 250 g/kg feed

Preparation and Application of Kepok Banana Peel Extract

Kepok banana peel extract was prepared using a maceration method with 96% ethanol as the solvent. The banana peels were thoroughly washed, dried, and ground

into powder. A total of 100 g of powder was soaked in 500 mL of ethanol for 3 × 24 h with periodic stirring. The filtrate was then filtered and evaporated to obtain a concentrated extract. The extract was subsequently applied to the feed using a coating method at 70–80°C by dissolving the extract according to the treatment dose, spraying it evenly onto the feed, and air-drying it before use.

Rearing of Fish Fingerlings

Nile tilapia fingerlings were reared for 28 days in culture containers at a stocking density of approximately ±1 fish/L. The containers were maintained under indoor environmental conditions to minimize fluctuations in external factors. During the rearing period, continuous aeration was provided for 24 h using an aerator to maintain stable dissolved oxygen levels in the culture medium. Feed was administered three times daily at 08:00, 12:00, and 16:00 WIB at a rate of 5% of biomass. Feed quantity was adjusted every seven days based on biomass measurements. Water exchange was carried out every two days by replacing 30–40% of the total media volume. Fish health condition and feeding activity were monitored daily throughout the rearing period.

Observed Parameters

The observed parameters included absolute weight growth, absolute length growth, and survival rate. Absolute weight growth was calculated as the difference between final and initial fish weight, whereas absolute length growth was calculated as the difference between final and initial fish length. Survival rate was determined based on the ratio of the number of fish alive at the end and at the beginning of the experiment.

Samples were collected randomly from each experimental unit to represent the fish population in each treatment. Observations were conducted periodically at the beginning, middle (day 14), and end (day 28) of the rearing period. Fish weight and length were measured using a digital balance and a ruler, respectively, while survival rate was calculated at the end of the experiment based on the number of fish remaining alive.

1. Absolute Weight Growth (BM)

The calculation was performed using the formula according to Effendie (1997):

$$\boldsymbol{BM = W_t - W_0}$$

Note:
BM = absolute weight growth (g)
W_t = average fish weight at the end of the rearing period (g)
W_0 = average fish weight at the beginning of the rearing period (g)

2. Absolute Length Growth (PM)

The calculation was performed using the formula according to Effendie (1997):

$$\boldsymbol{PM = L_t - L_0}$$

Note:
PM = absolute length growth (cm)
L_t = average fish length at the end of the rearing period (cm)
L_0 = average fish length at the beginning of the rearing period (cm)

3. Survival Rate (SR)

The calculation was performed at the end of the experiment using the following formula:

$$SR(\%) = \frac{N_t}{N_0} \times 100$$

Note:
SR = survival rate (%)
N_t = number of fish alive at the end of the rearing period (individuals)
N_0 = number of fish at the beginning of the rearing period (individuals)

4. Water Quality

Water quality parameters were observed as supporting variables, including temperature (°C), acidity (pH), and dissolved oxygen (DO). Measurements were taken every two days throughout the study, both in the morning (around 08:00 WIB) and in the afternoon (around 16:00 WIB), to obtain an overview of daily water quality fluctuations. Temperature was measured using a thermometer, pH using a pH meter, and dissolved oxygen using a DO meter. Prior to use, all measuring instruments were calibrated according to standard procedures to ensure measurement accuracy. The resulting water quality values were then compared with the optimal ranges for Nile tilapia fingerling culture, namely temperature of 25–30°C, pH of 6.5–8.5, and dissolved oxygen >5 mg/L, which are considered suitable for supporting the growth and survival of Nile tilapia (Nugroho and Sari, 2022).

Data Analysis

The observational data were analyzed using analysis of variance (ANOVA) at the 95% and 99% confidence levels to determine the effect of treatments on the observed parameters. Prior to analysis, the data were tested for statistical assumptions, including normality using the Shapiro–Wilk test and homogeneity of variance using Levene's test. If the ANOVA results indicated a significant difference ($P<0.05$) or a highly significant difference ($P<0.01$), the analysis was followed by the Least Significant Difference (LSD) test at the 5% level to determine differences among treatments.

RESULTS AND DISCUSSION

The effects of kepok banana peel extract on the growth performance and survival of Nile tilapia fry during the 28-day rearing period are presented and discussed below.

Growth Performance and Survival

For an overall comparison of treatment responses, the final values of absolute weight gain, absolute length gain, and survival rate are presented in Table 1.

Table 1. Final growth performance and survival of Nile tilapia fry fed diets supplemented with kepok banana peel extract

Treatment	Absolute Weight Gain (g)	Absolute Length Gain (cm)	Survival Rate (%)
P0 (Control)	3,43 ± 0,25^a	3,10 ± 0,26^a	78,3 ± 2,89
P1 (15%)	4,13 ± 0,15^b	3,63 ± 0,06^b	75,0 ± 5,00
P2 (20%)	4,80 ± 0,20^c	4,00 ± 0,17^c	85,0 ± 5,00
P3 (25%)	5,43 ± 0,15^d	4,43 ± 0,06^d	86,6 ± 2,89

Note: P0 = without extract; P1 = 15%/kg feed; P2 = 20%/kg feed; P3 = 25%/kg feed. Different superscript letters within the same column indicate significant differences based on the Least Significant Difference (LSD) test at the 5% significance level ($p < 0.05$).

