Application of organic fertilizer made from solid waste from shrimp ponds for tilapia nursery (*Oreochromis niloticus*)

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Abstract. The solid waste of super-intensive aquaculture ponds can be used as organic fertilizer. Organic fertilizers are useful in soil nutrient enrichment and improvement. The purpose of this study was to utilize the solid waste of super-intensive ponds as an organic fertilizer for the nursery of tilapia (*Oreochromis niloticus*). The treatments applied were: (A) organic fertilizer of solid waste of shrimp ponds with a dose of 0.1 kg/m^2, (B) organic fertilizer of solid waste of shrimp ponds with a dose of 0.2 kg/m^2, (C) organic fertilizer of solid waste of shrimp ponds with a dose of 0.3 kg/m^2, (D) without organic fertilizer (control). The parameters observed were the growth of natural feed (plankton), tilapia's growth and survival rate, and water quality. The growth and survival rate data were analyzed using one-way ANOVA, while water quality and natural feed data were analyzed descriptively. The result showed that the absolute growth of tilapia obtained during the study ranged from 0.1955-0.3158 g/ind with SGR 0.6517-1.0527 %/day. The highest phytoplankton abundance in treatment A was 102858 ind/L, and zooplankton was 70354 ind/L. The study's water quality supported tilapia's growth and natural feed.

1 Introduction

Shrimp farming activities generate cultivation waste, which, if not promptly managed, has the potential to contaminate the aquatic environment. The residual agricultural waste still contains a significant amount of organic nutrients. The waste comprises ammonia, organic matter, and solid substances. Shrimp cultivation waste can negatively impact the aquatic environment. The management of water, specifically the quantity and frequency of water changes, determines the extent of these effects. A higher frequency and quantity of water changes result in a larger potential waste load in super-intensive shrimp farming.

Sediment-induced siltation and the elevated nutrient concentration in waste lead to an excessive production of phytoplankton, resulting in a decline in the quality of dissolved oxygen [1]. The presence of significant amounts of organic nutrients in water bodies can lead to eutrophication in public waters. This, in turn, can lead to the mortality of aquatic creatures, sedimentation, fertilization of algae, and the generation of unpleasant odors [2]. More

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effective management of cultivation waste can yield beneficial outcomes. Aquaculture pond waste contains nutrients that can serve as organic fertilizer to cultivate natural feed within the pond.

The superintensive whiteleg shrimp farming technology has implications for the amount of garbage generated. The whiteleg shrimp farming feed yielded a retention rate of 22.27% for nitrogen (N) and 9.79% for phosphorus (P). As a result, the pond's aquatic environment lost and released a significant amount of nutrients, specifically 77.73% of nitrogen and 90.21% of phosphorus [3]. Whiteleg shrimp farming at a density of 50 individuals per square meter led to the discharge of 108,495 kg of nitrogen and 56,129.56 kg of phosphorus waste into the aquatic environment [4]. At stocking densities of 500 and 600 white shrimp per square meter, nitrogen retention was 30.47% and 33.34%, respectively, while phosphorus retention was 16.59% and 18.05%, respectively. The waste generated may reach 406.57 kgN and 100.33 kgP at a density of 500 individuals per square meter, or 532.30 kgN and 119.50 kgP at a density of 600 individuals per square meter [5].

A challenge associated with superintensive farming is the discharge of aquaculture effluent, which adversely impacts the water quality of the surrounding ecosystem. The accumulation of organic materials from residual feed and excrement contributes to this problem [6]. The release of water waste from farming activities leads to the degradation of the pond's aquatic environment. This waste contains high levels of nitrogen and phosphorus, as well as organic and nutritional waste. Additionally, the introduction of feed residues and feces into the water further contributes to the pollution. Eventually, the surrounding waters receive the discharge of this polluted water [7]. Shrimp farming generates approximately 12.6–21 kg of nitrogen and 1.8–3.6 kg of phosphorus per ton of shrimp produced, based on a feed conversion ratio (FCR) of 1.5. The waste generation will escalate as shrimp productivity improves [8].

