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Growth Performance and Survival of Nile Tilapia (*Oreochromis niloticus)* with the Addition Combination of *Tenebrio Molitor* L. and *Zingiber Officinale* R. Flour

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Abstract: The combination of *Tenebrio molitor* flour and ginger *Zingiber Officinale* contains bioactive compounds that will synergistically enhance the growth performance and health of Nile tilapia *Oreochromis Niloticus*. The aim of the research is to analyse feed efficiency, weight gain and fish weight, specific growth rate of fish, and fish survival with the addition of a combination of tenebrio flour and ginger with an optimal composition using a randomised block design. including control, namely (100% commercial feed), Treatment 1 (70% commercial feed + 25% *T. molitor* flour + 0.5% ginger flour), treatment 2 (40% commercial feed + 50% *T. molitor* flour + 1.0% ginger flour), and treatment 3 (10% commercial feed + 75% *T. molitor* flour + 1.5% ginger flour). The parameters observed were feed efficiency, absolute length and weight gain, specific growth rate (SGR), and survival. The results showed that treatment with the composition (40% commercial feed + 50% *T. molitor* flour+ 10% ginger flour) gave the best results in feed efficiency (65.77%), length gain (5.00 cm), weight gain (8.75 grams), SGR (2.99%), and survival (95.83%). This research has resulted in a new innovation to enhance growth and maintain fish health, thereby ensuring food security and the successful development of the fish farming industry.

Keywords: Growth performance; *Oreochromis niloticus*; *Tenebrio molitor*; *Zingiber officinale*

Introduction

The aquaculture industry is growing quickly and provides almost half of the fish that people eat around the world. As the world's population grows, expected 9.3 billion by 2050, food security has emerged as a major worldwide concern (Sangsawang et al., 2024). The demand for animal protein products has been rising worldwide over the past years (Abozaid et al., 2024). Food resources that is, sources of extraordinarily high-quality protein are therefore becoming more and more crucial. Fish is a very valued food for human consumption since it is an important source of protein among animal based diets, offering both required proteins, fats, vitamins and minerals (Ahmed et al., 2021; Noyens et al., 2024; Ashry et al., 2024).

Popular freshwater species with a long history of aquaculture is the Nile tilapia *(Oreochromis niloticus*) is a type of freshwater fish that is highly prized. The increasing demand for fish, particularly as wild fish stocks continue to diminish, is largely met by aquaculture. Global aquaculture production rose dramatically from 43 million metric tonnes (Mt) to 120.1 million Mt between 2000 and 2022 (Mengistu al., 2022). which is a very large amount and is increasing every year. This species grows quickly, makes it appropriate for intensive culture systems (Sayed & Fitzsimmons, 2022; Mengistu et al., 2022).

One of the main challenges in Nile tilapia *(Oreochromis niloticus*)) farming is the development of aquaculture feed that can support optimal fish growth with high feed utilisation efficiency. Mariod et al.

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(2020) in addition to the amount of protein contained in the feed, feed efficiency is also influenced by the quality of the protein source, the balance of amino acids and energy, nutrient digestibility, palatability, and the physiological condition of the fish. Therefore, the development of feed formulations should be directed towards the use of alternative ingredients that can provide nutrients while also supporting the physiological condition of the fish.

The diet quality nutrient of Nile tilapia has a significant impact on its growth performance and survival. To promote ideal growth and increased fish health, a meal that is nutritionally balanced profile amino acid, fatty acid, vitamin and minerals is necessary, but the main source of protein in aquafeeds, is becoming scarcer, more expensive, and competitive with other businesses (Munguti et al., 2022).