As shown in Table 1, dietary supplementation with kepok banana peel extract improved the growth performance of Nile tilapia fry, with the highest absolute weight gain and absolute length gain recorded in treatment P3. Survival also tended to be higher in P2 and P3 than in P0 and P1. Taken together, these data indicate a positive

response to increasing extract inclusion within the tested range. This response is biologically plausible because banana peel is known to contain phenolic compounds, flavonoids, dietary fiber, and other bioactive constituents that may contribute to antioxidant protection and functional nutritional effects (Vu et al., 2018; Zaini et al., 2022).

The potential relevance of these compounds to aquaculture should also be considered. Recent reviews have shown that natural antioxidants and phytogenic feed additives can mitigate oxidative stress, support immune competence, and improve overall growth performance in cultured fish, including Nile tilapia (Hu et al., 2025; Gruber et al., 2025). Thus, the positive treatment response observed in the present study is consistent with the broader literature on plant-derived feed additives in aquaculture.

Absolute Weight Gain

To determine whether the dietary treatments significantly affected absolute weight gain, the ANOVA results are presented in Table 2.

Table 2. Analysis of variance (ANOVA) for absolute weight gain

Source of Variation	SS	df	MS	F-value	F-table	
					5%	1%
Treatment	6.67	3	2.22	59.29**	4.07	7.59
Error	0.3	8	0.04			
Total	6.97	11				

Note: ** highly significant.

As presented in Table 2, dietary supplementation with kepok banana peel extract had a highly significant effect on absolute weight gain. The calculated F-value (59.29) was substantially higher than the critical F-values at both the 5% and 1% levels, confirming that the treatments produced statistically different responses. Referring again to Table 1, treatment P3 produced the highest absolute weight gain (5.43 ± 0.15 g), followed by P2, P1, and P0.

The superior weight gain in P3 suggests that higher inclusion of kepok banana peel extract improved nutrient utilization and growth efficiency. This effect may be associated not only with the nutritional contribution of the extract, but also with the activity of phenolic and flavonoid compounds, which are widely recognized as important natural antioxidants. In aquaculture systems, oxidative stress can reduce growth efficiency by diverting metabolic resources away from tissue accretion, whereas antioxidant supplementation may help maintain cellular function and improve productive performance (Hu et al., 2025). Banana peel itself has been reported to be rich in phenolic compounds and related bioactives with antioxidant properties (Vu et al., 2018; Zaini et al., 2022).

These findings are also in line with Fitrianingrum (2023) and Saputra et al. (2024), who reported that natural or locally sourced feed additives can improve fish growth. In a broader tilapia context, phytogenic additives have likewise been shown to enhance growth performance and resilience in Nile tilapia (Gruber et al., 2025). The relatively strong response in the present study may also be related to the use of the extract form, because extraction can increase the yield and availability of phenolic compounds and antioxidant activity compared with less processed materials (Islam et al., 2023).

Nevertheless, the positive response at the highest tested dose should be interpreted carefully. Although P3 gave the best result under the present conditions, additional increases beyond the tested range may not necessarily produce further

benefit. Plant-derived additives can become less effective at excessive inclusion levels if they alter feed palatability or impose metabolic constraints. Therefore, the biological optimum of kepok banana peel extract should be verified through further dose-response trials. This caution is also consistent with recent reviews emphasizing the need to optimize phytogenic additive dosage and formulation in aquafeeds (Hu et al., 2025; Gruber et al., 2025).

Absolute Length Gain

To assess whether the treatments also significantly influenced linear growth, the ANOVA results for absolute length gain are presented in Table 3.

Table 3. Analysis of variance (ANOVA) for absolute length gain

Source of Variation	SS	df	MS	F-value	F-table	
					5%	1%
Treatment	2.87	3	0.95	35.9**	4.07	7.59
Error	0.23	8	0.02			
Total	3.10	11				

Note: ** highly significant.

Table 3 shows that the treatments also had a highly significant effect on absolute length gain. The calculated F-value (35.9) exceeded the critical F-values at both significance levels, indicating that dietary supplementation with kepok banana peel extract significantly affected linear growth. As shown in Table 1, the highest absolute length gain was also recorded in P3 (4.43 ± 0.06 cm), followed by P2, P1, and P0.

