

**COMPARATIVE EFFECTIVENESS OF ELECTROLYSIS AND BIOFILTRATION
IN MANAGING WATER QUALITY FOR FRESHWATER NILE TILAPIA
(*Oreochromis niloticus*) AQUACULTURE**

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CERTIFICATE OF PANEL APPROVAL

This research paper, entitled “COMPARATIVE EFFECTIVENESS OF ELECTROLYSIS AND BIOFILTRATION IN MANAGING WATER QUALITY FOR FRESHWATER NILE TILAPIA (*Oreochromis niloticus*) AQUACULTURE”, prepared and submitted by, DANICA MARIE E. DICON, MARIELA V. RAMIREZ, GLENN CELESTE G. MANLUPIG, in fulfillment of the requirements for the degree of Bachelor of Science in Agricultural Biosystems Engineering, has been examined and is recommended for acceptance and approval.

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DEDICATION

This humble work is wholeheartedly dedicated to:

*To our beloved families, whose unwavering love, endless support, and sacrifices
have been our constant source of strength and inspiration;*

*To our esteemed mentors, whose wisdom, guidance, and encouragement have
shaped our journey and enriched our learning;*

*And above all, to Almighty God, whose grace, guidance, and abundant blessings
have sustained us and illuminated our path throughout this endeavor.*

Thank you!

Danica Marie E. Dicon

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ABSTRACT

This study compared the effectiveness of electrolysis and biofiltration in managing water quality and supporting Nile tilapia (*Oreochromis niloticus*) production under tropical freshwater aquaculture conditions in Oroquieta City, Misamis Occidental. The experiment was conducted from January to March 2026 using a single-factor Randomized Complete Block Design (RCBD) with three treatments and three replications. Treatments consisted of: A1 – Control; A2 – Electrolysis (low-voltage electrolysis); and A3 – Biofiltration (a lava rock trickle tower biofilter). A total of 450 juvenile Nile tilapia fingerlings were stocked at 50 fish per tank across nine tarpaulin tanks (1.0 m × 2.0 m × 0.65 m) over an 8-week production cycle. Results showed that biofiltration (A3) consistently maintained the lowest Total Ammonia Nitrogen (TAN) concentrations (mean: 0.25 mg/L), significantly below the stress threshold of 0.50 mg/L, while electrolysis (A2) achieved intermediate ammonia control (mean: 0.44 mg/L) and the control (A1) exhibited progressive ammonia accumulation (mean: 0.94 mg/L). Biofiltration produced significantly superior fish growth performance, feed conversion efficiency, and survival rates compared to both electrolysis and control treatments. Economically, biofiltration also generated the highest net income and return on investment, while electrolysis offered moderate returns relative to its higher energy costs. The findings suggest that biofiltration using lava rock media represents a more reliable, cost effective, and sustainable ammonia management strategy for small- to medium-scale tropical Nile tilapia aquaculture, while electrolysis may serve as a complementary or emergency ammonia reduction measure under specific conditions.

Keywords: *ammonia management, feed conversion ratio, fish growth performance, recirculating aquaculture system, total ammonia nitrogen.*

INTRODUCTION

Background of the Study

Aquaculture has emerged as one of the fastest-growing food production sectors worldwide, playing a critical role in meeting the escalating global demand for protein-rich food. Among the many species raised under aquaculture conditions, Nile tilapia (*Oreochromis niloticus*) stands out as the most widely farmed freshwater fish species due to its resilience, rapid growth, omnivorous feeding habits, and broad adaptability to diverse culture systems (FAO, 2020). *O. niloticus* has become a cornerstone of food security in many developing nations, particularly in tropical Asia and Africa, where it is a primary source of affordable animal protein for rural and urban communities alike.

Global tilapia production has expanded significantly over recent decades. The Food and Agriculture Organization (FAO, 2022) reported that worldwide tilapia production surpassed 6 million metric tons in 2021, with tropical regions including Southeast Asia, sub-Saharan Africa, and Latin America contributing a substantial share of total output. In the Philippines, tilapia aquaculture is a vital component of the national fisheries sector, supported by the Bureau of Fisheries and Aquatic Resources (BFAR) through government programs aimed at boosting domestic production and enhancing the livelihoods of small-scale fish farmers (BFAR, 2022). The country's tropical climate, characterized by warm temperatures and high rainfall, provides conditions that are broadly conducive to intensive Nile tilapia culture throughout the year.

Despite the considerable economic and nutritional importance of Nile tilapia aquaculture, the intensification of production systems has given rise to persistent water

quality challenges that limit productivity and sustainability. Under intensive tank and pond culture conditions, the rapid accumulation of nitrogenous waste primarily in the form of ammonia ($\text{NH}_3/\text{NH}_4^+$) poses one of the most serious threats to fish health and production efficiency. In intensive aquaculture settings, fish continuously release ammonia as a byproduct of protein digestion, primarily through the gills. When stocking densities are high and feeding is frequent as in the tank-based system used in this study, waste builds up faster than the water can naturally dilute it, leading to conditions that compromise fish health, reduce feeding activity, and in severe cases, result in mortality (Boyd & Tucker, 2012).

Research has documented that even ammonia levels below acutely lethal thresholds can slow growth, weaken disease resistance, and disrupt reproduction in Nile tilapia largely due to the toxic un-ionized NH_3 fraction (El-Sayed, 2006; El-Sherif & El-Feky, 2008). These chronic effects are particularly relevant in small tank systems where dilution is limited. The widely recognized sub-lethal stress threshold for Nile tilapia is 0.50 mg/L TAN, with concentrations exceeding 1.0 mg/L considered to induce chronic sub-lethal toxicity under tropical conditions (Boyd & Tucker, 2012). These thresholds are of particular relevance in small-scale tank-based culture systems, where the relatively low water volume per fish intensifies the rate of ammonia accumulation compared to large pond systems with greater dilution capacity.

The challenge of ammonia management is compounded under tropical conditions such as those prevailing in Mindanao, Philippines. The tropical climate of Mindanao adds another layer of complexity: warmer water speeds up fish metabolism and feed breakdown, both of which drive ammonia production higher. At the same time, higher temperatures

cause a greater share of total ammonia to exist in the more dangerous un-ionized NH_3 form, making the same TAN reading more harmful in a tropical setting than in a temperate one (Ip et al., 2001). As a result, tropical aquaculture systems are inherently more vulnerable to ammonia toxicity than their temperate counterparts at equivalent TAN concentrations, making effective ammonia management a particularly pressing concern for producers in the Philippine context.

Two principal strategies have been investigated for the control of ammonia in intensive freshwater aquaculture systems: biofiltration and electrolysis. Biofiltration works by harnessing naturally occurring nitrifying bacteria chiefly *Nitrosomonas* and *Nitrobacter* species that attach to a filter medium such as lava rock and break down ammonia stepwise into nitrite, then into the far less harmful nitrate. This process has been widely adopted in recirculating aquaculture systems for its chemical-free, continuous ammonia removal capability (Timmons & Ebeling, 2013; Summerfelt, 2006). A key advantage of biofiltration is its chemical-free nature and its production of no harmful by-products under normal operating conditions.