The solid waste from WWTP settling ponds can serve as a valuable source of organic fertilizer because of its relatively high nutrient content, including N total at 0.67%, P_2O_5 at 4.78%, and K_2O at 1%. The sample has an organic carbon content of 17.84%, a pH of 6.25, and a moisture content of 15.60%. The carbon-to-nitrogen ratio is also 17.84% [9]. Organic fertilizer derived from the solid waste of superintensive ponds significantly enhances the growth of klekap in aquatic environments [10]. Plants, animals, or organic waste are the sources of organic fertilizer. Furthermore, organic fertilizers are known to improve soil structure and increase water retention capacity compared to pesticides.

Tilapia (*Oreochromis niloticus*) is currently the most common commodity in aquaculture. Tilapia is a highly cultivable fish species that exhibits rapid growth and reproductive rates, as well as strong resistance to pests and illnesses [11]. Tilapia has a high tolerance to its environment, so it can be kept in lowlands with brackish water to highlands with fresh water. The habitat of this fish is quite diverse, it can be in rivers, lakes, reservoirs, swamps, rice fields, ponds, or fishponds. Tilapia commodities possess several advantages, including significant resistance to water quality and disease, broad tolerance to environmental conditions, efficient conversion of organic materials and agricultural waste into high-quality protein, robust growth potential, and suitability for intensive cultivation systems [12, 13, 14, 15].

Based on the description above, A study was undertaken to evaluate the efficacy of organic fertilizer derived from solid shrimp pond waste on the growth of natural feed and the growth performance of tilapia. The purpose of this study was to utilize the solid waste of super-intensive ponds as an organic fertilizer for the nursery of tilapia (*Oreochromis niloticus*).

2 Materials and method

The study was conducted at the Wet Laboratory, Research Institute for Brackishwater Aquaculture. It involved using 12 styrofoam containers measuring 70 x 37 x 26 cm^3. The containers were filled with pond soil at the bottom, with a thickness of approximately 5 cm. We maintained the water level in the containers at approximately 30 cm and painted the containers' walls. For this study, the rearing period of juvenile tilapia was for one month as experimental subjects.

Applying organic fertilizer to the maintenance tank before introducing the fish fry. We specifically use fermented sediment fertilizer and add an activator to the cultivation media. The organic fertilizer consists of urea at a dose of 0.02 kg/m2 and SP36 at a dose of 0.01 kg/m^2. The objective is to cultivate organic fodder in the container. Only after 2 weeks do we disperse the tilapia fry. The first population of test animals was 30 individuals per tub. The therapy utilized in this study involves varying the dosage of organic fertilizer derived from solid waste from shrimp ponds to enhance the production of natural feed and promote the growth of tilapia. The treatment administered is A: Organic fertilizer from solid waste from shrimp ponds at a dose of 0.1 kg per square meter. B: Organic fertilizer from solid waste from shrimp ponds at a dose of 0.2 kg per square meter. C: Organic fertilizer from solid waste from shrimp ponds at a dose of 0.3 kg per square meter. D: Without organic fertilizer (control group).

The variables measured during the experiment were the composition of plankton, the growth and survival of tilapia, and the quality of the water. They measured things like temperature, dissolved oxygen (using a DO meter), salinity (refractometer), pH (pH meter), TOM (titrimetry), alkalinity titrimetry), nitrate (the cadmium reduction method), and phosphate (the ascorbic acid method). The statistical software SPSS Program version 21.00 evaluated the growth and survival data using a variety of analysis of variance (ANOVA) methods. Descriptive analysis was used for the water quality data and the natural feed composition.

Absolute growth

The absolute growth of tilapia was determined with the following formula [16]:

$$\mathbf{Wm = W\,t - Wo} \tag{1}$$

Where:

Wm: Absolute growth of fish (grams)

Wt: Final average weight of fish (grams)

Wo: Initial average weight of fish at the initial of the study (grams)

Specific growth rate:

The specific growth rate (SGR) of tilapia was measured with the following formula [17]:

$$\boldsymbol{SGR}\ (\%/\boldsymbol{day}) = \mathbf{100}\boldsymbol{x}\,\frac{(\ln \boldsymbol{Wt} - \boldsymbol{ln W0})}{\boldsymbol{t}} \tag{2}$$

where Wt is the final weight of fish, W0 is the initial weight of fish, and t is the rearing period.