To address this issue, a feed formulation with a balanced intake of amino acids and fatty acids that meets the fish's needs is essential, as it can enhance growth and maintain the health of the fish (Stastnik et al., 2021). These limitations have prompted the hunt for substitute protein sources, such as meals made from insects, which have shown a lot of promise because of their rich nutritional profiles, on a dry matter basis, their protein contents range from 50 to 82%, which is equivalent to fishmeal's usual protein content of 60 to 72% (Eggink et al., 2022). *T. molitor* (TM) is a weak species possesses and abundance of nutrients, which makes it a potential substitute for food and feed in the future. The nutrients found in *T. molitor* include 46–55% protein, 24–36% fat, vitamins, and mineral (Ng et al., 2022; Moruzzo el al., 2021). to increase the growth of new cells so that tilapia (*O. niloticus*) can grow more quickly and healthily (Shafique et al., 2021; Mariod et al., 2020; Eberle et al., 2022).

Ginger rhizomes contain bioactive compounds that are important for maintaining fish health. Numerous bioactive substances, including phenolic and terpene lipids, organic acids, polysaccharides, and raw fibres (Kim et al., 2018). Ginger has been discovered to have biological properties in recent years, including antioxidan, anti-inflammatory, antibacterial (Ahmadifar at al., 2019; Lai et al., 2022), and anticancer properties ginger also help to reduce inflammation in the fish that is caused by bacterial infections, can increase the enzyme's digestive activity Ginger also serves as a natural appetite stimulant that helps fish consume more food (Brum et al., 2017; Gabriel, 2019; Lai et al., 2022).

Research so far has only focused on the addition of a single supplement in the form of TM flour, which has been proven to triple fish growth (Lampová et al., 2024) the combination of TP flour with Lin et al. (2020), and the mixture of TM flour with curcumin, which can increase antioxidant activity and the growth of Nile tilapia (Park et al., 2022). There is no information yet on research related to the addition of a combination of TM flour and ginger to commercial feed. The synergistic effect and combination of TM flour and ginger will enhance the physiological processes of fish and impact the growth and survival of Nile tilapia.

Understanding the quality of feed with the best nutrition for tilapia, in the form of a combination of TM and TJH flour, is very necessary. This can be done by evaluating several biological performance growth parameters (consumption efficiency, specific growth rate, and survival rate of tilapia). This evaluation is very important to obtain information about the success of adding TM and TJH supplements with a very effective combination to improve the productivity and health of tilapia (Gabriel, 2019; Zhang et al., 2022).

Food security and safety for humans are very important, so this research aims to obtain the best combination and composition of feed based on TM and JH flour to improve productivity and maintain the health of tilapia. Simple technology utilising organic-based feed is very good for development with the hope of producing environmentally friendly and safe organic fish for consumers, thereby achieving sustainable food security and safety for the community.

Method

Research Design

This study uses a Completely Randomised Design (CRD) consisting of 4 treatments and 6 replications are fish feed treatment formulation.

K: commercial fish feed 10%

P1: Commercial feed 70%. + T Molitor flour 25% ginger flour 0.5 %

P2: Commercial feed 40 %+ T molitor flour +50% and ginger flour 1.0%

P3: Commercial feed 10 %+ T Molitor flour 75 % _ Ginger flour 1.5 %

This research was conducted over 28 days with a 7-day acclimatisation period and a 21-day treatment period. According to Ririhena & Palinussa (2021), maintenance over 21 days yielded results that can be considered significant and can be used as a basis for further research or cultivation practices. The treatment given was the administration of commercial feed with the addition of *T. molitor* flour and ginger in different doses. The different doses in each treatment aimed to determine the optimal dose of *T. molitor* flour and ginger that would yield the best growth results for Nile tilapia (*O. niloticus*). Referring to the research by

Sangsawang et al. (2024), *T. molitor* flour was added to the feed at a minimum percentage of 25% to optimise fish growth. Meanwhile, the addition of ginger refers to the study by Pascon et al. (2024), where ginger concentration was added at a minimum percentage of 2% to the feed to serve as an antioxidant and fibre supplement. This study used ginger flour addition at percentages of 0.5, 1.0, and 1.5%.