Electrolysis takes a different approach: passing direct current through submerged electrodes triggers the formation of chemical oxidants in the water, which then break down ammonia and suppress harmful microorganisms. This makes it a fast-acting treatment option, though the oxidants produced such as hypochlorous acid and hydroxyl radicals vary depending on water chemistry and operating conditions (Li et al., 2021; Zou et al., 2020). Electrolysis has attracted interest as a rapid and controllable water treatment method that does not require the extended biological start-up period associated with biofilter colonization. However, concerns remain regarding the formation of potentially harmful

halogenated by-products, the energy costs of continuous operation, and the sensitivity of electrochemical efficiency to water conductivity and current density (Shen et al., 2019; Li et al., 2021).

Despite the availability of both technologies, direct comparative studies evaluating the real-world performance of electrolysis and biofiltration under Philippine tropical aquaculture conditions are lacking. Most published comparisons have been conducted in temperate or controlled laboratory settings, limiting the generalizability of their findings to small-scale commercial operations in Southeast Asia. Moreover, existing literature has rarely integrated simultaneous assessments of water quality improvement, fish growth performance, survival outcomes, and economic returns within a single controlled field experiment — information that is essential for evidence-based technology adoption by resource-limited farmers.

This thesis explored the comparative effectiveness of electrolysis and biofiltration in controlling water quality parameters for freshwater Nile tilapia (*Oreochromis niloticus*) aquaculture under tropical conditions in Oroquieta City, Misamis Occidental. The study was designed to generate practical, locally relevant evidence on the relative merits of these two ammonia management technologies across four dimensions: water quality regulation (TAN and pH), fish growth performance, survival rates, and economic viability. The results are intended to inform technology adoption decisions by small- to medium-scale tilapia producers in the Philippines and to contribute to the broader body of knowledge on sustainable intensification of tropical freshwater aquaculture.

Statement of the Problem

The sustainability of freshwater Nile tilapia aquaculture depends on efficient waste management and water quality regulation. Tropical fish farms often struggle with ammonia accumulation, leading to periodic fish kills, reduced growth performance, and increased operational costs. While biofiltration is well-regarded for its reliability, a practical drawback is the weeks-long period needed for the bacterial community to establish itself, and disruptions such as temperature swings can reduce its efficiency (Summerfelt, 2006). Electrolysis acts more immediately but raises concerns about ongoing energy costs, potential harmful chemical residues, and how prolonged exposure may affect fish physiology (Li et al., 2021). There is a lack of direct comparative studies evaluating biofiltration and electrolysis under real-world farming conditions in the Philippine context.

Objective of the Study

This study aimed to compare the effectiveness of electrolysis and biofiltration systems in managing water quality and supporting Nile tilapia (*Oreochromis niloticus*) production under tropical freshwater aquaculture conditions. Specifically, this study aimed to:

- evaluate the long-term impact of electrolysis and biofiltration on key water quality parameters, including Total Ammonia Nitrogen (TAN), pH; and
- assess the growth performance (body weight in kg and body length in cm) and;
- survival rates of Nile tilapia cultured under the two treatment systems, with 10 fish sampled per tank weekly over an 8-week production cycle;

- compare the operational costs, feed costs (floating pellets), gross sales, net income, and return on investment (ROI) of electrolysis and biofiltration.

Significance of the Study

This study holds significance at multiple levels. For aquaculture producers, it provides evidence-based insights into the most effective water treatment strategy under tropical conditions, directly impacting fish survival, growth rates, and profitability. For researchers, the comparative approach contributes to bridging the gap in literature between conventional biological methods and emerging electrochemical technologies in aquaculture. Policymakers and development agencies may also benefit from the findings, as they seek to promote sustainable aquaculture practices that balance productivity, affordability, and environmental stewardship.

Scope and Limitations of the Study

This study focused exclusively on freshwater Nile tilapia (*Oreochromis niloticus*) culture in 1.0 m × 2.0 m × 0.65 m concrete tanks under tropical environmental conditions in Oroquieta City, Misamis Occidental. The scope included comparing electrolysis and biofiltration in terms of water quality regulation, fish growth performance, survival rates, and operational efficiency over a single 8-week production cycle, with 10 fish sampled per tank each week. The study did not extend to other fish species, marine aquaculture, or alternative water treatment methods such as ozonation or UV sterilization. Limitations include potential variability in tropical climatic conditions and the restriction to one production cycle.

Definitions of Terms

Biofiltration, as applied in this study, is a water treatment approach that relies on nitrifying bacteria colonizing a filter medium to convert toxic dissolved ammonia into nitrite and then into nitrate, which is far less harmful to fish at typical concentrations.

Electrolysis, in the context of aquaculture water management, involves running an electric current between submerged electrodes to generate oxidizing compounds that chemically degrade ammonia and suppress pathogenic microorganisms in the tank water.

Ammonia ($\text{NH}_3/\text{NH}_4^+$) is a nitrogenous compound excreted by fish and resulting from feed decomposition; toxic at high concentrations.

Total Ammonia Nitrogen (TAN) is the total concentration of ionized (NH_4^+) and unionized (NH_3) forms of ammonia in water.

Specific Growth Rate (SGR) is the percentage increase in body weight per day, computed as $[(\ln W_f - \ln W_i) / t] \times 100$.

Feed Conversion Ratio (FCR) is the ratio of feed consumed to weight gained; a lower FCR indicates more efficient feed utilization.

Return on Investment (ROI) — $(\text{Net Income} / \text{Production Cost}) \times 100$; indicates profitability relative to cost.

Oxidation-Reduction Potential (ORP) is a measure of the tendency of a solution to acquire or release electrons; used to monitor electrolysis system activity.

MATERIALS AND METHODS

Time and Place of the Study

The experiment was conducted at Barangay Dulapo, Oroquieta City, Misamis Occidental, Philippines (Figure 1.). The study was carried out over a single 8-week production cycle from January 2026 to March 2026 during the dry season.

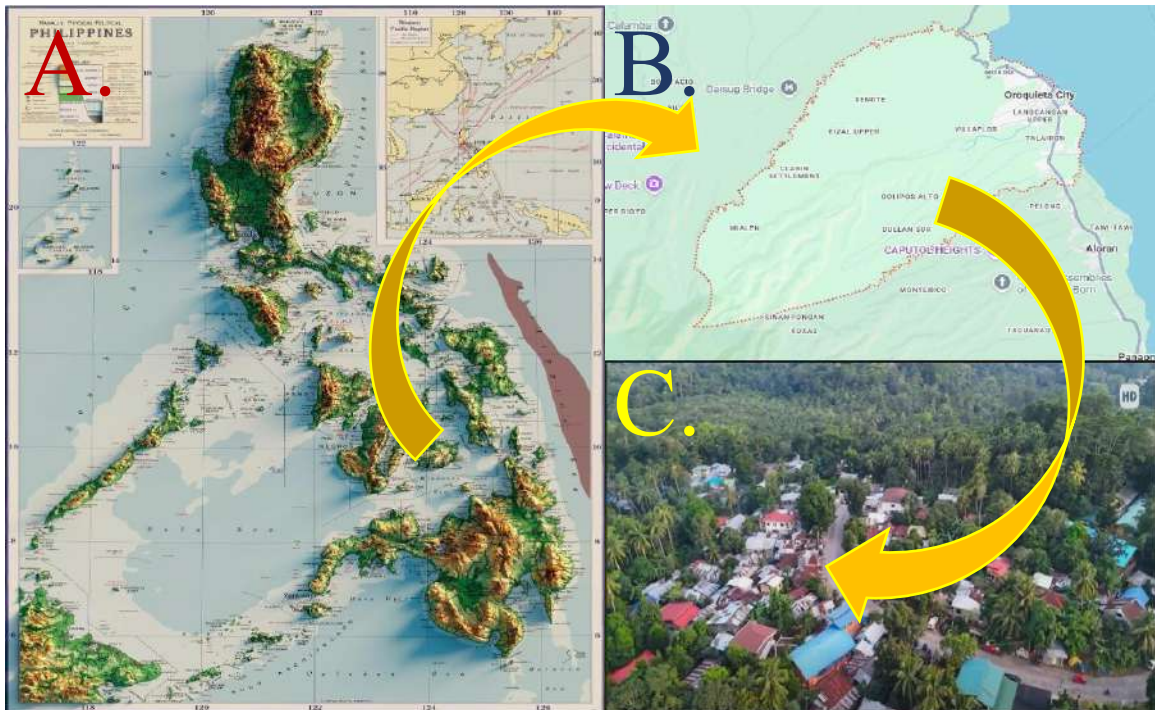


Figure 1. Map showing the location of the study area (source: Google Map)

Legend:

- A. Philippine map highlighting the province of Misamis Occidental
- B. Portion of Misamis Occidental map showing Oroquieta city
- C. Aerial view of the experimental site.