Survival Rate:
Survival rate (SR) was measured using the following formula [17]:

$$\boldsymbol{Survival\ rate\ (SR)}\ (\%) = \left(\frac{\boldsymbol{final\ amount\ of\ fish}}{\boldsymbol{initial\ amount\ of\ fish}}\right)\boldsymbol{x100} \quad (3)$$

3 Result

3.1. Growth performance and survival rate of juvenile tilapia (*O. niloticus*)

The study's results, displayed in Table 1, show that the absolute growth of tilapia with a dose of 0.1 kg per m^2 of organic fertilizer application was higher compared to those fed with a dose of 0.3 kg per m^2 and 0.2 kg per m^2 of fertilizer, as well as those without any organic fertilizer (control). Similarly, the specific growth of tilapia juvenile with an application dose of 0.1 kg/m^2 of organic fertilizer was significantly higher at 1.0527±0.0016 % $days^{-1}$, compared to the treatment with a dose of 0.3 kg/m^2 at 0.8220±0.0161 %$days^{-1}$, and the control at 0.6517±0.0045 %$days^{-1}$. In contrast to the findings [18], the growth rate of tilapia weight observed in this study deviates significantly. Their research reported a range of 3.20-4.17% per day during the nursery period. A study conducted by [19], found that red tilapia when reared in water with a salinity of 32 parts per thousand for 106 days, exhibited a specific growth rate of 3.70% per day. The tilapia's specific growth rate varies between 2.50% to 2.94% per day, depending on the feed percentages [20]. Average body weight value of 1.92 g/day and a specific growth rate of 1.41%/day in Tilapia (*O. niloticus*) fed duckweed [21]. The specific growth rates of red tilapia that were selected and those that were not selected were 1.47±0.14% weight per day and 1.33±0.11% weight per day, respectively. The selected red tilapia also had a growth rate of 0.74±0.09 g/day. These growth rates were observed these growth rates over 90 days, during which the fish received commercial feed [22]. The daily growth rate of 1.31%/day in tilapia fed with additional fish meal, 1.31 %/day in fish fed with copra meal, and 1.34% in fish fed with copra meal supplemented with sesame oil for 6 weeks of maintenance. [23]. The study conducted by [24], found that the tilapia in all treatments experienced an increase in both their absolute weight and specific growth rate. This indicates that the tilapia effectively utilized the natural feed, including plankton and developing klekap (bottom algae), provided to them. As the tilapia aged and grew, the amount of natural feed steadily decreased. The specific growth rate of tilapia fed a combination of commercial feed and tofu waste ranges from 2.29–2.49%/day.

Table 1. Growth performance of tilapia juvenile with different organic fertilizer applications

Treatment	Absolute Growth (g)	SGR (% $days^{-1}$)
A. (0.1 kg/m^2)	0.3158±0.0016	1.0527±0.0016
B. (0.2 kg/m^2)	0.2724±0.0034	0.9080±0.0034
C. (0.3 kg/m^2)	0.2466±0.0161	0.8220±0.0161
D. (Control)	0.1955±0.0045	0.6517±0.0045

The survival rate of juveniles of tilapia obtained during the study can be seen in Figure 3. Treatment A exhibited the highest survival rate at 87.8 ± 10.18%, whereas treatment B followed with a rate of 80.1 ± 14.56%. Treatment C exhibited a rate of 73.37 ± 20.82%, whilst treatment D recorded the lowest rate of 61.11 ± 19.24%. The survival of fish is significantly impacted by the characteristics of their habitat, such that favorable environmental conditions can enhance fish survival. The survival of fish is affected by both internal and external influences [16]. The survival rate of the produced tilapia fish exhibits significant divergence from the findings of other investigations. In their study, [24], observed that the red tilapia had an average survival rate of 53.48-59.54% for 112 days. The death of fish in all treatments can be attributed to the initial adaption process and incraising the salinity. The longevity of fish is directly linked to their ability to tolerate salinity, as excessive salinity levels lead to increased osmotic pressure, resulting in damage. Ultimately, fish that are unable to endure the harsh conditions of their environment will perish.

