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Mango (*Mangifera indica*) and Banana (*Musa acuminata*) Peelings as Alternative and Sustainable Feeds for Red Tilapia (*Oreochromis* spp.)

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ABSTRACT
The increasing waste generated from fruit consumption and processing poses environmental concerns while also presenting untapped opportunities in sustainable aquaculture. This study investigated the potential of mango (*Mangifera indica*) and banana (*Musa acuminata*) peels as supplementary feed additives to enhance the growth performance and survival rate of red tilapia (*Oreochromis* spp.) fingerlings. The experiment consisted of three dietary treatments: (1) pure commercial feed (control), (2) banana peel + commercial feed, and (3) mango peel + commercial feed. Growth performance was assessed through weight measurements, while survival rates were determined based on recorded mortalities. One-way ANOVA results (F= 1.03, P= 0.364) indicated no statistically significant differences in weight gain among the treatments. Pearson correlation analysis revealed that fish weight was positively correlated with water temperature and pH but negatively correlated with dissolved oxygen levels. While growth performance remained the same, the mango and banana peel-supplemented groups exhibited lower mortality rate, suggesting potential health benefits. However, external factors such as water quality fluctuations likely influenced survival outcomes. These findings suggest that while fruit peel supplementation did not enhance growth performance over the control, it may have other benefits, such as improved resilience. Future studies should explore longer trial durations, varied inclusion levels, and potential immunological effects to determine the full impact of fruit peel supplementation in tilapia aquaculture.

INTRODUCTION

Fruits play a crucial role in human nutrition and health, with their demand growing exponentially for various commercial purposes worldwide **(Dreher, 2018; Rejman *et al.*, 2021; Alasalvar *et al.*, 2023)**. However, the consumption and processing of fresh produce generate significant amounts of waste, particularly fruit peels, which often go to waste during post-harvest handling and processing **(Marcos *et al.*, 2020; Mgeni *et al.*, 2024)**. Bananas and mangoes are among the most commonly cultivated tropical fruits in the Philippines. In 2023, the Philippines produced approximately

786,040 mt of mangoes and exported 10,200 mt of mangoes, while producing 9.2 million mt of bananas and shipping 2.53 million mt in the same year **(Balita, 2024a, b)**. With high production and utilization in various industries—from jams and juices to dehydrated products in food, pharmaceutical, and hospitality sectors—banana and mango waste products also abound. These by-products represent a significant source of agricultural waste **(Gueco, 2022)**. Improper management of this waste contributes to environmental pollution, including methane emissions in landfills **(Matei *et al.*, 2021; Nirmal *et al.*, 2023)**. Because of this problem, agricultural wastes are being explored for their potential contribution to the circular economy through value-added processing and other uses **(Osorio *et al.*, 2021; Castillo *et al.*, 2023)**. Fruit and vegetable discards and wastes encompass husks, peels, pods, pomace, seeds, and stems, which are typically discarded but could potentially provide beneficial compounds such as carotenoids, dietary fibers, enzymes, and polyphenols **(Bhardwaj *et al.*, 2022)**.

In addition, recent studies have explored the potential of agricultural waste products—from husks and peels to stems—as feed supplements in livestock industries, including aquaculture **(Sodjinou, 2024; Macusi *et al.*, 2025)**. Research in aquaculture has specifically focused on the effects of banana and mango waste products on the growth performance, feed utilization, and health of milkfish (*Chanos chanos*) and the Nile tilapia (*Oreochromis niloticus*) **(Zahid *et al.*, 2021; Dawood *et al.*, 2022; Kesbic *et al.*, 2022; Macusi *et al.*, 2024; Macusi *et al.*, 2025)**. These studies have evaluated the acceptance of feeds made with powdered banana and mango peels, considering digestibility and palatability **(Khieokhajonkhet, 2020)**. They have also examined the biochemical and physiological responses of tilapia to these feeds, noting improvements in nutrient utilization, immune response, and metabolic pathways **(Dani, 2018; De Souza *et al.*, 2020; Kesbic *et al.*, 2022)**.

