Fisheries Journal, 15 (5), 2877-2889 (2025)
http://doi.org/10.29303/jp.v15i5.1705

NITROGEN AND POSPHATE ANALYSIS IN AQUAPONIC CULTIVATION SYSTEM BASED ON MAGGOT FEED (*Hermetia illucens*)

Analisis Nitrogen dan Fosfor pada Budidaya Sistem Akuaponik Berbasis Pakan Maggot *(Hermetia illucens)*

Fitri Emi Patimah[1*], Heriansah[2], Nursyahran[1], Ardi Eko Mulyawan[1]

[1]Aquaculture Study Program, Balikpapan Institute of Maritime Technology and Business,
[2]Aquatic Resources Study Program, Balikpapan Institute of Maritime Technology and Business

Perintis Kemerdekaan VIII Street No. 8 Tamalanrea, Makassar City

[*]Corresponding Author: mzaitti577@gmail.com

(Received July 11th 2025; Accepted December 9th 2025)

ABSTRACT

The aquaponics system is an alternative solution that can utilize waste from cultivation while saving land and water use. One common obstacle in tilapia and catfish cultivation is the use of artificial feed which is quite expensive from an economic point of view and produces large amounts of waste, which can degrade water quality. This study aims to compare water quality in tilapia and catfish cultivation in an aquaponics system using maggot-based feed. The study was conducted from March to May 2025 in Mandalle Village, Mandalle District, Pangkep Regency, and at the Pangkep State Agricultural Polytechnic Laboratory for measuring several water quality parameters. The study was designed on a field laboratory scale with two treatments: tilapia (A) and catfish (B), each replicated three times. Data were analyzed using an independent t-test with a 95% confidence level. The results showed that NH_3 levels at the beginning of treatment A: 0.003 mg/L and B: 0.002 mg/L, in the middle A: 0.124 mg/L and B: 0.102 mg/L, and at the end of treatment A: 0.065 mg/L. Meanwhile, the NO_3 levels at the beginning of treatment were A and B: 0.001 mg/L, mid A: 0.080 mg/L and B: 0.044 mg/L, and end A: 0.051 mg/L and B: 0.044 mg/L. For PO_4, the results were initial A and B: 0.002 mg/L, mid A: 0.048 mg/L and B: 0.015 mg/L, and end A: 0.051 mg/L and B: 0.022 mg/L. Aquaponic system with maggot feed provides a significant difference in phosphate levels, but does not show a significant difference in ammonia and nitrate levels.

Keywords: Aquaponic, Water Quality, Catfish, Tilapia

ABSTRAK

Sistem akuaponik menjadi salah satu solusi alternatif yang mampu memanfaatkan limbah hasil budidaya sekaligus menghemat penggunaan lahan dan air. Salah satu kendala umum dalam budidaya ikan nila dan ikan lele adalah penggunaan pakan buatan yang cukup mahal dari segi ekonomi dan menghasilkan limbah dalam jumlah besar yang dapat menurunkan kualitas air. Penelitian ini bertujuan untuk membandingkan kualitas air pada budidaya ikan nila dan ikan lele dalam sistem akuaponik yang menggunakan pakan berbasis maggot. Penelitian dilaksanakan dari bulan Maret hingga Mei 2025 di Desa Mandalle, Kecamatan Mandalle, Kabupaten Pangkep, serta di Laboratorium Politeknik Pertanian Negeri Pangkep untuk pengukuran beberapa parameter kualitas air. Penelitian dirancang dalam skala laboratorium lapang dengan perlakuan ikan nila (A) dan ikan lele (B), masing-masing diulang sebanyak tiga kali. Data dianalisis menggunakan uji t independen dengan tingkat kepercayaan 95%. Hasil penelitian menunjukkan bahwa kadar NH_3 pada awal perlakuan adalah A: 0,003 mg/L dan B: 0,002 mg/L, pada pertengahan A: 0,124 mg/L dan B: 0,102 mg/L, serta pada akhir perlakuan A: 0,065 mg/L. Sementara itu, kadar NO_3 pada awal perlakuan adalah A dan B: 0,001 mg/L, pertengahan A: 0,080 mg/L dan B: 0,044 mg/L, serta akhir A: 0,051 mg/L dan B: 0,044 mg/L. Untuk PO_4, hasilnya adalah awal A dan B: 0,002 mg/L, pertengahan A: 0,048 mg/L dan B: 0,015 mg/L, serta akhir A: 0,051 mg/L dan B: 0,022 mg/L. Penggunaan sistem akuaponik dengan pakan maggot memberikan perbedaan yang signifikan terhadap kadar posfat, namun tidak menunjukkan perbedaan nyata terhadap kadar amonia dan nitrat.

Kata Kunci: Akuaponik, Kualitas Air, Ikan Lele, Ikan Nila

INTRODUCTION

The agriculture and aquaculture sectors, including fisheries, play a vital role in human food production, increasing incomes, and creating jobs. Therefore, many communities have cultivated fish since ancient times. Commonly farmed freshwater fish include tilapia and catfish, using a monoculture system. Monoculture is a system that focuses on only one commodity in a single pond. However, over time, it produces waste that negatively impacts water quality (Jones *et al.,* 2015).