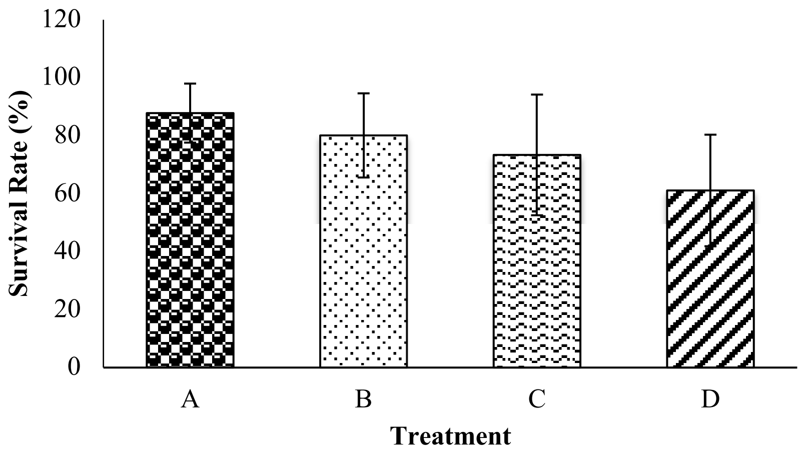

Fig.1. Survival rate of nile tilapia juveniles with different organic fertilizer applications

3.2. Species Composition of Plankton

The study in Table 2 identified two types of plankton: phytoplankton and zooplankton. The number of phytoplankton types and individuals was higher than that of zooplankton. The study found several types of phytoplankton, such as *Chaetoceros* sp., *Navicula* sp., *Nitzschia* sp., *Oscillataria* sp., *Dittyoccystis* sp., *Pleorisigma* sp., *Apocyclops* sp., *Coscinodiscus* sp., and *Prorcentrum* sp. The investigation identified several zooplankton species, including *Brachionus* sp., *Eupluts* sp., *Amphiprora* sp., *Copepoda* sp., *Colurella* sp., *Tintinopsis* sp., *Echinocampus* sp., and *Vorticella* sp. The *Oscillataria* sp. has the largest phytoplankton abundance at 146,790 individuals per liter, followed by *Nitzschia* sp. at 104,778 individuals per liter. The abundance of the zooplankton species, *Brachionus* sp, is approximately 109,655 individuals per litre, whereas the abundance of the *Copepoda* sp species is roughly 63,495 individuals per liter.

During the maintenance of white shrimp utilizing inorganic fertilizers alongside numerous organic fertilizers, plankton species were obtained throughout the experiment : *Gymnodinium* sp, *Gyrosigma* sp, *Synechocystis* sp, *Surirella* sp *Navicula* sp, *Pyrophacus* sp, *Oscillatoria* sp, *Pleurosigma* sp, *Synechocystis* sp, *Surirella* sp, *Thallasionema* sp, *Amphiprora sp, Aphanothocea sp, Coscinodiscus* sp, *Clindropyxis* sp, *Cyclotella* sp, *Caratium sp, Chaetoceros sp, Ditylum* sp, *Eutreptia* sp, *Guinardia* sp, *Globigerina* sp, *Gyrodinium* sp, *Lyngbia* sp, *Strombidium* sp, *Thallassiorira* sp, *Chlorella* sp, *Melosira* sp, *Nitzschia* sp, *Onychocamptus* sp, *Balanus* sp, *Branchionus sp, Acartia sp, Apocyclops sp, Echinocamptus sp, Naupli Copepoda, Copepoda* sp, *Nitocra* sp, *Polychaeta, Schamackeria* sp, and *Tintinnopsis* sp. [25]. Proportions of plankton composition categorized by class derived from the cultivation of milkfish utilizing various organic fertilizers. 41.86% (18 genera) Class Bacillariophyceae, 23.26% (10 genera) Crustacea, 11.63% (5 genera); Chromonadea, 6.98% (3 genera) Cyanophyceae, 6.98% (3 genera) Ciliata constituted 4.65% (2 genera), whereas Rotatoria represented 2.33% (1 genus), with Sarcodina and Polychaeta classes each being the lowest proportion. The predominant phytoplankton was *Nitzschia* sp., but the zooplankton was primarily composed of *Nauplii copepods*, which are a favorite food source for fish [26].