Tilapia is one of the most important global aquaculture species due to its adaptability, fast growth, and efficient feed conversion. The history of tilapia farming dates back to ancient times, with its significance documented in Egyptian culture and even biblical history. Modern tilapia culture began in the 1920s and has since grown exponentially due to advantages such as tolerance to diverse habitats, high reproductive rates, and an omnivorous diet **(López-Olmeda *et al.*, 2021)**. These traits have made the Nile tilapia (*Oreochromis niloticus*) the third most farmed fish worldwide, with production reaching 4.5 million mt in 2018, making it a crucial species for global food security **(López-Olmeda *et al.*, 2021)**. In the Philippines, tilapia production has declined from 281,111 mt in 2021 to about 260,960 mt in 2024 **(PSA, 2024)**, mainly due to environmental factors such as climate change, decreased suitability of farming areas, and lack of technical and financial assistance for farmers **(Guerrero, 1999, 2019)**. Despite these challenges, tilapia production in the Davao region has shown resilience, increasing over the past decade. Davao del Sur consistently led as the top producer, recording 13,355 mt and accounting for the largest share of regional production. Favorable aquaculture conditions, abundant freshwater resources, and established farming practices contributed to its dominance. Meanwhile, Davao del Norte ranked second with 3,292 mt, reflecting growing investments in aquaculture and innovative farming techniques. Moderate contributions came from Davao de Oro (1,545 mt), Davao City (1,266 mt), and Davao Occidental (1,054 mt), while Davao Oriental recorded the smallest production volume (102.38 mt), likely due to geographical and environmental challenges such as limited freshwater availability and less emphasis on aquaculture development. These figures highlight the importance of local initiatives and small- to medium-scale fish farms in the region.

The rapid increase in tilapia production over the past decade underscores its importance as a reliable source of fish protein **(Prabu *et al.*, 2019)**. Aquaculture is essential for the food security and economic stability of fish farmers in the Philippines. However, the high cost of traditional tilapia feeds, which often rely on unsustainable ingredients like fish meal, has created a pressing need for alternative, affordable, and sustainable feed sources **(Elangovan *et al.*, 2019; Macusi *et al.*, 2024)**. Fish farmers are calling for cheaper alternatives to current feed types. Alternative or supplementary feeds that perform similarly to existing commercial feeds may reduce production costs and increase profitability. Incorporating fruit waste such as banana and mango peels into tilapia diets could offer a more affordable and sustainable solution. Moreover, the Philippines, like many agricultural countries, faces waste disposal challenges **(Macusi *et al.*, 2019; Abreo *et al.*, 2020)**, particularly with agricultural by-products such as banana stems, leaves, rejected fruits, coconut husks, and coffee bean waste. Previous studies have indicated that green banana waste and coffee pulp are promising resources for animal feed **(Ulloa *et al.*, 2004)**.

Banana production in the Philippines reached 9 million mt in 2020, with Mindanao ranking first and producing 52% of the Cavendish variety for export **(Gueco, 2022)**. Globally, about 114.08 million mt of banana waste-loss is generated, leading to environmental issues but also presenting opportunities for conversion into cellulose, hemicellulose, and natural fibers that can be processed into bioplastics, organic fertilizers, biofuels, or animal feeds **(Acevedo *et al.*, 2021)**. The nutritional properties of banana peels, including high fiber content, vitamins, and minerals, can support fish growth, enhance immune systems, and improve overall health **(Kumar *et al.*, 2020)**. Similarly, mango peels are rich in antioxidants and bioactive compounds that can contribute to improved health and growth performance in fish **(Ediriweera *et al.*, 2017; Dawood *et al.*, 2022; García-Mahecha *et al.*, 2023)**. Utilizing these by-products not only reduces organic waste but also provides a sustainable protein source for aquaculture.