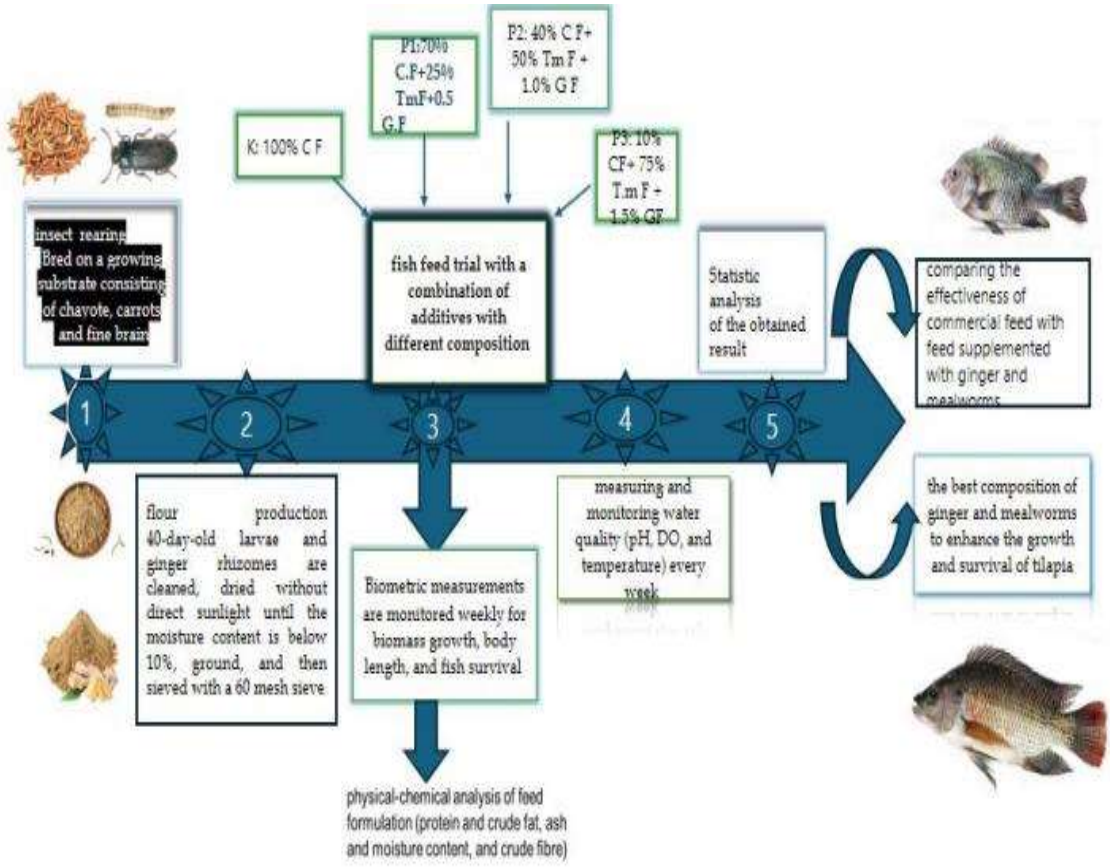


Figure 1. Research design

Preparation and Production of Feed

18-day-old BSf larvae reared in the fly house, Animal Husbandry Department of Sriwijaya University, were collected, cleaned, and then roasted with clean sand until they reached 30% dry weight. They were then ground with a blender and sieved using a mesh size of 60-80 to obtain uniform particle size. The same process is also applied to ginger (Pebiningrum et al., 2017). The production of commercial feed with the addition of *T. molitor* flour and ginger is carried out using the feed re-pelleting method. Commercial feed is mixed with *T. molito*r flour and ginger flour according to the treatment. The feed is mixed until smooth. After being kneaded, the feed is moulded using a pellet mill.