Conventional shrimp pond management predominantly depends on plankton, particularly phytoplankton, and zooplankton, as the principal source of natural nourishment. Preliminary fertilization in the initial phases of preparation nurtures and maintains this food source [27]. Fertilizer enhances the proliferation of natural food sources such as plankton, klekap, and benthos in aquaculture ponds [28]. The application of fertilizer with differing N/P ratios in each treatment influences both the abundance and composition of phytoplankton. Ponds subjected to fertilization exhibit a higher abundance of phytoplankton than those that have not been fertilized [29].

Table 2. Species composition and abundance of plankton on each treatment during the experiment.

No	Species	Abundance of Plankton (Ind/L)			
		A	B	C	D
Phytoplankton					
1	*Navicula* sp	1980	2157	3690	1577
2	*Nitzshia* sp	62411	11704	13375	16010
3	*Oscillatoria* sp.	37511	53952	28933	32314
4	*Coscinodiscus* sp.	0	0	100	0
5	*Pleurosigma* sp.	610	1007	200	2350
6	*Amphipora* sp.	306	2351	5916	204
7	*Prorocentrum* sp.	0	105	0	0
Total		102859	71276	52214	52455
Zooplankton					
8	*Copepoda* sp.	12554	11315	13681	24932
9	*Barchionus* sp.	53468	3972	10198	34942
10	*Vorticella* sp.	1164	-	-	-
11	Colurella sp.	816	918	307	408
12	*Apocyclops* sp.	2148	724	1530	3816
13	*Tintinopsis* sp.	0	102	100	0
14	*Echinocampus* sp.	204	0	104	0
15	*Euplotes* sp.	0	630	0	0
Total		70354	17661	25920	64098

3.3. Water quality

The environmental conditions of the maintenance medium can be influenced by both physical and chemical aspects of water quality, which in turn can impact the treatment process. Environmental conditions regulate the metabolic activities of aquatic species. Figures 2 and 3, below display the values of water quality measured for each treatment throughout the research period.

The temperature is critical because it directly impacts organisms' metabolism and growth. Fish exhibit a positive correlation between water temperature and metabolic activity, meaning that as water temperature increases, fish metabolism becomes more active, and conversely, as water temperature decreases, fish metabolism becomes less sprightly. Temperature conditions significantly influence the fish's longevity. Under cold conditions, the fish will experience a decrease in their desire to eat and become more vulnerable to illnesses. In contrast, when the temperature is very high, the fish will undergo respiratory distress and may incur lasting damage to their gills. The temperature will also influence the concentration of dissolved oxygen in the water. The investigation recorded temperatures during the experiment ranging from 27°C to 29°C. The water temperature range for cultured tilapia ranges from 15 to 37 degrees Celsius [30]. The temperature range in which fish can survive is between 25°C and 30°C, as reported [15].

The pH level has a significant impact on organisms' survival and well-being. Excessive and persistent fluctuations in acidity levels might impede growth and potentially lead to mortality. The study yielded a pH range of 7.9–8.2, which can be considered the ideal pH for fish growth. Generally, fish growth is excellent within a pH range of 6–9, [31]. The study recorded dissolved oxygen levels ranging from 2.4 mg/L to 5.1 mg/L. The dissolved oxygen levels in each treatment were nearly identical to those in the control treatment (D) on day 7, reaching a concentration of 4.0 mg/L. Nonetheless, the levels of dissolved oxygen in the maintenance medium remain favorable for tilapia growth and survival. [32], asserts that the optimal dissolved oxygen range for tilapia growth and development is 5 mg/L.