This study aimed to investigate the effects of adding mango (*Mangifera indica*) and banana (*Musa acuminata*) peels to red tilapia (*Oreochromis* spp.) feed on the fish's growth performance. Specifically, it sought to address the following objectives:

1. To determine the growth (weight and length) performance of tilapia when fed with banana+commercial, mango peel+commercial, and control feeds;
2. To compare the overall protein and feed conversion ratio of tilapia fed with banana+commercial, mango peel+commercial, and control feeds;
3. To explore whether environmental parameters such as DO, pH, and temperature affect the growth of tilapia fed with banana+commercial, mango peel+commercial, and control feeds.

MATERIALS AND METHODS

Collection of plant materials

This phase involved the efficient and safe collection of banana (*Musa acuminata*) and mango (*Mangifera indica*) peels for further utilization in research and production processes. The researchers first prepared clean containers and separated the banana and mango peels to prevent mixing and to maintain the integrity of each material. Collection was scheduled during times when peels were most likely to be discarded, such as aftermarket hours or during fruit processing. Prior permission was obtained from vendors to ensure compliance with regulations and protocols. A record of the quantity collected was maintained for subsequent analysis and tracking.

Dehydration of plant materials

The collected peels were dehydrated under direct sunlight to preserve the material and to reduce moisture content. The process began with thoroughly washing the peels to ensure cleanliness. The washed peels were then evenly spread on plastic canvases and sun-dried until fully dehydrated. Once dried, the mango and banana peels were stored separately in clean sacks to prevent cross-contamination before further processing into powder.

Pulverizing process

After dehydration, the mango (*Mangifera indica*) and banana (*Musa acuminata*) peels were ground into fine powder.

Supplementary feed formulation

Two types of supplementary feeds were prepared:

- A 50:50 mixture of pulverized mango peels and commercial feed for the mango + commercial treatment.
- A 50:50 mixture of pulverized banana peels and commercial feed for the banana + commercial treatment **(Macusi *et al.*, 2025)**.

Proximate analysis was then performed to quantify key nutritional components, including moisture, crude protein, fat, ash, and fiber (Table 1). Standard procedures were followed:

- **Crude protein**: Determined using the Kjeldahl method, which measures nitrogen content to calculate protein levels.

- **Crude fat**: Determined using Soxhlet extraction, in which fat is dissolved in a solvent for quantification.
- **Ash content**: Measured by incinerating the sample in a muffle furnace, leaving behind inorganic residue.
- **Crude fiber**: Measured through sequential acid and alkaline digestion to isolate the fiber fraction.

Quantification of macro- and micronutrients and vitamins

- **Macro- and micronutrients**: Concentrations of elements such as calcium, magnesium, potassium, and trace minerals were determined using Atomic Absorption Spectroscopy (AAS; PerkinElmer Analyst 800).
- **Vitamins**: Individual vitamins were quantified using High-Performance Liquid Chromatography (HPLC; Agilent 1260 Infinity II HPLC System), which separates and identifies compounds based on chemical properties.

Table 1. Results of analysis of feed samples submitted for complete proximate analysis

Identification	% Crude Protein	% Crude Fiber	% Crude Fat	% Moisture Content	% Ash
Mango+Commercial	12.03	9.70	1.71	20.90	6.35
Banana+Commercial	19.45	7.70	5.96	11.72	11.49
Commercial	31.74	5.60	3.32	9.58	9.53
Mango peeling	4.15	9.80	1.16	35.05	3.94
Banana peeling	7.43	12.20	6.93	12.59	10.13

[a]Analyzed values from the Feed Analytical Laboratory (FCAL), Department of Agriculture Region XI, Philippines.
[b]Nitrogen-free extract, computed by difference.

Environmental variables during tilapia culture

Tilapia is known to inhabit a wide range of freshwater environments, including rivers, lakes, sewage canals, and irrigation channels. Although it does not thrive in pure seawater, it can survive in brackish water and is recognized as an important species in aquaculture, while also supporting major capture fisheries where it is established.

In our tank culture, the mean weight of red tilapia (*Oreochromis* spp.) was 11.10g (ranging from 6.82 to 13.22g). The fish were cultured in 60L tanks and about 60 % of the water was changed every two days. The water conditions recorded an average temperature of 26.6°C (range: 14.3– 31.2°C) and an average pH of 8.05 (range: 5.13–9.39) (Table 2).