Prepare Tilapia Fish (O. niloticus)

In this investigation, 24 aquarium units with dimensions of 60 x 40 x 50 cm were used as containers. 72 tilapia fish were prepared. The tilapia used have a length of 6 ± 1.2 cm and a weight of 10 ± 0.5 grams. Each aquarium is filled with 3 fish. The test fish were adapted for 7 days in the aquarium maintained at the Tanjung Senai Fish Center, Ogan Ilir. Tanjung Senai Fish, Ogan Ilir. During the adaptation process, the fish were fed commercial feed (30% protein) ad libitum. The frequency of feeding was done using the Feeding Rate (FR) method, amounting to 5% of the fish's body weight. Feeding was conducted three times a day, namely in the morning at 09:00 WIB, in the afternoon at 12:00 WIB, and in the evening at 15:00 WIB. According to Moruzzo et al. (2021), feeding fish three times a day is more optimal for enhancing fish growth.

Data Analysis

The data obtained includes absolute length growth, absolute weight growth, daily growth rate, feed efficiency, and survival rate, which were analysed using one-way test with a 95% confidence level.

Feed Efficiency

The proportion that shows how well fish turn the feed they eat into growth is called feed efficiency. The more effectively the fish use the feed, the higher the feed efficiency value. Feed efficiency will be computed using the following formula (Ng et al., 2022)

$$\text{EP}\ (\%) = \frac{\text{Wt} - \text{W0}}{\text{F}} \times 100\% \quad (1)$$

Note:
Wt: Fish biomass at the conclusion of maintenance (g)
EP: Feed efficiency (%)
W0: The biomass of fish at the start of maintenance (g)
F: The quantity of feed used during up keep (g)

Absolute Length Increase

The absolute length increase of fish is the increase in the size of the fish's body length over a certain period. The length of the fish is measured from the tip of the snout to the tip of the tail fin. The absolute length increase of the fish during maintenance is calculated using the formula as follows:

$$\text{L} = \text{Lt} - \text{L0} \quad (2)$$

Explanation:
L: Absolute length increase of the fish (cm)
Lt: Average length of fish at the end of maintenance (cm)
L0: Average length of fish at the beginning of maintenance (cm)

Absolute Weight Gain

Absolute Weight Gain is the increase in fish body weight over a certain period. The initial weight of the absolute live weight gain of the fish during maintenance is calculated using the formula as follows:

$$\text{W} = \text{Wt} - \text{W0} \quad (3)$$

Note:
W: Absolute weight gain of fish (g)
Wt: Average weight of fish at the end of maintenance (g)
W0: Average weight of fish at the beginning of maintenance (g)

SGR, or Specific Growth Rate

The percentage of the difference between the initial and final weights divided by the length of the maintenance period is the specific growth rate. We will weigh the fish once every seven days. Using the formula, this seeks to ascertain the impact of feed formulation on the growth rate of Nile tilapia (*O. niloticus*):

$$\text{SGR}\ (\%) = \frac{\text{LnWt} - \text{LnW0}}{\text{T}} \times 100\% \quad (4)$$

Note:
SGR: Specific Growth Rate (% per day)
Wo: Average seed weight at the beginning of maintenance (g)
Wt: Average seed weight at the end of maintenance (g)
T: Duration of maintenance (days)

Survival Rate

The proportion of fish that successfully make it through the entire maintenance period is known as fish survival. The following formula can be used to calculate fish survival:

$$\text{SR}\ (\%) = \frac{\text{Nt}}{n0} \times 100\% \quad (5)$$

Note
SR: Fish survival rate (%)
Nt: Number of fishes at the end of maintenance (fish)
N0: Number of fishes at the beginning of maintenance (fish)

Quality of Water

Water is a critical medium. Temperature, pH, and the amount of dissolved oxygen in the water are all used to measure water quality. Temperature (thermometer digital), pH (pH meter digital, and dissolved oxygen (DO meter digital) measurements are taken at the start and finish of the investigation.