The impact of waste from feed poses a challenge to sustainable aquaculture. While artificial feed contributes to increased production, it is a source of waste, particularly in monoculture systems (Boyd *et al.,* 2020). Tilapia can only assimilate approximately 38% of the nitrogen (N) and 31% of the phosphorus (P) from the feed they consume, with the remainder being wasted (Sri-uam *et al.,* 2016). In tilapia farming, waste from feed and feces ranges from 15% to 20%. Meanwhile, liquid waste from catfish farming contains nutrients in the form of 1.32% nitrogen, 2.64% phosphorus, 0.35% potassium, and 0.63% organic carbon (C-organic) (Andriyeni *et al.,* 2017). Artificial feed (pellets) is relatively expensive, accounting for more than 50% of total production costs, which can reduce profits (Sanchez-Muros *et al.,* 2020). Artificial feed commonly used in fish farming is not only relatively expensive but also ineffective in accelerating fish growth. Therefore, more affordable feed that can support fish growth efficiently is needed.

Hermetia illucens larvae, also known as Black Soldier Fly (BSF), are a high-protein feed source. Their abundant nutritional content and ease of cultivation make maggots a promising alternative to expensive fish meal. Based on proximate analysis, fresh maggots have the highest crude protein content at 33.6%, followed by dried maggots at 31.2%, and supplemented maggots at 14.9% (Heriansah *et al.,* 2024). Furthermore, maggots also contain various amino acids, fatty acids, and minerals essential for fish growth (Devic *et al.,* 2018). However, uneaten maggot feed remains and can contribute to water quality degradation.

Water quality is a crucial aspect in developing aquaculture activities, so evaluating water quality parameters is essential. Several factors influence freshwater quality, including temperature, pH (acidity level), dissolved oxygen, ammonia, and nitrate (Marlina & Rakhmawati, 2016). Poor water quality can have serious impacts on fish health and survival, particularly due to waste from uneaten feed. Therefore, implementing an appropriate aquaculture system to manage this is essential (Dauda *et al.,* 2019).

Aquaponics is an alternative solution for aquaculture, enabling efficient waste utilization and saving land and water. Furthermore, this system offers the added benefit of yields from simultaneously cultivated plants (Marlina & Rakhmawati, 2016). In an aquaponic system, organic waste from fish is broken down by nitrifying bacteria, which then convert ammonia into nitrate, a compound that can be used as a nutrient source for plants.

Research on water quality in aquaponic systems shows that plants act as biological filters, directly absorbing nutrients from fish waste to support their growth. This process produces filtered, cleaner water, thus supporting fish survival. One problem faced by fish farmers is the use of artificial feed, which is relatively expensive and produces a lot of waste that can degrade water quality in aquaculture. Therefore, research was conducted on a maggot-based aquaponic system. In addition to being an alternative natural feed and being affordable, maggots also have the potential to reduce feed waste. The purpose of this study was to compare the water quality of tilapia and catfish in a maggot-based aquaponic system.

RESEARCH METHODS

The research was conducted from March to May 2025 in Mandalle Village, Mandalle District, Pangkep Regency, South Sulawesi Province. Several water quality parameters were measured at the Pangkep State Agricultural Polytechnic Laboratory.

Research Design

The study was designed on a field laboratory scale using two treatments, each replicated three times. The treatments in this study were two fish species: the nia (*Oreochromis niloticus*) and the catfish (*Clarias* sp.), reared in an aquaponic system. Both types of freshwater fish have favorable biological and economic attributes, particularly high consumer preference and the ability to utilize maggots as food (Heriansah *et al.,* 2024; Setiawan *et al.,* 2021).

Procedure

The research stages carried out are as follows:

a. Preparation of construction of a container for maintaining the aquaponic system

The aquaponics system for each treatment used seven 3-inch PVC pipes, each with nine planting holes. This resulted in a total of 63 aquaponics holes for each pond. Six additional holes were made on the sides of the center pipe, or at the left and right ends, to serve as water circulation channels into the pond. Furthermore, each planting hole was lined with flannel to maintain plant moisture and filter the water entering the pond.

b. Plant preparation

The plant used in this aquaponics system research is mustard greens (Brassica rapa L.). The first step is sowing, which involves cutting rockwool and placing it on a tray. After that, the rockwool is watered, and then a small hole is made in each piece of rockwool to plant the mustard greens. The rockwool is watered daily until the seeds germinate. Next, the mustard greens, which have grown several perfect leaves, are transferred into netpots provided in the aquaponics pipe holes.

c. Preparation of containers and cultivation water media

The fish farming system consists of six concrete pools, three each for tilapia and catfish. Each pool measures 2 m x 3 m x 1.5 m. The water used for the fish farming is freshwater with a water level of 80 cm. Water quality parameters are adjusted to the optimal range for tilapia and catfish farming.

d. Preparation of maggot feed

The maggots used are obtained from the Makassar Organic Macca Maggot Farm in the form of eggs and larvae. The eggs and larvae are then placed in separate rearing containers. The eggs hatch into larvae after 2-4 days and are then fed with fine bran. After 3-5 days, the larvae begin to grow and are transferred to several containers containing organic waste (rotten food and cow dung). Harvesting is carried out once the maggots have reached the desired size. The maggots are then dried in the sun for 3-7 days and fed to the fish.

e. Preparation of test animals

The test animals used in this study were tilapia (*Oreochromis niloticus*) obtained from the Citta Fish Seed Center (BBI), Soppeng Regency with a size of 7-9 cm. Meanwhile, catfish were obtained from cultivators in Paccerakkang, Makassar City with a size of 8-9 cm and catfish (*Clarias* sp.) Before being released, the test animals were adapted for 7 days in the holding pond.

f. Fish and plant maintenance

Tilapia and catfish were reared at a stocking density of 300 and 80 fish, respectively, for 90 days. Feeding was carried out three times daily (5% of biomass), at 7:00 a.m., 12:00 p.m., and 5:00 p.m. WITA to ensure the nutritional needs of the fish and plants were met throughout the rearing period. The mustard greens were reared for two cycles of 45 days each. Furthermore, water quality parameters were routinely measured to monitor the dynamics of water quality parameters during rearing.

g. Data collection

The water quality parameters analyzed in this study included ammonia (NH_3), nitrate (NO_3), and phosphate (PO_4). Water sampling was conducted in the first cycle at three time points: day 1 (beginning), day 23 (mid-cycle), and day 45 (end) using 350 mL sample bottles. These water quality samples were then analyzed in a water quality laboratory. In addition, water quality data such as temperature, dissolved oxygen, pH, and total dissolved solids were also collected consistently every day.

