

Assessment of Water Quality Parameters and their Relationship with Weight Gain of Common Carp (*Cyprinus carpio* L.) in an Iraq Aquaponic System

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Abstract - Aquaponics is an eco-friendly and sustainable method that combines plant cultivation and fish rearing into a single, integrated system. Fish waste is naturally recycled by the system and transformed into nutrients that plants may readily absorb by helpful bacteria. Three aquaponic systems, which are closed systems, fish culture common carp (*Cyprinus carpio*), with hydroponic plant production pepper (*Capsicum* spp.) and tomato (*Solanum lycopersicum*) were used in the 105-day trial, which ran from December 2024 to April 2025. The objective of this study was to evaluate selected physical and chemical water quality parameters and to examine their relationship with the weight gain of common carp (*C. carpio*). The results indicated that dissolved oxygen concentrations remained within the recommended limits throughout the experimental period. Nitrate concentrations were also maintained within the acceptable ranges for fish during the entire study. Electrical conductivity values were higher than the recommended limits, while pH values remained within the acceptable range for both fish and nitrifying bacteria. Furthermore, the results revealed a highly significant correlation between fish body weight and electrical conductivity as well as water temperature, in addition to a highly significant correlation between electrical conductivity and water temperature. An evaluation of the water quality provides a comprehensive understanding of the interactions and balance between fish, plants, and microorganisms in aquaponic systems. The study results showed that fish growth and bacterial efficiency are significantly affected by five water quality commonly measured in aquaponic systems: dissolved oxygen, pH, water temperature, nitrate concentration, and electrical conductivity.

تقييم معايير نوعية المياه وعلاقتها بزيادة وزن اسماك الكارب الشائع (*Cyprinus carpio* L.) في نظام الاكوابونيك في العراق

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المستخلص - الزراعة المائية المتكاملة هي طريقة صديقة للبيئة ومستدامة تجمع بين زراعة النباتات وتربية الأسماك في نظام واحد متكامل. يقوم النظام بإعادة تدوير مخلفات الأسماك بشكل طبيعي وتحويلها إلى مغذيات يسهل على النباتات امتصاصها بواسطة البكتيريا النافعة. استخدمت ثلاثة أنظمة زراعة مائية متكاملة، وهي أنظمة مغلقة وتربية الأسماك الكارب الشائع (*Cyprinus carpio*) وإنتاج النباتات المائية نبات الفلفل (*Capsicum* spp.) ونبات الطماط (*Solanum lycopersicum*)، استمرت التجربة 105 يوم، من كانون الأول 2024 إلى نيسان 2025. كان الهدف من هذه الدراسة تقييم معايير مختارة لنوعية المياه من الناحية الفيزيائية والكيميائية، ودراسة علاقتها بزيادة وزن اسماك الكارب الشائع (*C. carpio*). أشارت النتائج إلى أن تراكيز الأكسجين المذاب بقيت ضمن الحدود الموصى بها طوال فترة التجربة. كما بقيت تراكيز النترات ضمن الحدود المقبولة للأسماك طوال فترة الدراسة. كانت قيم التوصيل الكهربائي أعلى من الحدود الموصى بها، بينما بقيت قيم الرقم الهيدروجيني ضمن النطاق المقبول لكل من الأسماك وبكتيريا النيتروجينية. علاوة على ذلك، اوضحت نتائج التحليل الاحصائي والارتباط عن وجود ارتباط وثيق بين وزن الاسماك ودرجة حرارة

الماء والتوصيل الكهربائي، بالإضافة إلى ارتباط وثيق بين التوصيل الكهربائي ودرجة حرارة الماء. يوفر تقييم نوعية المياه فهماً شاملاً للتفاعلات والتوازن بين الأسماك والنباتات والكائنات الدقيقة في أنظمة الزراعة المائية المتكاملة. أظهرت نتائج الدراسة أن زيادة وزن الأسماك وكفاءة البكتيريا يتأثران بشكل كبير بخمسة عوامل لنوعية المياه تُفاس عادةً في أنظمة الزراعة المائية المتكاملة: الأوكسجين المذاب، والاس الهيدروجيني، ودرجة حرارة الماء، وتركيز النترات، والتوصيل الكهربائي
الكلمات المفتاحية: الكرب الشائع، نظام الاكوابونيك، نوعية المياه، الزيادة الوزنية، العراق.