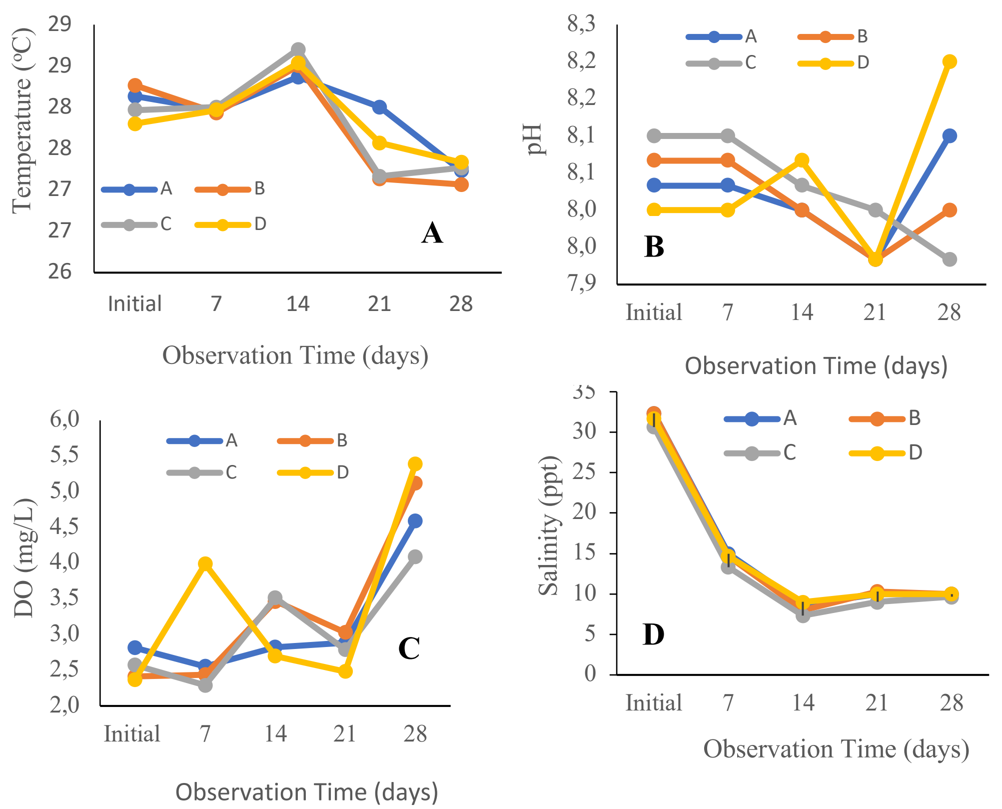

Fig.2. Water quality fluctuations in temperature (A), pH (B), dissolved oxygen (C), and salinity (D) during the experiment.

During the investigation, the salinity value was 7-32 ppt, this difference is thought to be caused by high evaporation and the addition of water in each treatment. According to [33], estuary waters exhibit different levels of salinity gradients, which are determined by the influx of fresh water from rivers and seawater brought in by tides. In addition, as stated by [27], further variations are influenced by the season and topography. According to [34], fish inhabiting environments with lower salinities use less energy for osmoregulation. The distribution of organisms, both vertically and horizontally, will be influenced by salinity conditions [33].