Data Analysis

Data for each water quality parameter in each maintenance container were analyzed using an independent t-test to obtain basic data patterns, such as mean values and standard deviations, and to compare the means of the two treatment groups to determine whether there were statistically significant differences. The independent t-test analysis was performed using SPSS for Windows v.25.0.

RESULT

Water quality in fish farming is a key factor that determines the health, growth, and survival of fish. Measurements of water quality parameters, such as ammonia (NH_3), nitrate (NO_3), phosphate (PO_4), pH (potential hydrogen), total dissolved solids, temperature, and dissolved oxygen, were described below:

Ammonia (NH_3)

The ammonia concentration measured at each measurement stage, namely the beginning, middle and end of the study can be seen in Figure 1.

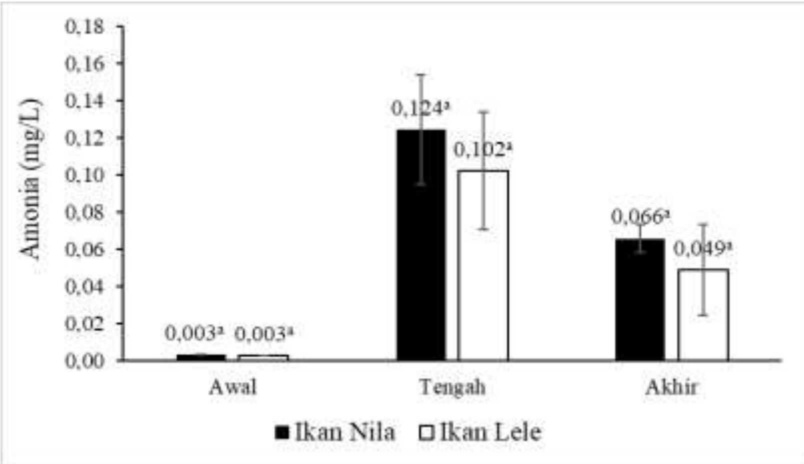

Figure 1. Ammonia (NH3) concentration of tilapia and catfish at the beginning, middle, and end of the study

Figure 1 shows that the ammonia (NH3) concentration in each treatment varied based on the measurement time. However, the results of the independent t-test analysis showed that there was no significant difference (P>0.05) in ammonia concentration in the media of tilapia and catfish reared in the maggot-based aquaponics system, either at the beginning, middle, or end of the study.

Nitrate (NO_3)

The results of nitrate (NO_3) concentration measurements at the beginning, middle, and end of the study are presented in Figure 2.

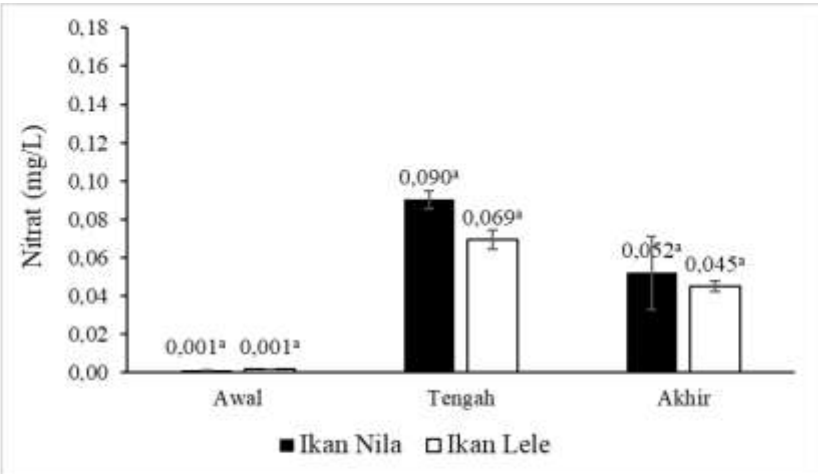

Figure 2. Nitrate (NO3) concentration in tilapia and catfish at the beginning, middle, and end of the study

The nitrate (NO_3) concentration in Figure 2 shows variations based on measurement time. However, independent t-test analysis showed no significant difference (P>0.05) in nitrate concentration in tilapia and catfish cultured in a maggot-based aquaponics system at the beginning, middle, or end of the study.

Phosphate (PO_4)

The results of the phosphate concentration (PO_4) measurements at the beginning, middle, and end of the study are presented in Figure 3.

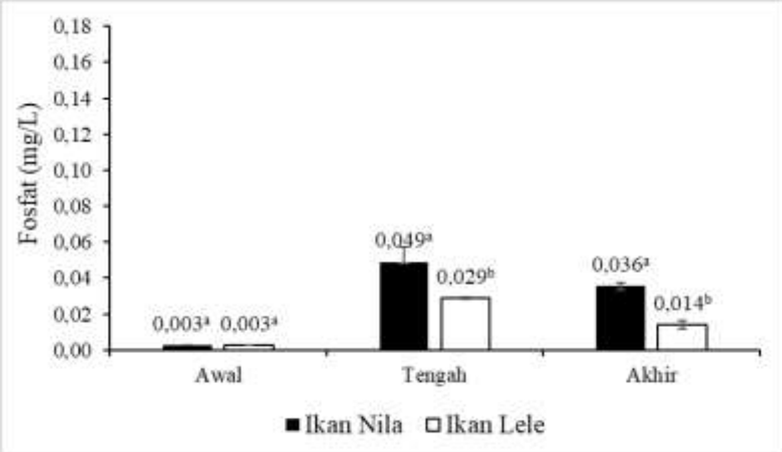

Figure 3. Phosphate (PO_4) concentration of tilapia and catfish at the beginning, middle, and end of the study

The phosphate (PO_4) concentrations shown in Figure 3 also varied in each treatment depending on the measurement time. However, the results of the independent t-test analysis showed a significant difference ($P<0.05$) in phosphate concentrations between tilapia and catfish in the maggot-based aquaponics system, both in the middle and at the end of the study.