Materials

The materials used in the study included nine concrete tanks measuring 1.0 m × 2.0 m × 0.65 m lined with thick black high-density polyethylene (HDPE) tarpaulin, bamboo poles, wooden lumber, PVC pipes, and polyethylene shade canopies. The electrolysis treatment required metal electrode plates, red-insulated electrical wiring, a central wooden terminal block, and a 12-volt lead-acid battery as the direct current power source. The biofiltration treatment required a commercial black plastic canister box filter unit, lava rock filter media, and a submersible water pump. Other materials included digital weighing scales, calibrated measuring boards, colorimetric ammonia test kits, data recording sheets, commercial floating extruded tilapia pellets (2–3 mm, 28–30% crude protein) at ₱50.00 per kilogram, and 450 juvenile Nile tilapia (*Oreochromis niloticus*) fingerlings.

Methods

Experimental Design and Treatments

The study used a single-factor experiment with three treatment levels arranged in a Randomized Complete Block Design (RCBD) with three replications. The single factor was ammonia reduction technology (Factor A), consisting of three levels: A1 – Control; A2 – Electrolysis (low-voltage electrolysis module); and A3 – Biofiltration (lava rock trickle tower biofilter). Nine tanks were used in total, with three tanks assigned per treatment. Three blocks were established to account for variability across the physical systems. Each tank was stocked with 50 juvenile Nile tilapia (*Oreochromis niloticus*), with

an initial mean body weight of 0.013 kg and initial mean total length of 4.8–4.9 cm. The treatment combinations are presented in Table A.

Experimental Layout

The study utilized a 1 x 2 x 0.60m Tarpaulin tanks for the experiment on Electrolysis vs. Biofiltration in Freshwater Nile Tilapia Aquaculture with three (3) treatments and three (3) replications. The experimental area was arranged in a 3-row by 3-column grid consisting of nine (9) experimental units. Each treatment appeared exactly once in every row and every column to control for positional or environmental variations.

T1	T3	T2
T3	T2	T1
T2	T1	T3

Figure 2. Layout of the experiment

Table A. Factors and Treatments of the Study on Electrolysis vs. Biofiltration in Freshwater Nile Tilapia Aquaculture.

Treatment	Factor	Description
T1	Control (A1)	
T2	Electrolysis (A2)	a low-voltage electrolysis module
T3	Biofiltration (A3)	a lava rock biofilter trickle tower

Tank Construction and Setup

Nine tarpaulin culture tanks, each measuring 1.0 m × 2.0 m × 0.65 m (length × width × height), were constructed using bamboo poles and wooden lumber as structural frames, internally lined with thick black high-density polyethylene (HDPE) tarpaulin to form watertight rectangular units (figure 3.). An effective water depth of 0.60 m was maintained in each tank in accordance with the Philippine Agricultural Engineering Standard (PAES) for freshwater fish culture structures, resulting in an operational water volume of approximately 1,200 liters per tank. Each tank provided a floor area of 2.0 m², accommodating 50 juvenile Nile tilapia at a stocking density of 25 fish/m² and 41.7 fish/m³, consistent with densities established by Baliao et al. (2004) and the range recommended by Suresh and Lin (1992) and Timmons and Ebeling (2013) for intensive tank culture of this species. All tanks were set up under shade structures made from polyethylene tarpaulin canopies supported by bamboo poles to protect the fish from direct solar radiation and rainfall. PVC pipes were incorporated into the frame for structural reinforcement and plumbing connections.

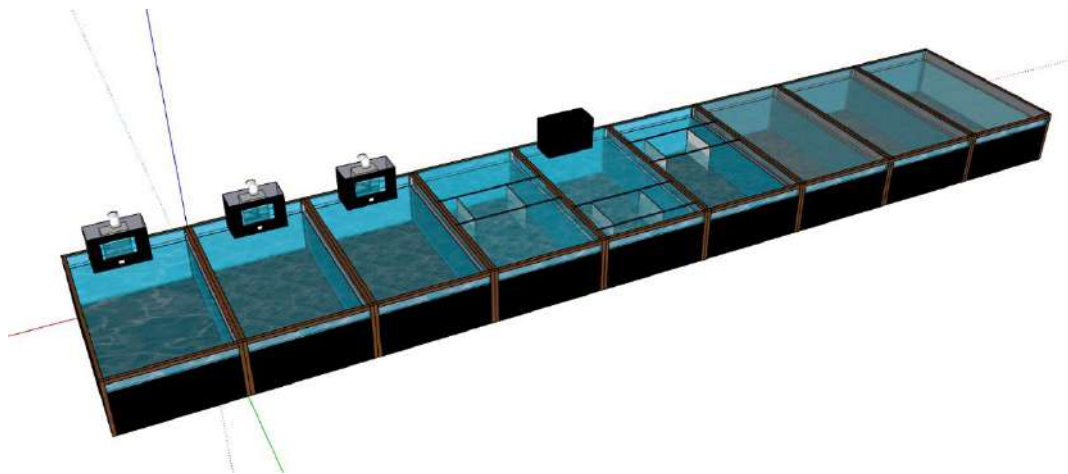


Figure 3. SketchUp design of the experimental facility

Electrolysis System

The electrolysis treatment (A2) utilized metal electrode plates submerged directly inside each of the three assigned tanks. The electrode plates in each tank were connected in parallel using red-insulated electrical wiring that converged at a central wooden terminal block mounted between the tanks. A 12-volt lead-acid battery positioned on an elevated wooden platform served as the direct current power source, enabling simultaneous low-voltage electrolysis across all three A2 treatment units. The electrochemical process was designed to oxidize dissolved ammonia and reduce microbial loads within the culture water, thereby improving water quality without the addition of chemicals.

Biofiltration System

The biofiltration treatment (A3) employed a commercial black plastic canister box filter unit mounted on the inner wall of each assigned tank. A submersible pump drew water from the tank into the filter housing, where the water passed through lava rock media serving as the biological support surface for nitrifying bacterial communities. Filtered water was returned to the tank through an outlet nozzle, creating a continuous recirculating flow. Nitrifying bacteria (primarily *Nitrosomonas* spp. and *Nitrobacter* spp.) colonized the lava rock surfaces over the course of the trial, converting toxic ammonia first to nitrite and subsequently to the relatively harmless nitrate through biological nitrification (Timmons & Ebeling, 2013)

Procurement of Fish and Feeding Management

A total of 450 juvenile Nile tilapia (*Oreochromis niloticus*) fingerlings were procured from a local supplier and distributed equally across the nine experimental tanks, with 50 fish per tank. All fingerlings were sourced from the same batch to ensure uniformity in initial size and age, with a mean initial body weight of 0.013 kg and a mean initial total body length of 4.8–4.9 cm. Water temperature was maintained at 25°C throughout the 8-week production cycle to approximate optimal tropical culture conditions for the species (Azaza et al., 2008).