The consistency between the weight and length responses suggests that the extract supported balanced somatic growth rather than weight gain alone. This is an important point because linear growth is closely related to overall structural development and reflects effective nutrient assimilation over time. Banana peel has been described as a source of nutritional and bioactive components, including dietary fiber and phenolic compounds, which may help support digestive function and physiological efficiency (Zaini et al., 2022; Vu et al., 2018). In addition, the broader aquaculture literature indicates that natural antioxidants and phytogenic feed additives can support better performance by improving stress tolerance and metabolic stability (Hu et al., 2025; Gruber et al., 2025).

The present result is therefore consistent with Hasan et al. (2021), who emphasized the importance of nutrient balance and feed utilization efficiency for fish growth. Compared with Fitrianingrum (2023), the increase in fish length observed here appears relatively greater, especially in P3. One plausible explanation is the form of the additive used. Extract-based supplementation may increase the accessibility of phenolic compounds and antioxidant fractions, as efficient extraction methods are known to improve the recovery and activity of banana peel phenolics (Islam et al., 2023). However, the observed response could also have been influenced by other experimental factors, such as initial fish size, rearing duration, and basal diet quality.

Survival Rate

To facilitate a clearer evaluation of treatment effects on viability, the survival data are summarized separately in Table 4.

Table 4. Survival rate of Nile tilapia fry fed diets supplemented with kepok banana peel extract

Treatment	Survival Rate (%)
P0 (Control)	78.3 ± 2.89
P1 (15%)	75.0 ± 5.00
P2 (20%)	85.0 ± 5.00
P3 (25%)	86.6 ± 2.89

Based on Table 4, the highest survival rate was observed in P3 (86.6 ± 2.89%), followed closely by P2 (85.0 ± 5.00%), while the lowest value was recorded in P1 (75.0 ± 5.00), even lower than the control. According to the statistical analysis, P2 and P3 were not significantly different ($p > 0.05$), but both differed significantly from P0 and P1 ($p < 0.05$). These results indicate that the beneficial effect of kepok banana peel extract on survival became more evident at inclusion levels of 20% and 25%.

The lower survival observed in P1 may reflect an early adaptation response to the supplemented diet. At a relatively low inclusion level, the extract may not yet have provided a sufficiently strong physiological benefit, while still influencing palatability or feed intake. By contrast, the higher survival in P2 and P3 may be associated with the antioxidant action of phenolic and flavonoid compounds, which can help reduce oxidative stress and support physiological stability. Reviews on aquaculture nutrition have emphasized that natural antioxidants can enhance stress tolerance, health status, and performance in cultured aquatic animals (Hu et al., 2025), while phytogenic feed additives in Nile tilapia have shown beneficial effects on productivity and resistance (Gruber et al., 2025).

In addition to dietary factors, survival in tilapia culture is strongly influenced by water quality. FAO guidance on tilapia culture identifies temperature, dissolved oxygen, and pH as key variables that must be routinely monitored, and FAO training materials indicate that tilapia performance is closely related to appropriate oxygen and pH conditions. More broadly, recent reviews on Nile tilapia production also identify water temperature, dissolved oxygen, and pH among the main environmental determinants of growth and survival. Therefore, the relatively favorable survival observed in this study was likely supported by the combined effects of dietary supplementation and suitable rearing conditions, consistent with Nugroho & Sari (2022).

Overall, the results indicate that kepok banana peel extract improved both the growth performance and survival of Nile tilapia fry, with the best overall response recorded in P3. However, because the survival values of P2 and P3 were not significantly different, the effective dose for survival may already have been reached at 20%. From a practical perspective, this is relevant because the biologically highest response is not always equivalent to the most efficient inclusion level. Further studies are therefore needed to identify the optimum dose based on growth response, feed efficiency, physiological status, and economic feasibility.

CONCLUSION

This study demonstrated that dietary supplementation with kepok banana peel extract improved the growth performance and survival of Nile tilapia fry during a 28-day rearing period. The extract significantly affected both absolute weight gain and absolute length gain, with the highest values consistently observed in treatment P3 (25%). Survival rate also tended to improve at higher inclusion levels, particularly in

treatments P2 (20%) and P3 (25%), although the difference between these two treatments was not statistically significant. These findings indicate that kepok banana peel extract has potential as a natural feed additive in Nile tilapia culture, likely due to its nutritional value and bioactive compounds that may enhance nutrient utilization and physiological condition. From a practical perspective, the 25% inclusion level produced the best overall growth response, while the effective range for survival appeared to be 20–25%. Further studies are needed to determine the optimum inclusion level based on biological performance, feed efficiency, and economic feasibility.

RECOMMENDATION

Based on the findings of this study, it is recommended that the use of *kepok* banana peel extract as a feed additive be further evaluated at a larger aquaculture scale and over a longer rearing period to assess the consistency of its effects on the growth performance and survival of Nile tilapia. Further studies should also investigate a more detailed range of extract dosages, as well as the underlying physiological and biochemical mechanisms, such as feed efficiency and immune response, in order to strengthen the potential application of *kepok* banana peel extract as a functional feed ingredient in sustainable Nile tilapia aquaculture.

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