Introduction

Fish are among the richest sources of protein and represent an important contributor to economic benefits in many countries worldwide. Various methods are used for fish culture, among which Aquaponics system (Timmons *et al.*, 2002; Majeed, 2018; kiggundu *et al.*, 2025).

Aquaponics is a sustainable and innovative farming technique that combines fish farming with hydroponics in a self-contained ecosystem. The system uses fish waste as an organic source of plant nutrients. Beneficial bacteria convert this waste into fertilizer for the plants, which in turn purify the water and return it clean to the fish tank (Homoki *et al.*, 2021). A typical aquaponics consists of Fish tank that contains fish and water, plant Grow peds Where plants grow in a soilless environment, Biofilter beneficial bacteria that convert harmful ammonia into nitrates beneficial to plants and water pump to transfer water from the fish tank to the plants (Diver, 2000; Hussain *et al.*, 2015).

One of the advantages of the aquaponic system frequently used to minimize total water usage and loss, Also, closed aquaculture systems reduce the amount of wastewater released into the environment (Martins *et al.*, 2009).

While closed aquaculture systems reduce the amount of waste-filled water released into the environment, the accumulation of hazardous materials inside the system requires careful monitoring. By effectively removing these accumulations, the concentration of harmful compounds is prevented (Lin *et al.*, 2002). Closed aquaculture systems that use water supplemented with nitrogenous and phosphorus compounds need to be closely studied because of the potential harm that could arise from directly releasing such effluents into natural water bodies (Love *et al.*, 2015). Good water quality is ensured by treating solid wastes, controlling dissolved minerals, organic matter, pH, dissolved gases, temperature, salinity, and other relevant variables (Cripps and Bergheim, 2000). Hydroponic gardening has been recognized as one of the most cutting-edge agricultural practices in the world since it was first used commercially in 1940. It is a common agricultural practice in many countries, particularly in Europe, the US, Australia, New Zealand, and Southeast Asia. This technology has not received much attention in Iraq, despite being essential in meeting a significant portion of the demand for vegetable crops in these countries (Barker and Pilbeam, 2007)

The main benefit of combining plants and fish in one system is the creation of an inexpensive infrastructure that uses plants to eliminate fish waste, conserves water, and increases total output by producing two crops at once (Wood *et al.*, 2012). As a subsystem of recirculating aquaculture systems, aquaponics uses biological treatment methods to remove waste. To attain water quality appropriate for both fish and plants, closed systems must incorporate both biological treatment and solid waste removal during water recirculation (Amin *et al.*, 2023).

Given that aquaponic systems are not widely applied in Iraq, this study aimed to investigate selected changes in water quality parameters within aquaponic systems and their relationship with fish weight gain.

Materials and Methods:

Materials required for constructing the systems:

1. 4 inch diameter pipes: 10 units
2. Submersible pumps: 6 units
3. -½inch diameter pipes: 2 units
4. Fiberglass tanks (1000 L): 3 units
5. Shade nets: 2 rolls
6. Plastic covering sheet: 1 roll
7. Steel support frames: 12 units
8. Plastic clamp: 1 unit
9. Electrical energy storage unit (power inverter): 1 unit
10. Large-capacity liquid batteries: 2 units
11. Air pump (aerator): 1 unit
12. Small aeration tubing: 6 units
13. Water heaters: 6 units
14. Pipe adhesive: 5 units
15. Floating fish feed (pelleted diet): 1 bag

Method of Connection systems:

Wooden support frames were constructed for the plant grow beds, which consisted of three units installed at a height of 80 cm. The supports were built using ½-inch angle material with a total length of 6 m. Five PVC pipes with a diameter of 4 inches and a length of 3 m were fixed using a specialized adhesive to prevent water leakage, covering a total cultivation area of 6 m². The spacing between adjacent pipes was 0.5 m. Each pipe was drilled with 25 holes of 2-inch diameter, with a distance of 0.25 m between successive holes.