All fishes were fed commercial floating extruded tilapia pellets (2–3 mm diameter, 28–30% crude protein) at a rate of 3–4% of estimated body biomass per day, adjusted weekly based on the mean body weight of 10 randomly sampled fish per tank. Daily rations were divided into two equal feedings administered in the morning and afternoon. Any uneaten feed remaining after 30 minutes was siphoned out to prevent water quality deterioration from organic loading. The same feeding protocol was applied uniformly across all three treatment groups throughout the 8-week trial period.

Data Gathered

Data collected throughout the production cycle covered water quality parameters, fish growth performance, survival rate, and financial returns. All parameters were recorded on a weekly basis over the 8-week duration of the experiment.

A. Water Quality Parameters.

Total Ammonia Nitrogen (TAN) was measured weekly using a colorimetric liquid test kit following the manufacturer's recommended procedure. A 5 mL water sample was collected from each tank using a clean syringe. Reagents were added sequentially, and the developed color was compared against the reference chart included in the kit to obtain TAN concentrations in mg/L. The safe TAN range for Nile tilapia was defined as below 0.5 mg/L, with concentrations above 1.0 mg/L considered indicative of stress conditions. Water pH was measured weekly using a calibrated digital pH meter. All water quality measurements were taken at the same time of day to minimize diurnal variation.

B. Fish Growth Performance.

Ten fish per tank were randomly sampled each week for individual body weight (kg) and total body length (cm) measurements. Body weight was obtained using a digital balance with a precision of 0.1 g, and total body length was measured from the tip of the snout to the end of the caudal fin using a calibrated measuring board. Weight Gain (WG) was calculated as the difference between final and initial body weight. The Specific Growth Rate (SGR) was computed as $[(\ln W_f - \ln W_i) / \text{Days}] \times 100$. The Feed Conversion Ratio (FCR) was determined by dividing the total feed consumed by the total weight gained. Survival Rate (%) was computed as the final fish count divided by the initial stocking number, multiplied by 100.

C. Financial Analysis

The economic performance of each treatment was evaluated by computing total production cost, gross sales, net income, and return on investment (ROI). Total production cost included fingerling cost, feed cost for commercial floating pellets at ₱50.00 per kilogram, equipment and maintenance expenses, electricity and water charges, and labor costs. Gross sales were computed based on total harvest weight multiplied by the prevailing market price of ₱180.00 per kilogram. Net Income was determined by subtracting the total production cost from gross sales. Return on Investment (ROI) was expressed as a percentage by dividing net income by total production cost and multiplying by 100.

Statistical Analysis

The one-way Analysis of Variance (ANOVA) in Randomized Complete Block Design (RCBD) was used to test the significant difference of the water quality parameters, fish growth performance, survival rate, and financial returns among the treatments. A total of 3 different treatments with 3 repetitions for each was used and the data gathered after the first and following weeks of the 8-week production cycle were recorded. Tukey's method (at 5% level of significance) was used to determine which of the different treatments vary significantly.

RESULTS AND DISCUSSION

This chapter presents the results gathered from the 8-week production trial on Nile tilapia (*Oreochromis niloticus*) cultured in 1.0 m × 2.0 m × 0.65 m tarpaulin tanks (1,200 L capacity; 0.60 m water depth; 50 fish per tank) under three ammonia reduction treatments: Control, Electrolysis, and Biofiltration. Water temperature at 25°C - 30°C throughout the 8-week production cycle. One-way ANOVA and Tukey HSD post-hoc comparisons ($\alpha = 0.05$) were applied to all response variables; statistically significant differences were detected for every parameter measured, prompting rejection of all five null hypotheses.

Water Quality Parameters

Total Ammonia Nitrogen (TAN)

The three treatments diverged in TAN management capacity from the very first week and maintained distinct, non-overlapping trajectories through Week 8, a pattern reflected in the extremely high ANOVA F-value and confirmed by complete pairwise separation in the Tukey HSD test.

Table 1. Mean, Standard Deviation, and One-Way ANOVA of Total Ammonia Nitrogen (TAN, mg/L) Among Treatments

Treatment	Mean (mg/L)	SD	F-value	p-value	Decision
Control (A1)	0.9396	0.00361	17,406.600	0.000	Reject H_0
Electrolysis (A2)	0.4375	0.00625			
Biofiltration (A3)	0.2542	0.00361			

Note: $F(2,6) = 17,406.600$, $p < 0.001$. Tukey HSD: all three treatment pairs significantly different ($p < 0.05$). Significance threshold: $\alpha = 0.05$.

Table 1a. Weekly Mean and Standard Deviation of TAN (mg/L) by Treatment

Treatment	Initial	W1	W2	W3	W4	W5	W6	W7	W8
Control (A1) – Mean	–	0.50	1.00	1.00	1.00	1.00	1.02	1.00	1.00
Control (A1) – SD	–	0.000	0.050	0.050	0.000	0.050	0.029	0.050	0.000
Electrolysis (A2) – Mean	–	0.25	0.27	0.48	0.48	0.52	0.52	0.48	0.50
Electrolysis (A2) – SD	–	0.000	0.029	0.029	0.029	0.029	0.029	0.029	0.000
Biofiltration (A3) – Mean	–	0.25	0.25	0.27	0.25	0.27	0.25	0.25	0.25
Biofiltration (A3) – SD	–	0.000	0.000	0.029	0.000	0.029	0.000	0.000	0.000

Note: F-values at every weekly interval were statistically significant at $p < 0.001$ from Week 1 onwards. All pairwise treatment differences confirmed by Tukey HSD ($p < 0.05$).

Biofiltration (A3) held TAN to a narrow band of 0.25 – 0.27 mg/L across all eight weeks less than half the 0.50 mg/L sub-lethal threshold and consistent with the near-complete nitrification efficiency expected of a well-matured lava rock biofilm (Timmons & Ebeling, 2013). The stable TAN readings in A3 tanks reflect the activity of an established biofilm: nitrifying bacteria coating the lava rock surfaces processed incoming ammonia continuously, aided by the recirculating pump that kept water flowing through the filter. By the third week, the biofilm appeared fully active, after which TAN levels showed almost no variation across replicate tanks.

The control (A1) tells a starkly different story. TAN doubled from 0.50 mg/L in Week 1 to a plateau around 1.00 mg/L by Week 2, a level that Boyd and Tucker (2012) associate with chronic sub-lethal toxicity under tropical temperatures where it remained

for the rest of the trial. This plateau likely reflects a dynamic equilibrium between continued ammonia excretion and partial natural volatilization rather than any buffering capacity of the system itself.

Electrolysis (A2) occupied the middle ground in both concentration and consistency. TAN was well-controlled in Weeks 1–2 (0.25–0.27 mg/L) but climbed to 0.48–0.52 mg/L from Week 3 onward, straddling the stress threshold unpredictably. This instability most likely reflects the sensitivity of electrochemical ammonia oxidation to fluctuating water conductivity and electrode fouling over time (Shen et al., 2019), limitations that are largely absent from biological nitrification once the biofilm has matured. The extreme F-value (17,406.600) underscores how tightly the data clustered within each treatment differences among groups were not statistical noise but a consistent, mechanistically driven outcome.