Result and Discussion

Feed Efficiency

The efficiency with which the supplied feed may be transformed into the biomass of the fish's body is known as feed efficiency. The addition of *T. molitor* flour and ginger in various feed compositions had a highly significant impact on the feed efficiency of Nile tilapia (*O. niloticus*), according to the results of analysis post hoc test of the data with a 95% confidence level or ($p < 0.05$).

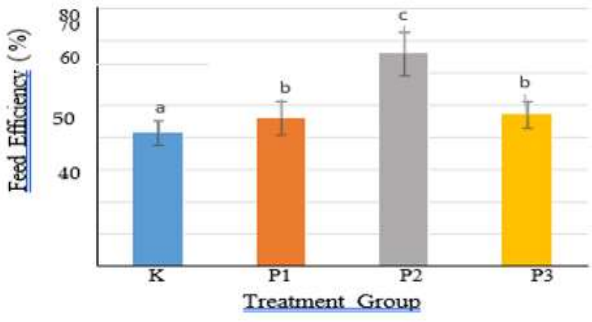


Figure 2. Feed efficiency of Nile tilapia *(O. niloticus*)

Note: Significantly different results in the 5% BNT post hoc test are indicated by numbers in the same column that are followed by distinct superscript letters. K = 100% commercial feed for *O. niloticus* (Nile tilapia), P1 is equal to

70% commercial feed plus 25% *T. molitor* flour plus 5% ginger flour; P2 is equal to 40% commercial feed plus 50% *T. molitor* flour plus 1.0% ginger flour; and P3 is equal to 10% commercial feed plus 75%.

When compared to the other treatments, Treatment K had the lowest feed efficiency result (41.40%). It is believed that Nile tilapia (*O. niloticus*) under treatment K suffer from a decrease in appetite as a result of nutritional deficiencies. The nutrients in ineffective commercial feed will impede fish growth and increase their susceptibility to illnesses (Kanani et al., 2014; Gabriel, 2019). Fish infected with bacteria often experience a decrease in appetite, causing the feed provided to be less utilised by tilapia fish for optimal growth (Hua, 2021; Zhang et al., 2022).

The best feed efficiency value, 65.77%, is obtained with Treatment P2 (40% commercial feed + 50% *T. molitor* flour + 1.0% ginger flour). Fish benefit greatly from the phytobiotic effects of ginger's active ingredients, which include gingerol, shogaol, and essential oils. It can cause the digestive glands to secrete more lipase, amylase, and protease. The feed's protein and carbohydrate digestibility are greatly improved by these enzymes' increased activity. Ginger serves as an appetiser (appetite stimulant) (Lampová et al., 2024) and speeds up the absorption of the feed in the small intestine (Stastnik et al., 2021). Fish supplemented with ginger exhibit superior body weight gain (growth performance) and feed efficiency than fish without ginger due to their increased appetite and enhanced digestibility (Hua, 2021; Karlsen et al., 2015; Indriati et al., 2023).

The comparatively high proportion of *T. molitor* flour and ginger in the feed, which has a high protein content and provides growth nutrition, is thought to be the cause of this. In the meantime, the primary ingredient in ginger, gingerol, boosts nutrient absorption, aids with digestion, and increases fish appetite.) state that a feed efficiency rating of 50% to 100% is considered good. As a result, in treatment 2, more feed is used from the active elements of ginger and chitin and oligosaccharide from *T. molitor* flour than is not used. In order to get a higher degree of life pleasure (Brum et all., 2017; Abozaid et al., 2024; Zhang et al., 2022). The addition of TM and TJH flour with a balanced composition can enhance nutrient absorption and metabolism, and the chitin and oligosaccharides in TM flour can have prebiotic properties, thereby improving gut health, TJH flour greatly boosts feed (Pascon et al., 2024).

efficiency, increase to absorb nutrien enhances development rate, and fortifies the immune system (Ahmadifar et al., 2019; Zhang et al., 2022; Mohan et al., 2020).