Temperature

The daily temperature measurement data for each treatment are presented in Figure 4. Based on the results of the independent t-test, there was no significant difference ($P>0.05$) in the temperature parameters between the tilapia and catfish media maintained using a maggot-based aquaponic system.

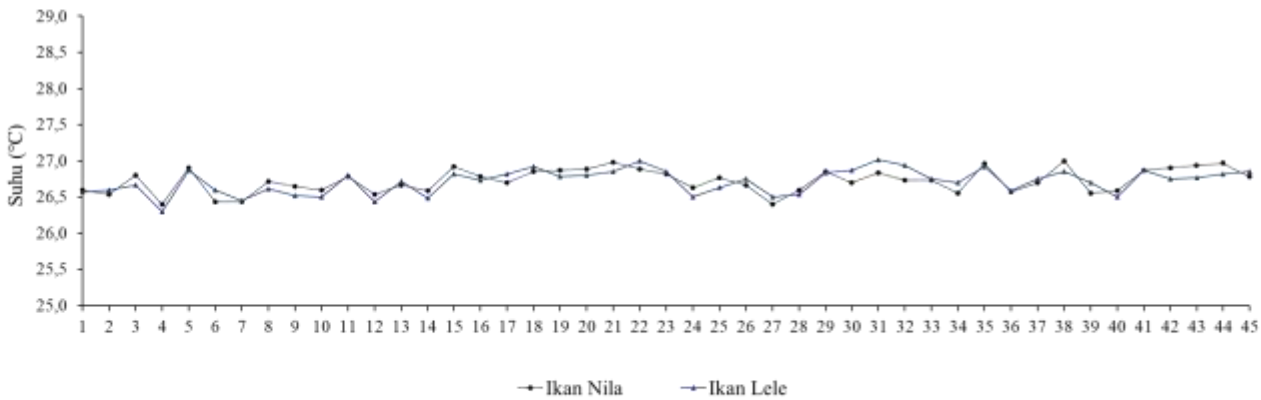

Figure 4. Daily temperature of each treatment

Dissolved oxygen

The results of daily dissolved oxygen measurements for each treatment are shown in Figure 5. The results of the independent t-test analysis showed that there was no significant difference ($P>0.05$) in the water quality parameters between tilapia and catfish media maintained using a maggot-based aquaponic system.

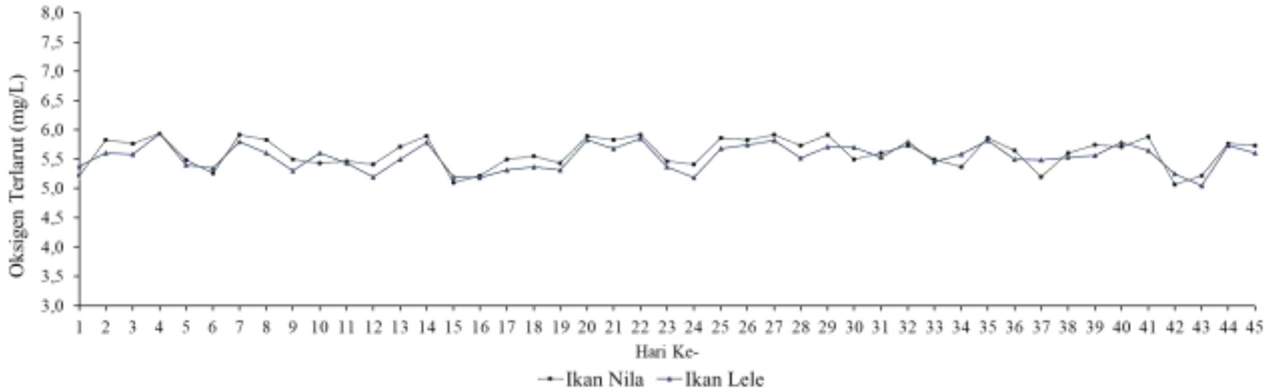

Figure 5. Daily dissolved oxygen for each treatment

pH

The results of daily pH measurements for each treatment are shown in Figure 6. The results of the independent t-test analysis showed that the pH in the maggot-based aquaponic system in tilapia and catfish media did not show any difference (P>0.05).