Water pH

Table 2. Mean, Standard Deviation, and One-Way ANOVA of Water pH Among Treatments

Treatment	Mean	SD	F-value	p-value	Decision
Control (A1)	7.6750	0.02500	444.735	0.000	Reject H ₀
Electrolysis (A2)	7.0875	0.02165			
Biofiltration (A3)	7.3208	0.02602			

Note: F (2,6) = 444.735, p < 0.001. Tukey HSD: all three treatment pairs significantly different (p < 0.05). All means fall within the optimal range of 6.5–8.5 for Nile tilapia.

Water pH tracked predictable patterns tied to the biochemistry of each treatment but remained within the 6.5–8.5 range that Boyd and Tucker (2012) and Popma and Masser (1999) identify as optimal for Nile tilapia throughout the entire trial in all three groups.

While ANOVA detected statistically significant differences among treatments (Table 2), their practical magnitude warrants careful interpretation.

Table 2a. Weekly Mean and Standard Deviation of Water pH by Treatment

Treatment	Initial	W1	W2	W3	W4	W5	W6	W7	W8
Control (A1) – Mean	–	7.47	7.57	7.67	7.67	7.77	7.77	7.73	7.77
Control (A1) – SD	–	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Electrolysis (A2) – Mean	–	7.03	7.03	7.07	7.10	7.13	7.10	7.13	7.10
Electrolysis (A2) – SD	–	0.058	0.058	0.058	0.000	0.058	0.000	0.058	0.000
Biofiltration (A3) – Mean	–	7.03	7.03	7.07	7.10	7.13	7.10	7.13	7.10
Biofiltration (A3) – SD	–	0.058	0.058	0.058	0.000	0.058	0.000	0.058	0.000

Note: Weekly ANOVA F-values significant at $p < 0.001$ for all weeks. All treatment means within the optimal pH range of 6.5–8.5.

The control's gradual upward drift — from 7.47 in Week 1 to 7.77 by Week 5 — reflects the alkalinity contributions of ammonia accumulation and reduced respiratory CO₂ washout, a well-documented pattern in low-turnover tank systems (Boyd, 2015). The electrolysis group held a slightly acidic profile (7.03–7.13) attributable to the proton-generating side-reactions inherent in low-voltage electrochemical processes, though the absolute depression was too small to constitute a physiological concern. Biofiltration showed an intermediate pH trajectory that parallels the electrolysis group closely, consistent with the mild alkalinity consumption associated with bacterial nitrification. The statistical significance of inter-treatment pH differences ($F(2,6) = 444.735$, $p < 0.001$) is

therefore a function of extremely low within-treatment variance rather than biologically consequential magnitude — an important distinction when interpreting ANOVA results in applied aquaculture research.

Growth Performance of Nile Tilapia

Table 3. Mean, Standard Deviation, and One-Way ANOVA of Individual Body Weight (kg/fish) at Week 8

Treatment	Mean (kg)	SD	F-value	p-value	Decision
Control (A1)	0.1660	0.00100	4,923.000	0.000	Reject H_{03}
Electrolysis (A2)	0.2080	0.00100			
Biofiltration (A3)	0.2470	0.00100			

Note: $F(2,6) = 4,923.000$, $p < 0.001$. Weekly F-values: $W1=48.00$, $W2=147.00$, $W3=367.00$, $W4=723.00$, $W5=1,387.00$, $W6=2,191.00$, $W7=3,472.00$; all $p < 0.001$. Tukey HSD: all pairs significantly different at every week

Table 3a. Weekly Mean and Standard Deviation of Individual Body Weight (kg/fish)

Treatment	Initial	W1	W2	W4	W6	W8	F (W8)	p
Control (A1)	0.0130	0.0210	0.0340	0.0680	0.1180	0.1660	4,923.000	0
SD	0.00000	0.00100	0.00100	0.00100	0.00100	0.00100		
Electrolysis (A2)	0.0130	0.0250	0.0410	0.0850	0.1470	0.2080		
SD	0.00000	0.00100	0.00100	0.00100	0.00100	0.00100		
Biofiltration (A3)	0.0130	0.0290	0.0480	0.0990	0.1720	0.2470		
SD	0.00000	0.00100	0.00100	0.00100	0.00100	0.00100		

Note: ANOVA significant at every weekly interval ($p < 0.001$). Tukey HSD: all three treatments statistically distinct at every measurement point.

Growth divergence among treatments was visible as early as Week 1 and compounded week by week, culminating in outcome differences at Week 8 that are both statistically unambiguous and practically substantial (Table 3 & 3a, 4 & 4a). Null hypotheses H_{03} and H_{04} were rejected for every weekly measurement interval, not merely at the study endpoint.

Table 4. Mean, Standard Deviation, and One-Way ANOVA of Individual Body Length (cm) at Week 8

Treatment	Mean (cm)	SD	F-value	p-value	Decision
Control (A1)	12.2000	0.10000	676.000	0.000	Reject H ₀
Electrolysis (A2)	13.6000	0.10000			
Biofiltration (A3)	15.2000	0.10000			

Note: $F(2,6) = 676.000$, $p < 0.001$. Weekly F-values: $W1=37.00$, $W2=91.00$, $W3=169.00$, $W4=243.00$, $W5=301.00$, $W6=397.00$, $W7=547.00$; all $p < 0.001$. Tukey HSD: all pairs significantly different at every week.

Table 4a. Weekly Mean and Standard Deviation of Individual Body Length (cm)

Treatment	Initial	W1	W2	W4	W6	W8	F (W8)	p
Control (A1)	4.8000	5.5000	6.3000	8.1000	10.4000	12.2000	676.000	0.000
SD	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000		
Electrolysis (A2)	4.8000	5.8000	6.8000	9.0000	11.5000	13.6000		
SD	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000		
Biofiltration (A3)	4.9000	6.2000	7.4000	9.9000	12.7000	15.2000		
SD	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000		

Note: ANOVA significant at every weekly interval from Week 1 onward ($p < 0.001$). Tukey HSD: all pairs significantly different at every measurement point.

From a stocking weight of 0.013 kg shared equally across all nine tanks, the trajectories diverged immediately. Biofiltration fish weighed 38% more than controls by the end of Week 1 alone (0.029 vs. 0.021 kg) a gap attributable to better appetitive behaviour and feed efficiency in a low-ammonia environment before significant biofilm maturation effects would even be expected. By Week 8, the A3 group's 0.247 kg mean represented a 19-fold increase from stocking weight, compared to 16-fold for electrolysis (0.208 kg) and 13-fold for controls (0.166 kg). Body length mirrored this pattern exactly, with A3 reaching 15.2 cm against 13.6 cm (A2) and 12.2 cm (A1).

The mechanistic link between water quality and growth is well established. Fish under persistent ammonia stress even at levels that do not cause direct mortality tend to eat

less and redirect energy toward managing physiological stress rather than toward growth, which accounts for the compounding weight differences observed across the eight weeks (El-Shafai et al., 2004). In the control tanks, where TAN remained near or above 1.0 mg/L from Week 2 onward, fish experienced eight weeks of unrelenting low-grade ammonia stress. The electrolysis tanks provided partial relief, but the variable, sometimes threshold-straddling TAN concentrations from Week 3 onward limited the growth advantage electrolysis could deliver relative to the biofiltration benchmark.