Absolute Weight Gain and Length

Fish growth is the progressive increase in size and body weight that results from the synthesis of cells and proteins, mostly in networks of muscles and as seen in Figure 2, we conducted an additional BNT test on the absolute weight of tilapia (*O. niloticus*). ANOVA with a 95% confidence level, or $p < 0.05$, was used to evaluate the data. It can be inferred from the ANOVA results that there is a significant difference between the feed and absolute weight of tilapia (*O. niloticus)* and the *T. molitor* and ginger flour in their composition because the p-value for the absolute length and weight of tilapia fry is less than 0.05.

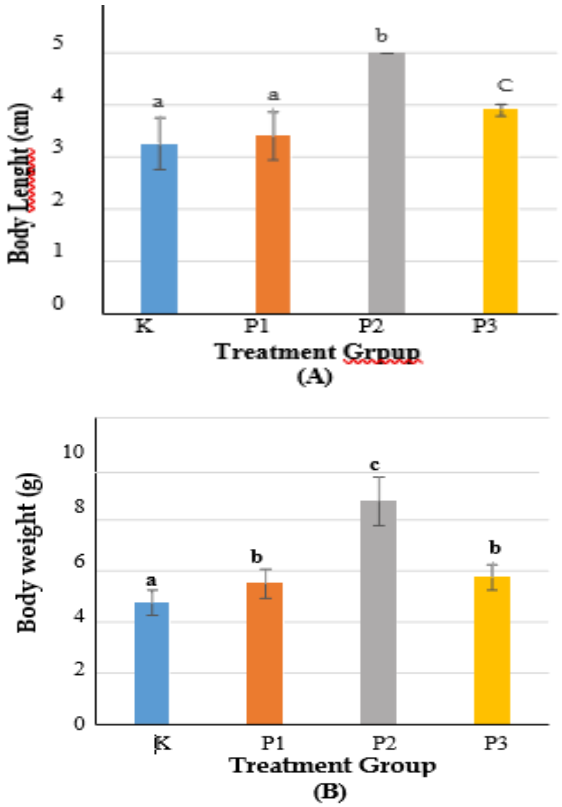


Figure 3. The absolute length gain (A) and the absolute weight gain (B) of tilapia are both interchangeable. The treatment groups consisted of the control group (K), 100% commercial feed of tilapia (*O. niloticus*); Treatment 1, 70% commercial feed + 25% *T. molitor* flour + 5% ginger flour; Treatment 2, 40% commercial feed + 50% *T. molitorm* flour + 10% ginger flour; and Treatment 3, 10% commercial feed + 75% *T. molitor* flour + 15% ginger flour. *p-value less than 0.05, one-way analysis of variance (ANOVA); **p-value less than 0.01, TS = not significant.

Specific Growth Rate (SGR)

Specialized growth rate (SGR) is the rate of fish growth over a given period. The data was analyzed using ANOVA with a confidence level of 95% or ($p < 0.05$). From The results of the ANOVA test obtained a p-value < 0.05. the difference in SGR levels from each

treatment is directly related to the balance between fatty acids and amino acids in the feed. Balanced Ratio: Fatty acids (particularly EFA such as PUFA and HUFA) are an efficient primary energy source for fish. If the meal contains fatty acids in the proper proportions and ratios, the fish will burn these fatty acids as energy for everyday activities and basic metabolism. This allows amino acids (proteins) to be totally spared and precisely allocated for the synthesis of new muscle tissue, hence boosting the SGR score.

The treatment groups consist of the control group (K), commercial feed for Nile tilapia *(O. niloticus)* 100%; Treatment 1, commercial feed 70% + T. molitor flour 25% + ginger flour 0.5%; Treatment 2, commercial feed 40% + T. molitor flour 50% + ginger flour 10%; and Treatment 3, commercial feed 10% + T. molitor flour 75% + ginger flour 1.5%. *p-value < 0.05, one-way ANOVA; ** p-value < 0.01, TS = not significant.