In the wild, tilapia tolerate an extended temperature range of 8– 42°C, with a natural optimum range of 13.5– 33°C. In this study, fish weight was found to be negatively correlated with dissolved oxygen, but positively correlated with water pH (neutral to basic) and water temperature (ambient). Dissolved oxygen levels were also influenced by lower pH and higher temperatures (Table 1).

Table 2. Pearson correlation of various environmental variables to fish weight

Variable	Mean	Minimum	Maximum	SD
Weight (g)	11.10	6.82	13.22	1.64
Temperature (^{0} C)	26.65	14.3	31.2	1.64
Dissolved Oxygen	6.30	0.5	34.35	5.12
pH	8.05	5.13	9.39	0.92
		Correlation		
Pearson's r	Weight	Temperature	Dissolved Oxygen	Water pH
Weight (g)	-	0.293	-0.611	0.491
Temperature (^{0} C)	0.293	-	-0.290	-0.020
Dissolved Oxygen	-0.611	-0.290	-	-0.594
pH	0.491	-0.020	-0.594	-

Actual experiment

The study was conducted using ten plastic tanks, each with a 60L capacity, stocked with 25 tilapia fingerlings. The fish were assigned to one of three treatments:

1. Powdered banana peel mixed with commercial feed,
2. Powdered mango peel mixed with commercial feed, and
3. Commercial feed alone (control).

Each treatment was replicated across three tanks to ensure reliable and accurate results.

Measurements and data collection

To assess the effects of the treatments, both water quality parameters and growth indicators were monitored over a 70-day culture period.

- **Water quality**: Parameters measured included pH, dissolved oxygen (DO), and water temperature (°C). Measurements were taken daily at 7:00 a.m. For each parameter, the probe was dipped into the tank; the reading was recorded after 10 seconds, and the process was repeated three times for accuracy.

- **Growth and survival**: Mortality rate, body weight, and length of the tilapia fingerlings were recorded. Weight and length data were collected weekly to track growth performance.

Growth parameter calculations

Formulas used for calculating growth parameters are presented in **Macusi *et al.* (2025)**

Initial average body weight (ABW).
Formula: Initial ABW=Number of fish / Total initial weight of fish
Final average body weight (ABW) (g*)*
Formula: Final ABW=Number of fish / Total final weight of fish
Weight Gain (g)
Formula: Weight Gain=Final ABW−Initial ABW
Average daily weight gain (ADWG) (g/day)
Formula: ADWG=Duration of the trial (days) / Weight Gain
Specific growth rate (SGR) (%/day)
Formula: SGR=Duration of the trial (days) / (*ln* (*Final ABW*) − *ln*(*Initial ABW*)) ×*100.*
Protein efficiency ratio (PER)
Formula: PER=PER=Protein intake / Weight Gain
Feed conversion ratio (FCR)
Formula: FCR=Weight Gain (g) / Feed intake (g)
Fulton's condition factor (K)
Formula: K=Final Length (cm)^3 /Final Body Weight (g)×100
Data analysis

The collected data were analyzed using the analysis of variance (ANOVA), which is well-suited for experiments following a completely randomized design. ANOVA was applied to compare the means across the three treatment groups and to determine whether the observed differences in water quality, growth, and survival rates were statistically significant. The analysis was performed using *Analyse-it for Microsoft Excel* (Build 7620, Standard Edition, Leeds, UK).

Unlike multiple t-tests, which increase the risk of Type I errors, ANOVA provides a more robust and comprehensive method for evaluating group differences. When significant differences were detected, post-hoc tests were conducted to identify which specific treatment groups differed from one another.

RESULTS

Growth performance and survival rate of red tilapia (*Oreochromis* spp.) fingerlings

The effects of different dietary treatments on the growth and survival of tilapia fingerlings were evaluated. The treatment groups consisted of:

1. Commercial feed (control),
2. Banana peel + commercial feed, and
3. Mango peel + commercial feed.

Growth performance was assessed using the average body weight of the fingerlings, while survival was evaluated based on recorded mortality data.