Survival Rate

Mortality patterns across the three treatments were coherent with the water quality hierarchy, lending additional mechanistic credibility to the TAN data and supporting the rejection of H_{05} (Table 5.).

Table 5. Mean, Standard Deviation, and One-Way ANOVA of Survival Rate (%) Among Treatments

Treatment	Mean (%)	SD	F-value	p-value	Decision
Control (A1)	82.00	2.00	39.000	0.000	Reject H_{05}
Electrolysis (A2)	92.00	2.00			
Biofiltration (A3)	96.00	2.00			

Note: $F(2,6) = 39.000$, $p < 0.001$. Tukey HSD: all three treatment pairs significantly different ($p < 0.05$). Significance threshold: $\alpha = 0.05$.

The biofiltration group lost only 2 fish per tank on average (96.0% survival), predominantly in the first two weeks before the biofilm was fully established. The electrolysis group averaged 4 deaths per tank (92.0%); most mortalities occurred in the second half of the trial, when TAN concentrations had stabilized above 0.50 mg/L, consistent with delayed stress accumulation. The control group suffered the heaviest losses

— a mean of 9 fish per tank (82.0% survival) — with deaths distributed across all eight weeks, reflecting the near-continuous exposure to supra-threshold ammonia from Week 2 onward.

The 14-percentage-point gap between the best and worst outcomes translates directly into harvest economics: in a commercial system with 100 tanks per farmer, that difference represents roughly 700 additional marketable fish per cycle — a figure that reframes the technology choice from a water chemistry question into a livelihood decision.

Financial Analysis

Economic performance tracked the biological hierarchy without exception. Despite marginally higher total costs than the control (₱2,480–2,490 vs. ₱2,215), both active treatment systems generated substantially greater returns by virtue of superior survival and growth (Table 6.).

Table 6. Financial Analysis of Nile Tilapia Production under Different Ammonia Reduction Technologies (8-Week Cycle)

Parameter	Control (A1)	Electrolysis (A2)	Biofiltration (A3)
Fingerling Cost (₱)	150	150	150
Feed Consumed (kg)	10.3	13.0	14.4
Feed Cost @ ₱50/kg	515	650	720
Equipment & Maintenance	1,000	1,000	1,000
Electricity & Water	50	200	100
Labor & Miscellaneous	500	500	500
Total Production Cost/Tank (₱)	2,215	2,490	2,480
Survival Rate (%)	82.0	92.0	96.0
Final Mean Weight (kg/fish)	0.166	0.208	0.247
Total Harvest/Tank (kg)	20.42	28.70	35.57
Gross Sales/Tank (₱)	3,677	5,167	6,404

Net Income/Tank (₱)	1,462	2,677	3,925
ROI (%)	66%	107%	158%
Payback Period	1 cycle	1 cycle	1 cycle

Note: Selling price = ₱180.00/kg; feed price = ₱50.00/kg. All three systems recovered full production costs within the single 8-week cycle.

Biofiltration's net income of ₱3,925 per tank was 2.7 times that of the control and 1.47 times that of the electrolysis system. Its FCR advantage (1.28 versus 1.65 for controls) means that despite consuming 4.1 kg more feed per tank than the control, the biofiltration group converted that feed into substantially greater fish mass, keeping unit production costs competitive. Electrolysis incurred the highest electricity bill (₱200/tank vs. ₱100 for biofiltration), a structural disadvantage that widened relative to its lower harvest yield. Nevertheless, at 107% ROI, electrolysis remains a genuinely profitable option — particularly relevant for farmers who cannot wait the two to four weeks required for biofilm establishment before stocking a new cycle.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and the statistical analyses performed, the following conclusions are drawn:

1. All five null hypotheses (H_{01} – H_{05}) were rejected. Statistically significant treatment differences were confirmed for TAN ($F=17,406.600$), pH ($F=444.735$), body weight at Week 8 ($F=4,923.000$), body length at Week 8 ($F=676.000$), and survival rate ($F=39.000$), all at $p < 0.001$. Tukey HSD post-hoc tests identified complete pairwise separation among all three treatment groups for every variable.
2. Lava rock trickle tower biofiltration consistently maintained TAN at 0.25 mg/L throughout the 8-week culture period, demonstrating superior ammonia removal efficiency and greater stability compared with low-voltage electrolysis under tropical production conditions.
3. Growth divergence was systematic and began in Week 1. The biofiltration group's final weights (0.247 kg; 15.2 cm) exceeded those of the electrolysis group (0.208 kg; 13.6 cm) by 19% and those of the control (0.166 kg; 12.2 cm) by 49%, reflecting the compounding benefit of a sustained low-ammonia rearing environment on feed intake and anabolic efficiency.
4. Harvest biomass and survival tracked the same hierarchy: 35.57 kg and 96% (A3), 28.70 kg and 92% (A2), and 20.42 kg and 82% (A1). The 14-percentage-point survival gap between biofiltration and the control represents a production difference large enough to be decisive at commercial scale.

5. Biofiltration was the most financially efficient system despite marginally higher feed consumption, achieving a ROI of 158% against 107% for electrolysis and 66% for the control. Its lowest FCR (1.28) meant that greater absolute feed input translated into disproportionately greater harvestable biomass.

Based on the findings of this study, the following recommendations are proposed:

1. Lava rock trickle tower biofiltration is recommended as the primary ammonia management strategy for small- to medium-scale Nile tilapia production in HDPE-lined concrete tanks under tropical Mindanao conditions, as it demonstrated superior biological and economic performance.
2. Low-voltage electrolysis may serve as a secondary ammonia control strategy during the initial culture phase before biofilm establishment or during periods of biofilter recovery. Its positive return on investment and improved survival performance indicate its potential as a supplementary treatment, provided that electricity consumption and electrode maintenance are effectively managed.
3. Central filtration without additional ammonia treatment is not recommended for intensive Nile tilapia tank culture under tropical conditions due to elevated TAN levels, higher mortality, and lower economic returns.
4. Future studies should evaluate: (a) hybrid electrolysis–biofiltration systems; (b) long-term biofilm stability across successive production cycles; (c) economic performance under higher stocking densities and commercial-scale operations; and (d) alternative locally available biofilter media, such as rice hull char, coconut husk, and recycled plastic carriers, to reduce production costs for small-scale producers.

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APPENDIX A

EXPERIMENTAL LAYOUT

T1	T3	T2
T3	T2	T1
T2	T1	T3



Figure 1. Map showing the location of the study area (source; Google Earth)