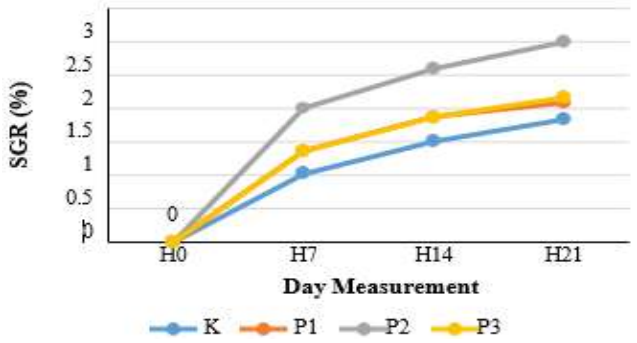


Figure 4. Specific growth rate of Nile tilapia

The average of a specific item increases by one cent every eight days. The highest rate of specialized growth is observed at Stage 2 (commercial harvest 40% + *T. molitor* 50%+ ginger 1.0%). This is due to the fact that the fish possess an optimal nutritional capacity and are required by the squid (*O. niloticus*) to maintain their size. On the seventh day following the first experiment with the addition of *T. molitor* and ginger to the sample, a p-value of less than 0.05 was obtained, indicating a highly significant difference in the rate of specific *O. niloticus* growth from day 0 to day 7. The more feed that can be converted into fish biomass, the higher the biomass of the niloticus fish *(O. niloticus*).

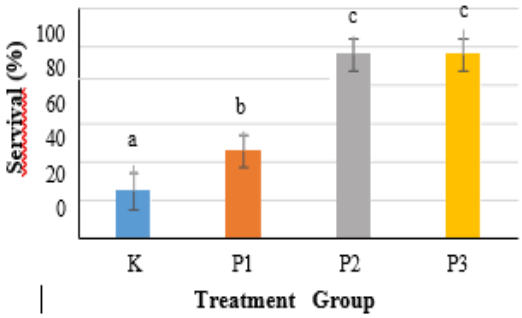


Figure 5. Survival of Nile Tilapia

The treatment groups consist of the control group (K), commercial feed for Nile tilapia (O. niloticus) 100%; Treatment 1, commercial feed 70% + T. molitor flour 25% + ginger flour 0.5%; Treatment 2, commercial feed 40% + T. molitor flour 50% + ginger flour 1.0%; and Treatment 3, commercial feed 10% + T. molitor flour 75% + ginger flour 1.5%. *p-value < 0.05, one-way ANOVA; ** p-value < 0.01, TS = not significant.

Treatment K showed the lowest survival rate, at 25%, compared to the other treatments. This was due to a lack of selectivity in the selection process for tilapia, indicating that the fish were exposed to pathogens.or bacteria during maintenance. Entry Pathogens in the rearing media can be caused by several factors such as poor water quality, contaminated feed, excessively high fish density, and poor environmental hygiene.

Where conditions are weak, treatment is needed. with feed commercial no capable return system immune body from seed fish indigo. Fish seeds indigo *(O. niloticus)* Which indicated exposed. The pathogen was identified on the 14th – 21st day where the fish had the characteristics of red gills and wounds on the body. According to Francissca & Muhsoni (2021), level continuity life Also influenced from feed Which given, the more Good And optimal the performance of the feed, the better the level of sustainability for life.

The feed content provided a protective effect on the fish by increasing endurance and strengthening the immune system. as well as repair function digestion. According to Karlsen et al. (2015), chitin content has an immunopotentiating effect on the immune response of fish and can protect these fish from bacterial challenges. Tenebrio contains chitin or oligosaccharide fractions that may function as prebiotic agents. Numerous studies have demonstrated that chitin/chitosan can enhance homeostasis and intestinal health in fish by increasing beneficial bacteria and modulating gut microbiota. When *T. molitor* is added to fish feed, the variety of the gut microbiota is increased in relation to the synthesis of SCFA, which influences the growth of beneficial

lactic acid bacteria (LAB) with strong antibacterial activity against *Aeromonas spp.*, *Pseudomonas aeruginosa*, *Listeria monocytogenes*, *Salmonella Typhimurium*, dan *E. coli*enhancing gut health (Kanani et al., 2014).