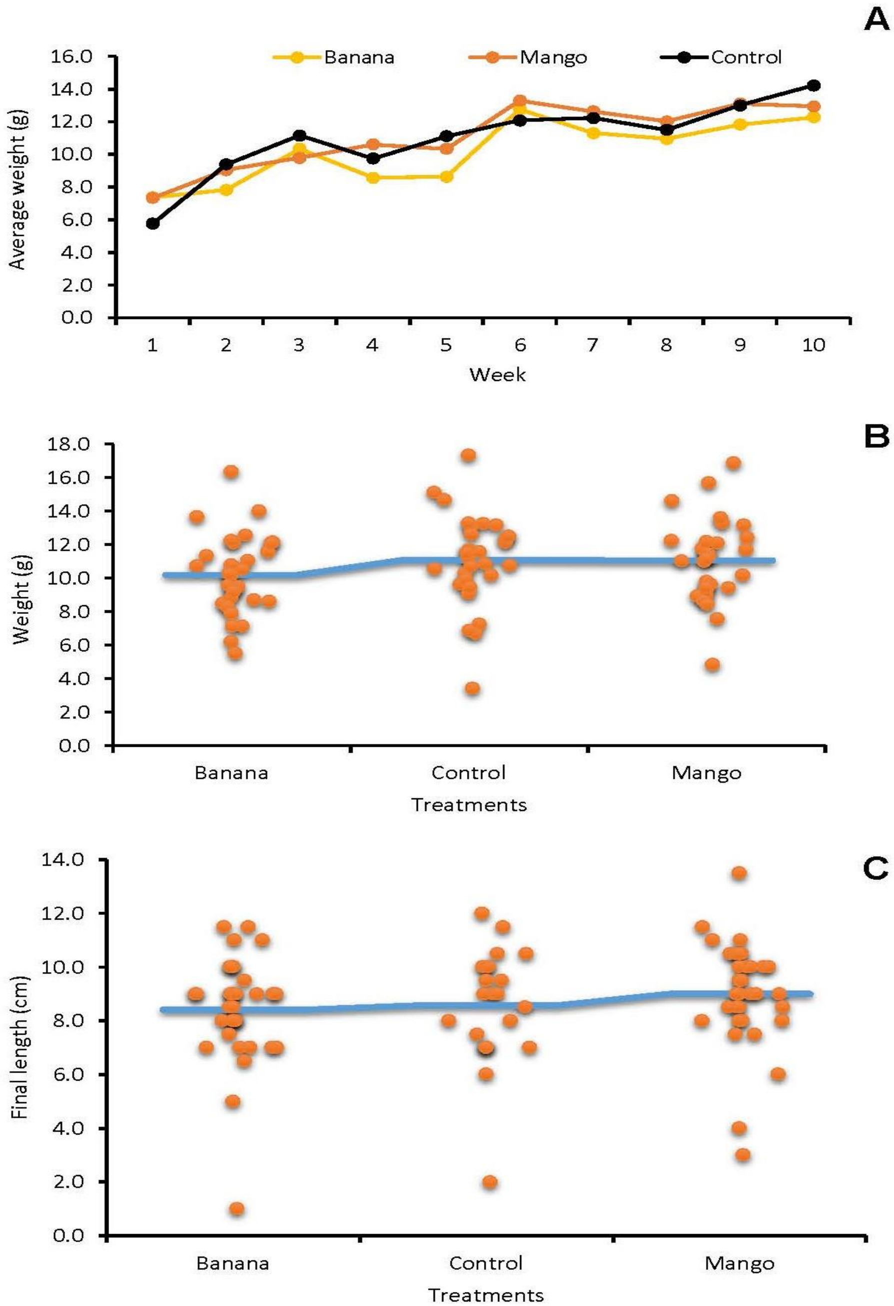

Fig. 1. Comparison of the average weight of red tilapia (*Oreochromis* spp.) fingerlings using banana, control and mango feed treatments in 10 weeks (A); the different treatments were not significantly different from each other in terms of weight (B) and length (C) even after 70 days of fish culture (P>0.05)