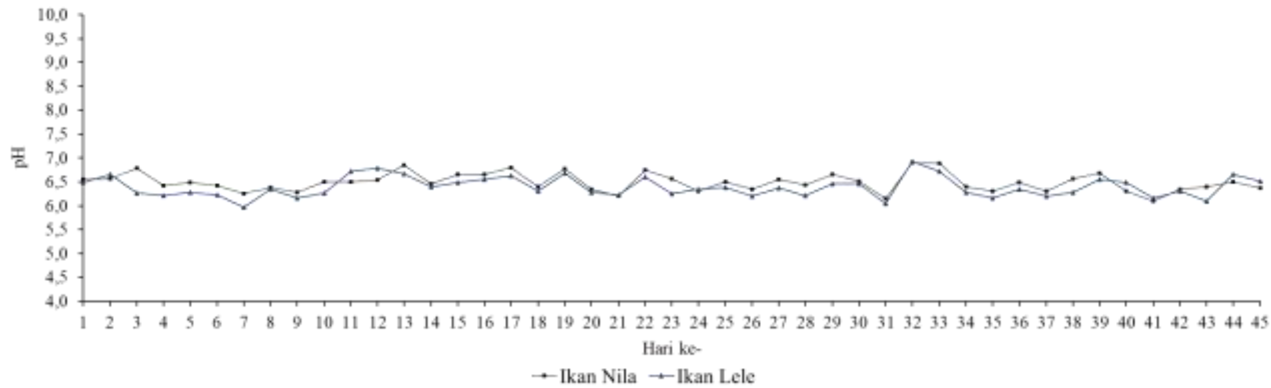

Figure 6. Daily pH for each treatment

Total dissolved solids

The results of daily total dissolved solids measurements for each treatment are shown in Figure 7. The results of the independent t-test analysis showed that the total dissolved solids in the tilapia and catfish aquaponic systems were also not significantly different (P>0.05).

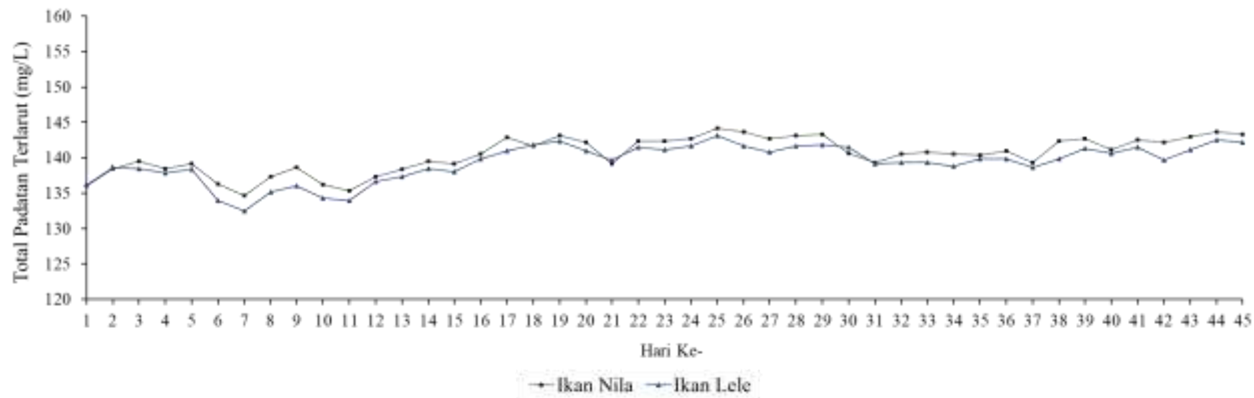

Figure 7. Total daily dissolved solids for each treatment

DISCUSSION

Ammonia (NH_3)

The results of NH_3 measurements showed that the concentration at the beginning of the study (day 1) was relatively low and did not differ significantly ($P>0.05$) between treatments (Figure 1). However, the average NH_3 concentration increased significantly in the middle of the study (day 23) but did not show a significant difference ($P>0.05$) between treatments. At the end of the study (day 45), the NH_3 concentration was observed to decrease significantly, but there was still no significant difference ($P>0.05$) between the media in tilapia and catfish. The lack of significant differences ($P>0.05$) in NH_3 concentrations between tilapia and catfish media is thought to be due to several factors, including the relatively similar ammonia production levels of both species when fed the same feed (5% dry maggot biomass), the aquaponics system's significant role in stabilizing NH_3 concentrations (Baiyin *et al.,* 2021) in both tilapia and catfish ponds, the relatively similar presence of mustard greens in the tilapia and catfish tanks as active nitrogen-absorbing biofilters (Utomo *et al.,* 2023), and the relatively uniform environmental conditions, such as temperature and dissolved oxygen levels, in the tilapia and catfish ponds.

The increased NH_3 concentration midway through the study was due to the accumulation of remaining maggot feed, feces, and metabolic excretions (Nursida *et al.,* 2023) from tilapia and catfish that had decomposed in the water. The amount of feed given to tilapia and catfish increased as their weight increased. Meanwhile, the aquaponics system is still in the process of achieving biological equilibrium, particularly for the mustard greens, which are still small and have small roots. It is known that the nutrient uptake capacity of plants is directly related to the biomass and surface area of their roots (Baiyin *et al.,* 2021). This explanation may be relevant to the observed drastic increase in the NH_3 concentration in the tilapia and catfish water medium midway through the study (day 23). Subsequently, the NH_3 concentration decreased significantly at the end of the study, but there was still no significant difference ($P>0.05$) between the NH_3 concentrations in the tilapia and catfish media. This indicates that the remaining maggot feed, feces, and metabolic excretions from the tilapia and catfish that have decomposed into NH_3 are relatively similar and can be absorbed well by the mustard greens as their biomass and root surface area increase.

The tilapia and catfish in this aquaponics system (mustard green) study were fed dried maggots, representing 5% of the fish biomass. The NH_3 concentration at the end of the study in each fish medium was relatively low, namely 0.066 mg/L in tilapia and 0.049 mg/L in catfish. The results of previous research on monoculture cultivation of aquaponic biofloc systems (kangkung plants) based on commercial feed (5% of biomass) obtained final NH_3 concentrations in tilapia media of 0.50 mg/L and catfish 0.80 mg/L (Zidni *et al.,* 2019). The NH_3 concentration in tilapia media fed with 10% dry maggots of biomass in the maintenance of a multi-trophic system (tilapia, freshwater lobster, mussels, and rice) was 0.19 mg/L (Heriansah *et al.,* 2024). Total ammonia nitrogen (TAN) in tilapia fed commercial feed at 5% of the biomass in an aquaponic system (pak choy) was 0.37 mg/L (Setiadi *et al.,* 2018).