Water Quality

Water quality parameters are something that important during fish maintenance. This is because the quality of water very influential faced rate fish growth and survival rate. Poor water quality can inhibit growth and even cause death. Therefore, it is important to ensure that quality water during maintenance meets standard Which in accordance for life fish. Quality water during maintenance fish nila *(O. niloticus)* is presented as in tables 1 and 2 which resulted in the death of 1 animal in test second. According to El-Hack et al. (2022), level continuity life fish can be categorized.

Table 1. Average water quality at the beginning of tilapia *(O. niloticus)* maintenance

Treatment	Temp (° C)	Dissolved Oxigen (%)	pH
K	25.8 ± 0.23	8.1 ± 0.45	7.1 ± 1.02
P1	25.8 ± 0.78	8.1 ± 0.76	7.1 ± 0.99
P2	25.8 ± 0.88	8.1 ± 0.78	7.1 ± 1.23
P3	25.8 ± 1.01	8.1 ± 0.90	7.1 ± 1.09

Table 2. Average water quality at the ending of tilapia *(O. niloticus)* maintenance

Treatment	Temp (° C)	Dissolved Oxigen (%)	pH
K	26 ± 0.23	7.1 ± 0.23	8.1 ± 1.22
P1	26.8 ± 0.78	7.1 ± 0.9	8.2 ± 1.0
P2	27.8 ± 1.34	7.1 ± 1.45	8.5 ± 0.9
P3	27.8 ± 1.67	7.1 ± 1.67	8.5 ± 1.3

Based on tables 1 and 2, the average water quality at the beginning and in end maintenance Still in limit tolerance for the living needs of tilapia *(O. niloticus).* According to El-Hack et al. (2022), range quality water Good maintenance of tilapia (*O. niloticus*) is at a temperature of 25-32℃, pH between 6.5-8.5, And oxygen dissolved >5 mg.L-1. Mark temperature water maintenance tilapia fish (*O. niloticus*) during the study, namely 25.8 ℃. This temperature is in the range optimal for maintenance fish indigo (*O. niloticus*). The optimal temperature maintains the physiological condition of the fish still stable, like guard metabolism, growth, and the immune system of fish during maintenance. According to Indriati et al. (2023), optimal temperature will support activity enzyme digestion And absorption nutrition, so that fish can utilize feed efficiently. Besides That, the temperature that stable help maintain the level of dissolved oxygen in the water, which is essential for fish respiration (Karlsen et al., 2015).

Conclusion

A perfect functional feed formulation is produced by combining Tenebrio molitor flour with ginger flour. Ginger flour functions as a biological catalyst (bioregulator), while Tenebrio molitor provides the nutritional base (material supplier). In order to get a higher degree of life pleasure, this combination greatly boosts feed efficiency, enhances development rate, and fortifies the immune system. Adding of *T. molitor* and ginger flour to commercial feed significantly affected feed efficiency, growth, and survival of tilapia (*O. niloticus*). Treatment 2 (40% commercial feed + 50% *T. molitor* flour + 1.0% ginger flour) was the best treatment because this treatment can increase the efficiency of feeding, growth and survival compared to other treatment. This formulation can be developed as effective, low-cost, and environmentally friendly feed for tilapia.

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Authors Contributions

The following are the contributions of the authors: conceptualization, data curation, formal analysis, funding acquisition, project administration, resources, supervision, validation, and writing review, S.L. and N.; data curation, investigation, N., E.J., and N.T.; methodology, formal analysis, and writing original draft, S.L., M., and M.K.

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Conflict of Interest

The writers have disclosed no conflicts of interest.

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