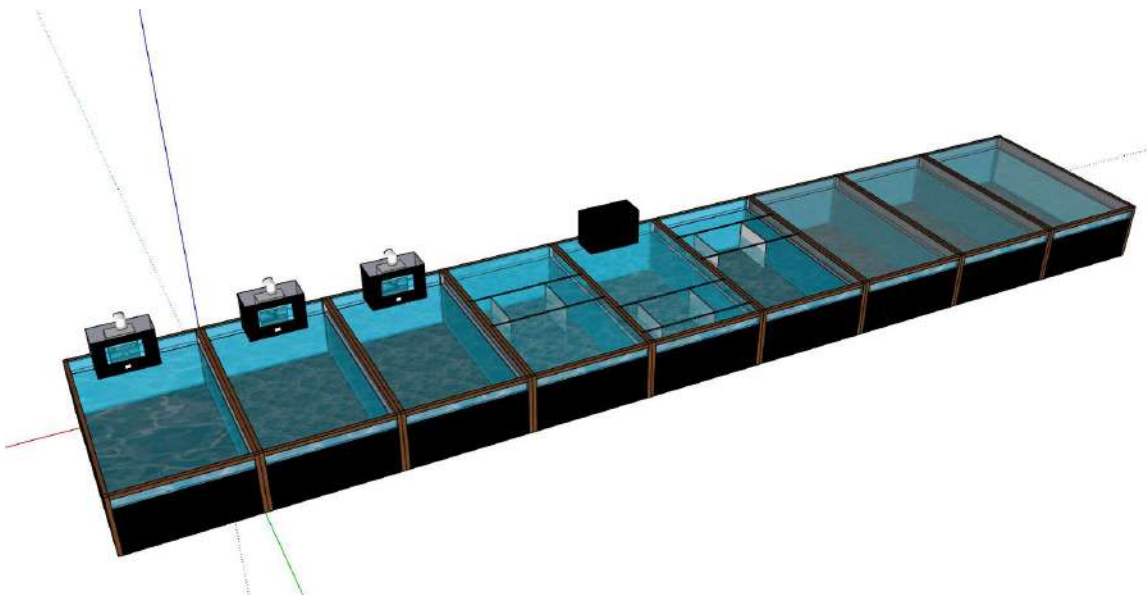


Figure 3. SketchUp design of the experimental facility

APPENDIX B

STATISTICAL COMPUTATIONS AND RESULTS

Table 1. Mean, Standard Deviation, and One-Way ANOVA of Total Ammonia Nitrogen (TAN, mg/L) Among Treatments

Treatment	Mean (mg/L)	SD	F-value	p-value	Decision
Control (A1)	0.9396	0.00361	17,406.600	0.000	Reject H_{01}
Electrolysis (A2)	0.4375	0.00625			
Biofiltration (A3)	0.2542	0.00361			

Table 1a. Weekly Mean and Standard Deviation of TAN (mg/L) by Treatment

Treatment	Initial	W1	W2	W3	W4	W5	W6	W7	W8
Control (A1) – Mean	–	0.50	1.00	1.00	1.00	1.00	1.02	1.00	1.00
Control (A1) – SD	–	0.000	0.050	0.050	0.000	0.050	0.029	0.050	0.000
Electrolysis (A2) – Mean	–	0.25	0.27	0.48	0.48	0.52	0.52	0.48	0.50
Electrolysis (A2) – SD	–	0.000	0.029	0.029	0.029	0.029	0.029	0.029	0.000
Biofiltration (A3) – Mean	–	0.25	0.25	0.27	0.25	0.27	0.25	0.25	0.25
Biofiltration (A3) – SD	–	0.000	0.000	0.029	0.000	0.029	0.000	0.000	0.000

Table 2. Mean, Standard Deviation, and One-Way ANOVA of Water pH Among Treatments

Treatment	Mean	SD	F-value	p-value	Decision
Control (A1)	7.6750	0.02500	444.735	0.000	Reject H ₀₂
Electrolysis (A2)	7.0875	0.02165			
Biofiltration (A3)	7.3208	0.02602			

Table 2a. Weekly Mean and Standard Deviation of Water pH by Treatment

Treatment	Initial	W1	W2	W3	W4	W5	W6	W7	W8
Control (A1) – Mean	–	7.47	7.57	7.67	7.67	7.77	7.77	7.73	7.77
Control (A1) – SD	–	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Electrolysis (A2) – Mean	–	7.03	7.03	7.07	7.10	7.13	7.10	7.13	7.10
Electrolysis (A2) – SD	–	0.058	0.058	0.058	0.000	0.058	0.000	0.058	0.000
Biofiltration (A3) – Mean	–	7.03	7.03	7.07	7.10	7.13	7.10	7.13	7.10
Biofiltration (A3) – SD	–	0.058	0.058	0.058	0.000	0.058	0.000	0.058	0.000

Table 3. Mean, Standard Deviation, and One-Way ANOVA of Individual Body Weight (kg/fish) at Week 8

Treatment	Mean (kg)	SD	F-value	p-value	Decision
Control (A1)	0.1660	0.00100	4,923.000	0.000	Reject H ₀₃
Electrolysis (A2)	0.2080	0.00100			
Biofiltration (A3)	0.2470	0.00100			

Table 5. Mean, Standard Deviation, and One-Way ANOVA of Survival Rate (%) Among Treatments

Treatment	Mean (%)	SD	F-value	p-value	Decision
Control (A1)	82.00	2.00	39.000	0.000	Reject H _{0s}
Electrolysis (A2)	92.00	2.00			
Biofiltration (A3)	96.00	2.00			

Table 6. Financial Analysis of Nile Tilapia Production under Different Ammonia Reduction Technologies (8-Week Cycle)

Parameter	Control (A1)	Electrolysis (A2)	Biofiltration (A3)
Fingerling Cost (₱)	150	150	150
Feed Consumed (kg)	10.3	13.0	14.4
Feed Cost @ ₱50/kg	515	650	720
Equipment & Maintenance	1,000	1,000	1,000
Electricity & Water	50	200	100
Labor & Miscellaneous	500	500	500
Total Production Cost/Tank (₱)	2,215	2,490	2,480
Survival Rate (%)	82.0	92.0	96.0
Final Mean Weight (kg/fish)	0.166	0.208	0.247
Total Harvest/Tank (kg)	20.42	28.70	35.57
Gross Sales/Tank (₱)	3,677	5,167	6,404
Net Income/Tank (₱)	1,462	2,677	3,925
ROI (%)	66%	107%	158%
Payback Period	1 cycle	1 cycle	1 cycle