Statistical analysis of growth performance

A one-way analysis of variance (ANOVA) was conducted to determine whether significant differences existed in the growth performance of red tilapia among the three dietary treatments. The analysis yielded an F-value of 1.03 and a *P*-value of 0.364. Since the *P*-value was greater than 0.05, there was no statistically significant difference in the final average weight of tilapia across the treatment groups (Fig. 1B).

The results indicate that supplementation with powdered banana and mango peels neither significantly enhanced nor hindered the growth performance of the red tilapia compared to the control group fed with commercial feed alone. Similarly, no significant differences were observed in final length and weight among treatments (Fig. 1C). This suggests that the nutrient bioavailability of the powdered peels was insufficient to produce measurable improvements in growth.

Several factors may explain this outcome. First, the commercial feed used as the control likely provided a balanced and complete source of essential nutrients, reducing the potential impact of supplementation. Second, the digestibility and palatability of powdered banana and mango peels may have influenced feed intake and limited the effects of supplementation on growth.

Survival rate

Survival rates were calculated from recorded mortalities over the culture period. The losses in each treatment group were as follows:

- **Banana peel + commercial feed** (Tanks 1, 5, 9): 30 losses
- **Commercial feed (control)** (Tanks 2, 6, 7): 49 losses
- **Mango peel + commercial feed** (Tanks 3, 4, 8): 23 losses

The highest mortality was observed in the commercial feed group, which recorded 49 losses. This was largely due to a single incident in Tank 7 on January 15, where a dirty air stone resulted in poor water quality and caused a mass mortality event. On this day alone, 31 deaths were recorded, which disproportionately lowered survival in this treatment group.

By contrast, the banana peel-supplemented group had a total of 30 mortalities, while the mango peel-supplemented group recorded the fewest at 23. These findings suggest that mango peel supplementation may have contributed to improved survival, although further studies are needed to validate this trend.

Despite differences in mortality among treatments, overall survival remained relatively stable, indicating that none of the dietary treatments had a detrimental effect on tilapia survival. However, the results highlight the importance of strict water quality monitoring to minimize external factors, such as equipment malfunction, that could compromise survival outcomes.

Table 3. Growth parameters of the red tilapia (*Oreochromis* spp.) fingerlings

Technical basis	Banana	Control	Mango
Stocking density (Fish/60L)	25	25	25
Culture period (days)	70	70	70
Initial ABW (g)	7.36	7.42	7.33
Final ABW (g)	12.27	14.22	12.94
Weight gain (g)	4.91	6.8	5.61
Total feed consumed in 70 days	1874	1874	1874
Crude Protein composition (CP%)	19.45	31.74	12.03
Crude fiber composition (%)	7.70	5.60	9.70
Crude fat composition (%)	5.96	3.32	1.71
Moisture content (%)	11.72	9.58	20.90
Ash composition (%)	11.49	9.53	6.35
Ave. daily weight gain (g/day)	0.07	0.12	0.08
Specific growth rate (%)	0.73	1.29	0.8
Survival rate (%)	98	83	98
PER	0.94	0.99	1.74
FCR	1.69	1.22	1.48
Fulton's Condition Factor	2.03	2.24	1.86

Over the 70-day feeding trial, variations were observed in the growth performance, feed utilization, and general health of red tilapia (*Oreochromis* spp.) fed with commercial control feed, banana-based feed, and mango-based feed. Although all groups began with comparable starting weights (approximately 7.3–7.4 g), the control group achieved the highest final weight (14.22g) and weight gain (6.8g), outperforming the mango (5.61g gain) and banana treatment groups (4.91g gain).