The NH_3 concentration in this study was significantly lower than in previous studies. The low NH_3 concentration in this study indicates that dry maggot feed produces less nitrogen waste and is more efficiently utilized by the fish (Heriansah *et al.,* 2024; Setiawan *et al.,* 2021). Meanwhile, the presence of mustard greens as a biofilter appears to play a significant role in absorbing ammonia (Utomo *et al.,* 2023). The combination of maggot feed and the mustard greens aquaponic system has been shown to produce excellent water quality, characterized by stable NH_3 concentrations at levels safe for tilapia and catfish, well below 1 mg/L (Lawson, 1995).

Nitrate (NO_3)

NO_3 measurements showed that the concentration at the beginning of the study (day 1) was still low and did not differ significantly between treatments (P>0.05) (Figure 2). The NO_3 concentration then increased significantly on day 23, but remained without significant differences (P>0.05). At the end of the study (day 45), the NO_3 concentration decreased significantly, but still showed no significant difference (P>0.05) between the tilapia and catfish media. The absence of a significant difference in NO_3 concentration between the tilapia and catfish media (P>0.05) throughout all stages of the study indicates that both fish species produce relatively similar nitrogen loads and that the aquaponics system is able to stabilize nitrogen dynamics (Baiyin *et al.,* 2021) regardless of fish species. In other words, biofiltration efficiency and nutrient uptake by the mustard greens are more dominant in determining NO_3 concentration than differences in metabolic characteristics between tilapia and catfish.

The low NO_3 concentration at the beginning of the study (day 1) is suspected to be due to the nitrification process not yet being optimal. In this initial phase, the nitrifying bacterial populations—Nitrosomonas (oxidizes ammonia to nitrite) and Nitrobacter (oxidizes nitrite to nitrate) (Debroy *et al.,* 2025)—were still adapting, resulting in limited nitrate production. Over time, particularly toward the middle of the study (day 23), the activity of these two bacterial groups increased in line with plant root growth, a stable microbial environment, and increased substrate availability (ammonia and nitrite) from fish metabolism and feed residues (Rudoy *et al.,* 2025). This explains why NO_3 concentrations increased significantly in the middle phase of the study.

However, by the end of the study (day 45), NO_3 concentrations had decreased significantly again. This decrease is common in aquaponic systems because plants experience increased nitrogen requirements for growth (Debroy *et al.,* 2025). Nitrate is the primary form of nitrogen absorbed by plants (Baiyin *et al.,* 2021), so increasing plant uptake rates will reduce NO_3 concentrations in the water. Furthermore, the stable nitrifying bacterial population at the end of the study maintained a balance between nitrate production and utilization, preventing nitrate accumulation at the end of the study.

The NO_3 concentration at the end of this study in each fish culture medium was relatively low, at 0.052 mg/L in tilapia and 0.045 mg/L in catfish. Previous research on monoculture aquaponic biofloc cultivation (water spinach) using commercial feed (5% of biomass) found final NO_3 concentrations in tilapia and catfish media of 0.5 mg/L each (Zidni *et al.,* 2019). The NO_3 concentration in tilapia fed commercial feed at 5% of biomass in an aquaponic system (pak choy) was 1.93 mg/L (Setiadi *et al.,* 2018) and mustard greens at 0.55 mg/L (Utomo *et al.,* 2023).

The NO_3 concentration in this study was very low compared to previous studies. The low nitrate accumulation indicates that the nitrification process is running well, but the nitrate formed is directly utilized by the mustard greens (Utomo *et al.,* 2023) and therefore does not accumulate in the water medium. Overall, these results indicate that the combination of maggot feed and an aquaponics system with mustard greens can suppress nitrogen accumulation through a stable nitrification process and optimal nitrate uptake by the plants.

Phosphate (PO_4)

PO_4 measurements showed that the concentration at the beginning of the study (day 1) was still low and did not differ significantly between treatments (P>0.05) (Figure 3). The PO_4 concentration then increased significantly midway through the study (day 23), but remained without significant differences (P>0.05). However, at the end of the study (day 45), the PO_4 concentration decreased significantly and showed a significant difference (P<0.05) between the tilapia and catfish media. The low PO_4 concentration at the beginning of the study (day 1) was due to the relatively limited initial phosphorus content in the water used in the system. The water used in this study had undergone filtration and sedimentation processes to remove suspended particles and dissolved nutrients.

The PO_4 concentration at the middle of the study (day 23) increased significantly, indicating phosphate accumulation in the rearing media. This accumulation is likely due to the excretion of tilapia and catfish and the degradation of dried maggot feed residues, which release phosphorus into the media (Nursida *et al.,* 2023). Furthermore, it is suspected that microbial activity in the aquaponic system, decomposing complex organic compounds into soluble inorganic phosphate, increased (Rudoy *et al.,* 2025). Despite this increase, the difference in concentration between media was still insignificant. This is likely because both fish species produce relatively similar amounts of phosphorus, while the mustard plants' absorption capacity during the early growth phase is not yet optimal (Baiyin *et al.,* 2021).