APPENDIX C

DOCUMENTATION

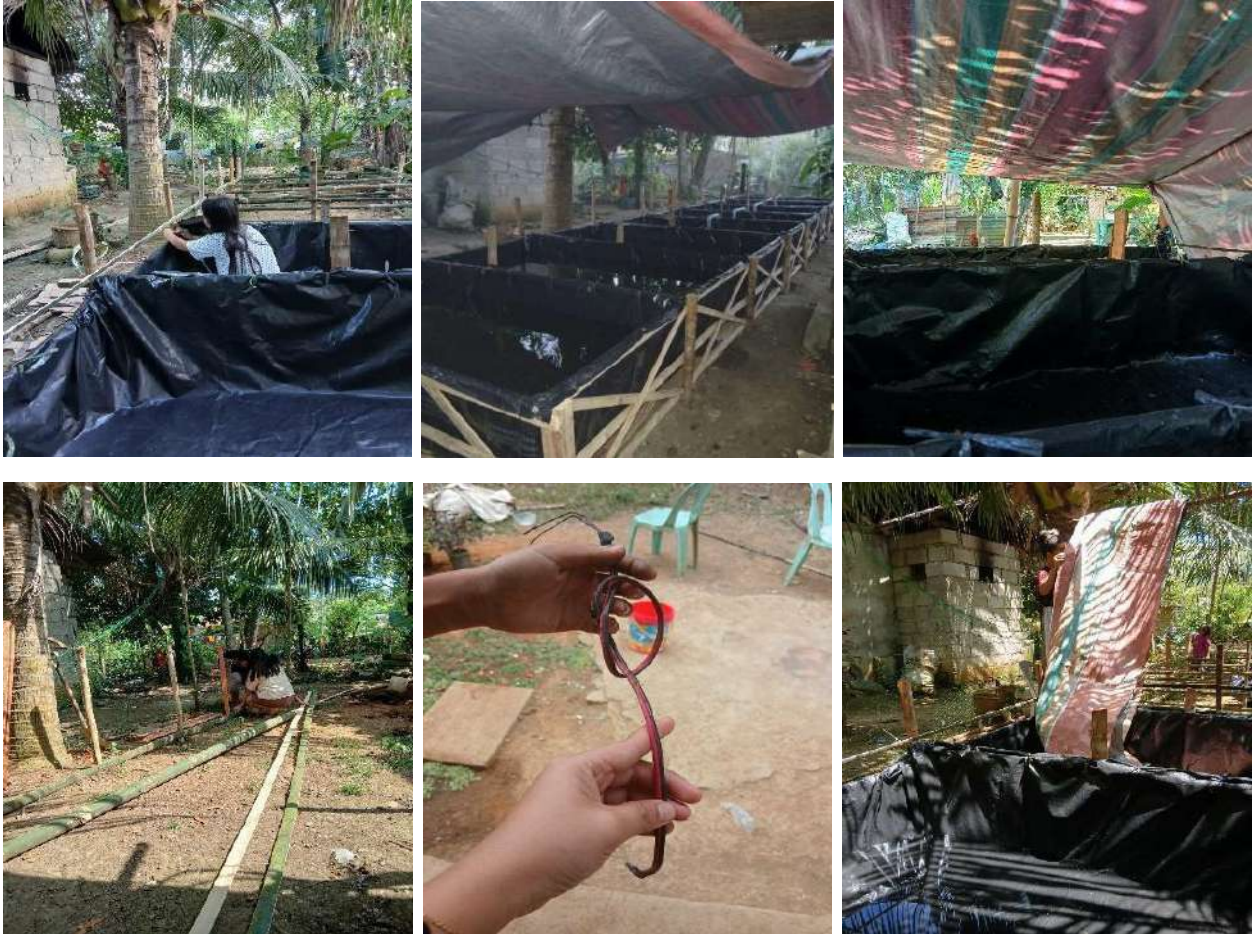


Figure 4. Study Site and Tank Setup



Control



Electrolysis



Biofiltration

Figure 5. Treatment Systems



Figure 6. Fish and Feed

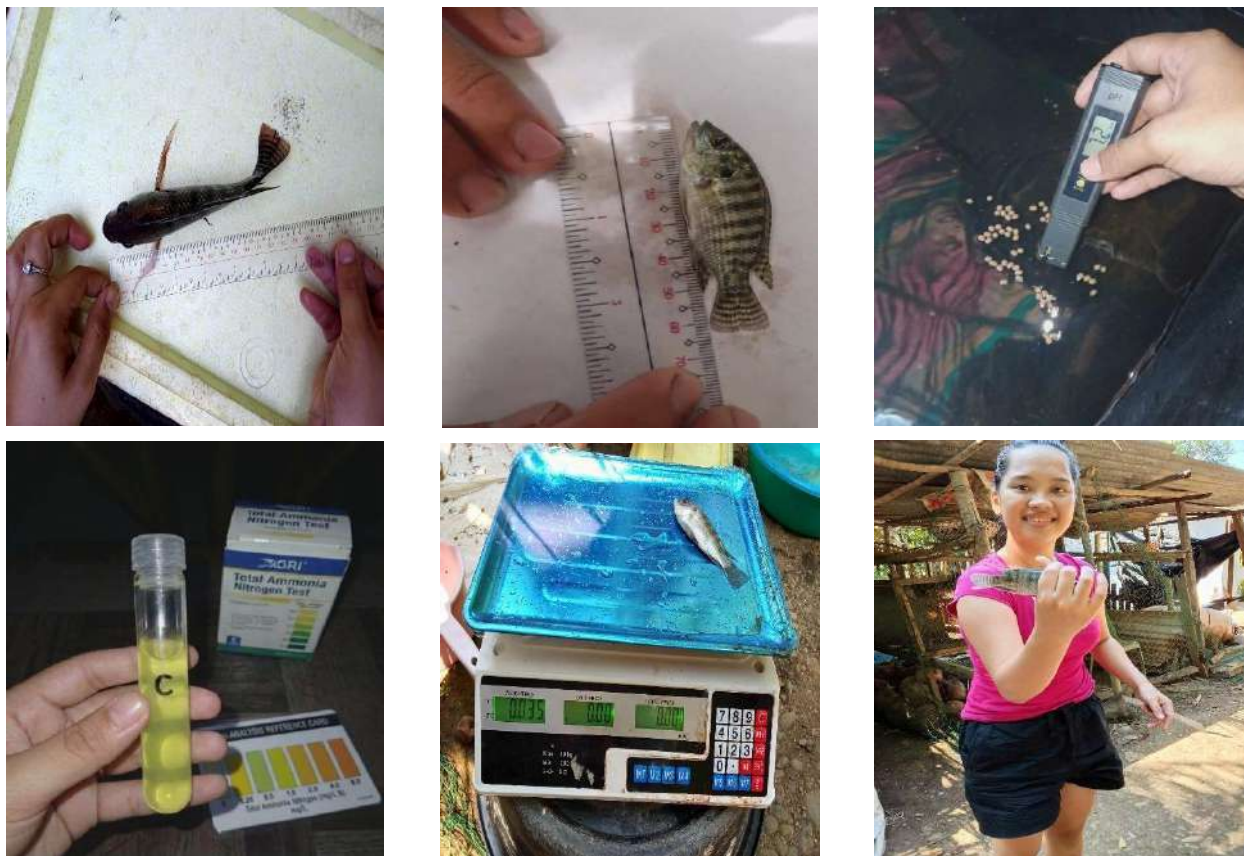


Figure 7. Data Collection Procedures

APPENDIX D


TURNITIN RESULTS

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APPENDIX E

GRAMMARLY RESULT

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In Partial Fulfillment of the Requirements for the Degree BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING

MARIELA V. RAMIREZ
DANICA MARIE E. DICON
GLENN MANLUPIG
MAY 2026

iii ii CERTIFICATE OF PANEL APPROVAL This thesis entitled "**COMPARATIVE EFFECTIVENESS OF ELECTROLYSIS AND BIOFILTRATION IN MANAGING WATER QUALITY FOR FRESHWATER NILE TILAPIA (*Oreochromis niloticus*) AQUACULTURE**" prepared and submitted by **MARIELA V. RAMIREZ, DANICA MARIE E. DICON, GLENN MANLUPIG** in partial fulfillment of the requirements for the degree Bachelor of Science in Agricultural and Biosystems Engineering, is hereby recommended for approval.

GETHER P. ENARIO, PhD Adviser /Statistician

Date

This undergraduate thesis is approved in partial fulfillment of the requirements for the degree Bachelor of Science in Agriculture and Biosystems Engineering. Approved by the Oral Examination Committee with a rating of .

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: H.T. Feliciano St., Ozamiz City, Misamis Occidental

CURRICULUM VITAE

Name : Glenn Celeste G. Manlupig
Address : Pulot, Ozamiz City, Misamis Occidental
Date of Birth :
Place of Birth :
Age :
Nationality : Filipino

PERSONAL PARTICULAR

Civil Status : Single
Religion : LDS
Name of Parents : **Mother:** Celestina Manlupig
: **Father:**

EDUCATIONAL ATTAINMENT

Elementary : Iligan City SPED Center
:
Junior High School :
:
Senior High School :
:
Tertiary : Misamis University
: Ozamis City Misamis Occidental