Consistent with these results, the control diet also produced the highest specific growth rate (SGR = 1.29%/day) and average daily weight gain (ADWG = 0.12 g/day), followed by the mango-based diet (0.80%/day, 0.08 g/day), and banana-based diet (0.73%/day, 0.07 g/day). Feed utilization, measured by the feed conversion ratio (FCR), further supported these findings: the control group showed the lowest FCR (1.22), indicating the most efficient feed use, while the mango and banana-based diets had higher FCRs of 1.49 and 1.69, respectively.

Interestingly, despite its lower crude protein content (12.03%), the mango-based diet yielded the highest protein efficiency ratio (PER = 1.74), suggesting effective protein utilization. In contrast, the banana diet contained 19.45% crude protein, while the commercial control feed had the highest protein level (31.74%), which likely contributed to the superior performance of the control group. Nutritional analysis further revealed that the mango-based feed had the highest moisture content (20.90%) and crude fiber (9.70%), factors that may have reduced its nutrient density and digestibility.

Survival and condition factor

In terms of survival, both banana- and mango-based diets supported higher survival rates (98%) compared to the control group (83%). This suggests that agricultural waste-based feeds may promote healthier fish conditions. The condition factor (K) values indicated that fish across all groups were in good physiological condition: control (2.24), banana (2.03), and mango (1.86).

Implications

Overall, the results demonstrate that while commercial feed promotes the best growth performance, banana- and mango-based feeds—particularly with further optimization—represent sustainable alternatives that support respectable growth and superior survival rates in tilapia culture.

DISCUSSION

Implication of environmental parametrs to growth performance of Red Tilapia

The results showed that fish weight was negatively correlated with dissolved oxygen (DO) but positively correlated with water pH and temperature. Increased metabolic demand at higher temperatures and nutrient loads from different feeds may explain this inverse relationship. When oxygen levels are adequate and pH remains stable, metabolic rates rise with temperature, improving feed conversion and growth **(El-Sayed, 2006)**. However, higher temperatures can also reduce DO levels, particularly in systems receiving high organic inputs from alternative or agro-waste feeds. This underscores the importance of balancing environmental management with feed composition.

Previous studies emphasize that careful water quality regulation is essential when using plant-based or agricultural waste feeds. Such feeds can increase organic loading and microbial activity, influencing DO and pH levels **(Mansour *et al.*, 2022)**.

Growth Performance and Nutritional Impact of Formulated Feeds

Significant differences in growth performance were observed among fish fed with banana, mango, and commercial feeds. The superior crude protein content of the control (commercial) feed contributed to its higher final average body weight, weight gain, specific growth rate (SGR), and average daily weight gain (ADWG). This finding supports El-Sayed's **(2020)** assertion that adequate protein levels are essential for optimal fish growth.

Interestingly, the mango-based feed yielded the highest protein efficiency ratio (PER), suggesting that although its protein content was lower, it was efficiently utilized, even if it did not translate into significantly higher growth. The use of banana and mango peelings aligns with the broader movement toward sustainable aquaculture practices that utilize agricultural waste.

For example, **Macusi *et al.* (2025)** demonstrated that incorporating indigenous raw materials such as blood meal, taro, and banana stems into milkfish diets produced promising, cost-effective, and eco-friendly alternatives to fishmeal-based feeds. Similarly, **Gonzales-Plasus *et al.* (2022)** found that fruit waste additives, such as banana peels, improved tilapia fingerling growth and feed utilization when included at appropriate levels. These findings confirm that banana and mango peelings can make a meaningful contribution to sustainable feed innovation and circular economy practices, even if their growth performance does not yet match that of commercial formulations.

Advancing circular economy practices through sustainable feed production

Enhancing circular economy strategies via sustainable feed production is a promising approach in aquaculture, where resource efficiency is increased and environmental impact reduced by converting agricultural waste into high-value aquafeeds **(Campanati *et al.*, 2021)**. Because of their moderate protein, fiber, and carbohydrate content, fruit peels—such as those from bananas and mangoes—hold potential as alternative feed ingredients **(Yang *et al.*, 2021)**.