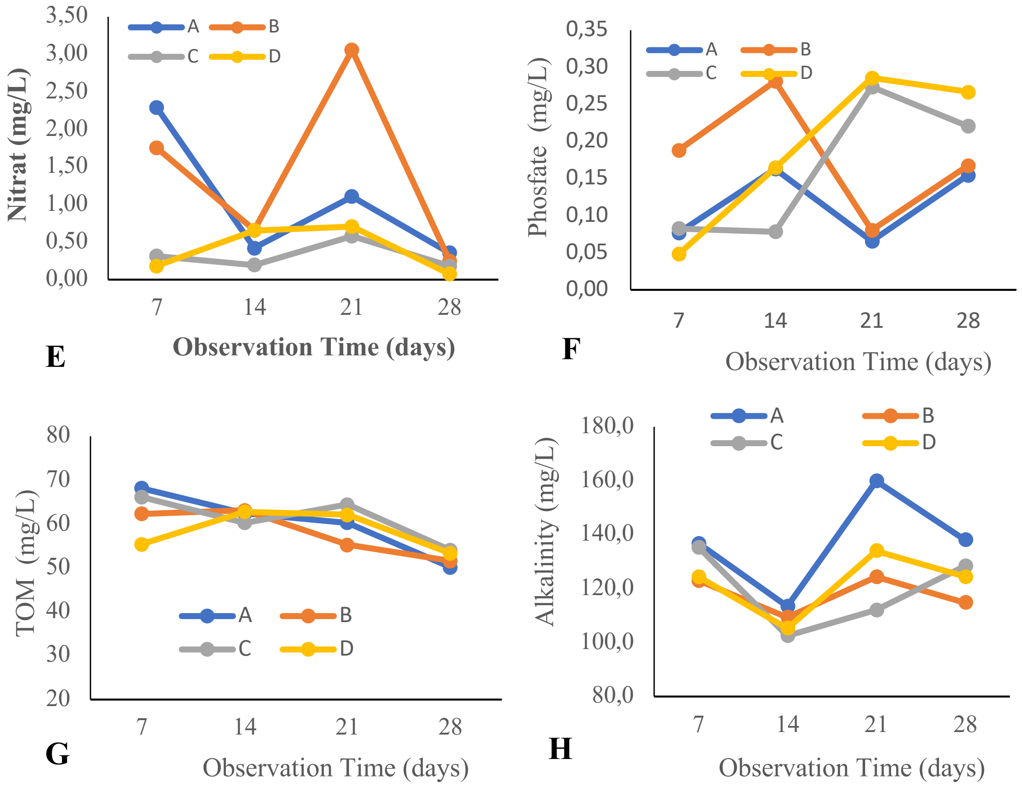

Fig.3. Fluctuations of water quality in Nitrate (E), Phosphate (F), TOM (G), and Alkalinity (H) during the experiment.

The presence of nitrogen in water is composed of several molecules, however, the ones that pose toxicity to fish and other aquatic species include ammonia (NH_3-N) and nitrites. Furthermore, several substances originate not only from the atmosphere but also from food waste, deceased organisms, and the excrement produced by the metabolic processes of aquatic animals. The nitrate content in tilapia maintenance media ranges from 0.0734-3.0562 mg/L, phosphate ranges from 0.0482-0.2858 mg/L, Alkalinity ranges from 102.5-159.9 mg/L, and TOM ranges from 50.17-68.13 mg/L. Nitrate content in ponds tend to increase along with maintenance time, which is around 0.0015–2.6618 mg/L [24]. Nitrate-nitrogen concentrations over 0.2 mg/L may lead to eutrophication, promoting the accelerated proliferation of algae and aquatic vegetation [33]. Phosphate content in tilapia maintenance media is between 1.15 to 1.18 mg/L [35]. Phosphate content in tilapia maintenance media ranges from 0.0276–1.1114 mg/L [24].

Alkalinity refers to the ability of water to counteract the effects of acids or the amount of anions present in water that can neutralize hydrogen cations. Alkalinity can be described as the ability of water to resist a decrease in pH, also known as buffering capacity. As alkalinity increases, water becomes more effective at buffering and reducing swings in pH. The alkalinity concentration observed during the investigation varied between 102.5 and 159.9 mg/L. The ideal alkalinity range for intensive fish farming was found to be between 100 and 150 mg/L [31]. The total organic matter content continuously decreased across all treatments throughout the trial, with values between 50.1 to 68.13 mg/L. The total organic matter content in the polyculture of tiger shrimp (*Penaeus monodon*), tilapia (*Oreochromis niloticus*), and seaweed (*Gracilaria* sp.) ranged from 54.51 to 75.56 mg/L [36].

4. Conclusions

Based on this research, it is possible to conclude that the best treatment for tilapia nursery is treatment A in the form application of organic fertilizer derivate from pond solid waste with a dose of 0.1 kg/m^2 and that all treatments can support the optimal growth of natural feed that can be utilized by tilapia during their growing period. Water quality during maintenance can be tolerated as tilapia grows and survives.

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