At the end of the study (day 45), PO_4 concentrations decreased significantly and began to show a significant difference ($P<0.05$) between the tilapia and catfish media. This decrease was closely related to increased phosphorus uptake by the mustard plants entering the growth phase, where phosphate becomes an essential nutrient for leaf and stem formation (Debroy *et al.,* 2025). The significant difference between the tilapia and catfish media is likely influenced by the different growth patterns of the mustard plants. The mustard plants in the catfish tank grew better than the tilapia tanks. The nutrient uptake capacity of plants increases with their biomass and root surface area (Baiyin *et al.,* 2021).

The final PO_4 concentration in each fish culture medium was relatively low, at 0.052 mg/L in tilapia and 0.045 mg/L in catfish. Previous research on tilapia fed commercial feed at 5% of their biomass in an aquaponics system (with bok choy) yielded a final PO_4 concentration of 0.19 mg/L (Setiadi *et al.,* 2018). The final PO_4 concentration in tilapia fed commercial feed at 5% of their biomass in an aquaponics system (with mustard greens) was 0.46 mg/L (Utomo *et al.,* 2023).

The PO_4 concentration in this study was relatively low compared to previous studies. Feeding dried maggots as much as 10% of the fish biomass used is thought to produce less phosphorus waste than commercial feed because maggots have a high protein content that is more easily digested by fish and results in minimal phosphorus excretion (Heriansah *et al.,* 2024). Commercial feeds used in previous studies may produce more phosphorus waste that is not commensurate with the plant's ability to absorb phosphate. The results of this study indicate that the combination of dried maggot feed with mustard plants in an aquaponic system can suppress phosphate accumulation, thereby reducing the risk of eutrophication usually associated with high phosphate concentrations.

Temperature, dissolved oxygen, and pH

Temperature, dissolved oxygen, and pH are important water quality parameters that play a vital role in fish survival. Temperature is known to affect plant nutrient uptake, and metabolic rates and nutrient uptake processes, including nitrogen and phosphate, tend to increase within the optimal temperature range (Debroy *et al.,* 2025). Water temperatures during the study in tilapia and catfish culture media were not significantly different ($P>0.05$). Daily temperatures remained relatively stable throughout the culture period, ranging from 26.3–27.0°C (Figure 4), which is optimal for both fish and plants (Zidni *et al.,* 2019). Aquaponic pond construction for both tilapia and catfish ponds utilizes shade netting to reduce heat in the ponds. Furthermore, aquaponic pipes and mustard greens shaded in each pond also appear to help reduce heat exposure in the water column. This results in relatively equal heat distribution across both media, resulting in no significant difference in water temperature between the tilapia and catfish ponds.

Dissolved oxygen is essential for fish metabolism, and Nitrosomonas bacteria convert nitrite into nitrate, which is essential for the plants (Rudoy *et al.,* 2025). Daily dissolved oxygen levels during the study in tilapia and catfish culture media were not significantly different (P>0.05), ranging from 5.1–5.9 mg/L throughout the entire culture period (Figure 5). This dissolved oxygen range is within the optimal range for fish and plants (Zidni *et al.,* 2019). Continuous water flow from small, specially designed pipe holes in the tilapia and catfish aquaponics systems appeared to be effective as an aeration system in this study. Furthermore, through photosynthesis, plants in each pond produce oxygen, which is released into the water (Rudoy *et al.,* 2025). This condition resulted in relatively equal dissolved oxygen levels in both media, resulting in no significant difference in dissolved oxygen levels in the water in the tilapia and catfish ponds.

The pH in aquaponic systems significantly affects nutrient availability, the nitrification process, and the health of plants and fish (Debroy *et al.,* 2025). Daily pH values during the study in tilapia and catfish media were not significantly different (P>0.05), ranging from 6.0 to 6.9 (Figure 6). This pH range is within the tolerance range for fish and plants (Zidni *et al.,* 2019). A decrease in pH can occur due to water quality degradation caused by leftover feed and feces. The lack of significant differences in pH between tilapia and catfish media is due to several key factors related to the relatively similar characteristics of the aquaponic systems..

Total dissolved solids

Total dissolved solids (TSS) is the sum of all solid particles suspended in water. The main sources of TSS in aquaponic systems are inorganic substances (floating hydroponic roots, leftover feed, and fish feces) and inorganic waste (rockwool). The decrease in TSS levels occurs due to the oxidation of ammonia by nitrifying bacteria (Dwiardani *et al.,* 2021). The daily pH during the study in the tilapia and catfish aquaponic media ranged from 132.5 to 144.2 mg/L, which was not significantly different (P>0.05) between the two rearing media (Figure 7). The physical design of the aquaponic system and the same waste source provided uniform environmental conditions between the two ponds, so there were no external factors that could cause differences in suspended particles between the tilapia and catfish ponds.

CONCLUSION

All water quality parameters in the maggot-based aquaponic system, including NH_3, NO_3, pH, and TPT, were not significantly different between tilapia and catfish media, except for the PO_4 parameter, which showed a statistically significant difference. This difference indicates that phosphorus dynamics in the system are more sensitive to variations in excretion between fish species and plant uptake rates than other water quality parameters. The results obtained in this study confirm that combining alternative feed solutions (maggots) with an aquaponic system has several advantages compared to using commercial feed.

ACKNOWLEDGEMENT

The author recognizes that the success of this research and publication is inseparable from the assistance, support, and cooperation of various parties. Therefore, with the utmost respect, the author expresses his deepest gratitude to all parties who have contributed from the beginning to the completion of this research and publication.

REFERENCES

Baiyin, B., Tagawa, K., Yamada, M., Wang, X., Yamada, S., Shao, Y., An, P., Yamamoto, S., & Ibaraki, Y. (2021). Effect of Nutrient Solution Flow Rate on Hydroponic Plant Growth And Root Morphology. *Plants*, *10*(1840), 1–11.