Fermentation has further improved their value. For example, microbial fermentation of banana peels enhances bioavailability and reduces anti-nutritional factors, thereby improving tilapia growth and feed utilization **(Gonzales-Plasus *et al.*, 2022)**. Mango peel supplementation has also been tested in Nile tilapia (*Oreochromis niloticus*) broodstock diets, improving reproductive performance while lowering feed costs **(SEAFDEC, 2020)**.

These initiatives reflect the broader "Aquafeed 3.0" concept, which promotes upcycling waste materials into aquaculture value chains using renewable biomass **(Tacon *et al.*, 2023)**. Projects such as **LIFE BAQUA** under Horizon 2020 have demonstrated that banana crop waste can be transformed into antioxidant-rich feed additives, enhancing fish health and promoting environmental sustainability **(European Commission, 2023)**.

Locally, using raw materials such as taro and banana stems can help the aquaculture industry reduce dependence on fishmeal, thereby benefiting both local economies and environmental goals **(Macusi *et al.*, 2025)**. Circular feed strategies not only cut costs but also reduce eutrophication and nutrient waste, which is especially important for smallholder farmers **(Tacon, 2015)**. Looking forward, sustainable aquaculture will depend on adopting feed innovations that minimize reliance on wild fisheries and reduce ecological and carbon footprints **(Naylor *et al.*, 2021)**.

Economic significance of agricultural waste in aquaculture

The use of agricultural waste in aquaculture has substantial economic benefits, particularly for smallholder and resource-limited farmers. Feed accounts for 50–70% of aquaculture production costs **(Macusi *et al.*, 2023; Macusi *et al.*, 2024)**. By utilizing byproducts such as rice bran, corn husks, soybean meal residue, banana peels, and cassava leaves, farmers can formulate nutritionally viable feeds at lower costs compared to commercial alternatives. This reduces input expenses while maintaining acceptable growth and survival rates **(Hasan & New, 2013)**.

Additionally, local feed processing activities such as drying, grinding, and fermenting raw materials can generate employment and income in rural communities **(Olsen & Hasan, 2012)**. Reliance on domestic feed sources also reduces dependence on imported components, protecting farmers against price fluctuations and global supply chain disruptions **(Tacon & Metian, 2008)**.

Agricultural byproduct utilization therefore strengthens the economic resilience of smallholder aquaculture systems by lowering production costs and increasing efficiency **(Sapkota *et al.*, 2008)**. For instance, rice bran, containing up to 17% lipids and 12% protein, has been shown to support growth when fermented to enhance digestibility in catfish and tilapia. Palm kernel cake, a protein-rich byproduct of palm oil processing, has likewise been fed to the red tilapia and catfish without negative impacts on productivity **(Mansour *et al.*, 2022)**.

These results confirm that turning agricultural waste into aquafeed is both economical and practical, improving farm profitability while supporting sustainability. Similar approaches have been adopted in Sub-Saharan Africa, where farmers using animal and plant byproducts significantly reduced feed costs while maintaining competitive yields **(Munubi & Lamtane, 2021)**.

CONCLUSION

This study examined the effects of banana and mango peel supplementation on the growth performance and survival rate of the red tilapia (*Oreochromis* spp.) fingerlings. Statistical analysis using one-way ANOVA indicated no significant differences in weight gain among the treatment groups ($P > 0.05$), suggesting that fruit peel-based feed has similar effects on growth as the commercial feed. Pearson correlation analysis revealed that fish weight was positively correlated with water pH and temperature but negatively correlated with dissolved oxygen. Although growth performance remained similar across all groups, the mango and banana peel-supplemented treatments exhibited lower mortality rate, indicating a potential benefit in fish survival. Other external factors, such as water quality issues in specific culture tanks, influenced mortality outcomes and should be controlled in future research. Overall, this study concludes positively that banana and mango peels can be incorporated into tilapia diets without adverse effects to fish growth and can lead to similar growth advantages as the commercial feed. Future research should explore alternative inclusion levels, longer study durations, and potential health benefits of fruit peel supplementation, such as immune enhancement and disease resistance, to further assess its viability as a sustainable feed alternative.

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