Boyd, C. E., D'Abramo, L. R., Glencross, B. D., Huyben, D. C., Juarez, L. M., Lockwood, G. S., McNevin, A. A., Tacon, A. G. J., Teletchea, F., Tomasso, J. R., Tucker, C. S., & Valenti, W. C. (2020). Achieving Sustainable Aquaculture: Historical and Current

Perspectives and Future Needs and Challenges. *Journal of the World Aquaculture Society*, *51*(3), 578–633. https://doi.org/10.1111/jwas.12714

Debroy, P., Majumder, P., Majumdar, P., Das, A., & Seban, L. (2025). Analysis of Opportunities and Challenges of Smart Aquaponic System : A Summary of Research Trends And Future Research Avenues. *Sustainable Environment Research*, *35*(18), 1–19.

Devic, E., Leschen, W., Murray, F., & Little, D. C. (2018). Growth Performance, Feed Utilization and Body Composition of Advanced Nursing Nile Tilapia *(Oreochromis niloticus)* Fed Diets Containing Black Soldier Fly *(Hermetia illucens)* Larvae Meal. *Aquaculture Nutrition*, *24*(1), 416–423. https://doi.org/10.1111/anu.12573

Dwiardani, K. H., Prayogo, & Rahardja, B. S. (2021). Utilization of *Nitrosomonas* sp. and *Nitrobacter* sp. probiotic Towards Total Suspended Solid and Ammonia Level in Nile Tilapia Culturing Using Aquaponic System. *IOP Conf. Series: Earth and Environmental Science 679*, 012067. https://doi.org/10.1088/1755-1315/679/1/012067

Heriansah, Fathuddin, Kabangnga, A., Nursidi, & Alfarifdy, I. M. (2024). Enhanced growth Potential of Tilapia *(Oreochromis niloticus)* Through Maggot-Based Feeding in Multi-Trophic Systems. *Journal of Aquaculture and Fish Health*, *13*(3), 375–387. https://doi.org/10.20473/jafh.v13i3.51287

Jones, A. C., Mead, A., Kaiser, M. J., Austen, M. C. V., Adrian, A. W., Auchterlonie, N. A., Black, K. D., Blow, L. R., Bury, C., Brown, J. H., Burnell, G. M., Connolly, E., Dingwall, A., Derrick, S., Eno, N. C., Gautier, D. J. H., Green, K. A., Gubbins, M., Hart, P. R., … Sutherland, W. J. (2015). Prioritization of Knowledge Needs for Sustainable Aquaculture: A National and Global Perspective. *Fish and Fisheries*, *16*(4), 668–683. https://doi.org/10.1111/faf.12086

Lawson, T. B. (1995). *Fundamentals of Aquacultural Engineering*. Chapman and Hall Publishers.

Marlina, E., & Rakhmawati. (2016). Kajian Kandungan Ammonia pada Budidaya Ikan Nila (*Oreochromis niloticus*) Menggunakan Teknologi Akuaponik Tanaman Tomat *(Solanum lycopersicum)*. *Prosiding Seminar Nasional Tahunan*, 181–187.

Nursida, N. F., Heriansah, H., Kabangnga, A., Nursidi, N., Sulmiati, A., & Putri, A. A. (2023). Ammonia-Nitrogen (NH3-N) in the coculture System of Aquatic Animals and Rice Plants in Brackish Water. *Jurnal Sains Akuakultur Tropis*, *8*(1), 50–59.

Rudoy, D., Olshevskaya, A., Shevchenko, V., Prazdnova, E., & Odabashyan, M. (2025). Prospects for The Application of Probiotics to Increase The Efficiency of Integrated Cultivation of Aquatic Animals And Plants in Aquaponic Systems. *Fishes*, *10*(251), 1–20.

Sanchez-Muros, M. J., Renteria, P., Vizcaino, A., & Barroso, F. G. (2020). Innovative Protein Sources in Shrimp *(Litopenaeus vannamei)* Feeding. *Reviews in Aquaculture*, *12*(1), 186–203. https://doi.org/10.1111/raq.12312

Setiadi, E., Widyastuti, Y. R., & Heru Prihadi, T. (2018). Water Quality, Survival, and Growth of Red Tilapia, *Oreochromis niloticus* Cultured in Aquaponics System. *E3S Web of Conferences*, *47*. https://doi.org/10.1051/e3sconf/20184702006

Setiawan, H., Putra, I. L. I., Alfatah, R., & Nasikhudin, A. N. (2021). The Effectiveness Combination of Maggot with Commercial Feed on Growth, Structure of Intestine and Skeletal Muscle Mutiara Catfish. *Journal of Aquaculture and Fish Health*, *11*(1), 70–80. https://doi.org/10.20473/jafh.v11i1.26063

Sri-uam, P., Donnuea, S., Powtongsook, S., & Pavasant, P. (2016). Integrated Multi-Trophic Recirculating Aquaculture System for Nile Tilapia *(Oreochlomis niloticus)*. *Sustainability (Switzerland)*, *8*(7). https://doi.org/10.3390/su8070592

Utomo, A., Effendi, H., & Darmawangsa, G. M. (2023). Excess Nutrient Removal from Fish Culture Using Aquaponics System : A Laboratory Scale. *Bioflux*, *16*(2), 1145–1155.

Zidni, I., Buwono, I. D., & Mahargyani, B. P. (2019). Water Quality in The Cultivation of Catfish *(Clarias gariepinus)* and Nile Tilapia *(Oreochromis niloticus)* in The Aquaponic Biofloc System. *Asian Journal of Fisheries and Aquatic Research*, *4*(2), 1–6. https://doi.org/10.9734/AJFAR/2019/v4i230048