A small outlet hole was drilled at the mid-diameter of each pipe to allow water drainage from the grow beds toward the fish tanks. Another hole was drilled at the lower part of the pipe diameter to control the water level inside the grow beds using a water control valve. Three fish tanks made of fiberglass, each with a capacity of one ton, were prepared. A measuring scale was installed inside each tank to monitor and regulate the water level. The plant grow beds were connected to the fish tanks using three ½-inch diameter pipes, each 8 m in length, equipped with submersible pumps to transfer water from the fish tanks to the grow beds. Fish were then stocked into the tanks and fed lightly for a period of 25 days.

An air pump was connected to the tanks through distributed aeration tubes to ensure adequate oxygenation. The submersible pumps were operated by connecting them to the electrical power supply to enable water circulation and to stimulate the activity of nitrifying bacteria. The systems were covered with green agricultural shading netting. A biofilter with a capacity of 20 L was constructed and filled with agricultural netting to trap solid wastes and uneaten feed originating from the fish tanks, as well as to increase the available surface area for bacterial colonization.

The filter was perforated at the top to allow the entry of water from the fish tanks and at the bottom to facilitate the discharge of treated water into the plant grow beds.

Figure (1) represents a simplified model of an aquaponics system, showing the circulation of water between fish tanks, filtration units, and growing tanks, where waste is converted into plant nutrients before the purified water is returned to the tanks. The actual system would have

included several fish tanks, additional pumps, aeration and heating units, and a power backup system to ensure stable operation.

Plant cultivation cups were prepared by perforating them with multiple holes using a soldering tool, allowing plant roots to come into direct contact with the water inside the grow beds. After 45 days, two small-sized water heaters were installed in each fish tank in order to maintain a suitable temperature for the fish. The systems were completely integrated after polystyrene trays were prepared with plant seedlings, such as pepper (*Capsicum* spp.) and tomato (*Solanum lycopersicum*). The remaining tanks were filled with water from the previously stocked fish tank, and more water was added to meet the necessary levels.

Seedlings were then transferred to the plant grow beds, placed into the prepared cultivation cups, and stabilized using a small amount of gravel and cut pieces of agricultural netting to support the plants. Tomato plants were cultivated in the first and second systems, while pepper plants were cultivated in the third system.

The number and initial weight of the fish were as follows:

First tank: stocked with 25 fish with a total biomass of 730 g.

Second tank: stocked with 20 fish with a total biomass of 570 g.

Third tank: stocked with 20 fish with a total biomass of 670 g.

A planting density of 12 tomato plants per square meter was adopted, resulting in a total of 72 plants grown in a plant grow bed with an area of 6 m² (1 m width × 6 m length). The grow bed was connected to a fiberglass tank with a capacity of one tonne.

One end of thin supporting strings was attached to the plant grow beds, while the other end was fixed to the upper shade structure to support the plants and protect them from breakage and mechanical movement during the course of the experiment. Fish were fed with imported floating pelleted feed, with feeding rates ranging between 3% - 5% of the total fish biomass.

Chemical and Physical Analyses of Water Samples:

Water samples were collected from the fish-rearing tanks and plant grow beds. A total of 7-8 samples were obtained, at a rate of two samples from each system, at semi-monthly intervals. Sampling was conducted using plastic bottles with a capacity of 1.5 L, and the samples were transported immediately to the laboratory for analysis.

The measured parameters included:

1. pH, electrical conductivity (EC), and water temperature

These parameters were measured in situ using a pH meter (WTW Multi 3410 SET C), German manufacture.

2. Dissolved Oxygen (DO)

The dissolved oxygen concentration was determined using Winkler modified method, as described in reference (APHA, 1999).

3. Nitrate Ion (NO₃⁻)

Nitrate concentration was determined colorimetrically using the cadmium reduction method, as described in reference (APHA, 1999).

Fish Weight Gain:

Fish weight was measured using a sensitive balance at semi-monthly intervals for each system separately. Weight gain was calculated by first reducing the water level in the tanks, then

transferring the fish using a bucket containing water. Another container filled with water was placed on the sensitive balance and tared, after which the fish were added and the average weight of fish in each tank was recorded.

Statistical analysis:

The statistical program Statistical Package for Social Science (SPSS) (V. 20) used to conduct the statistical analysis of some of the study results under the significance level of (0.01) and (0.05).

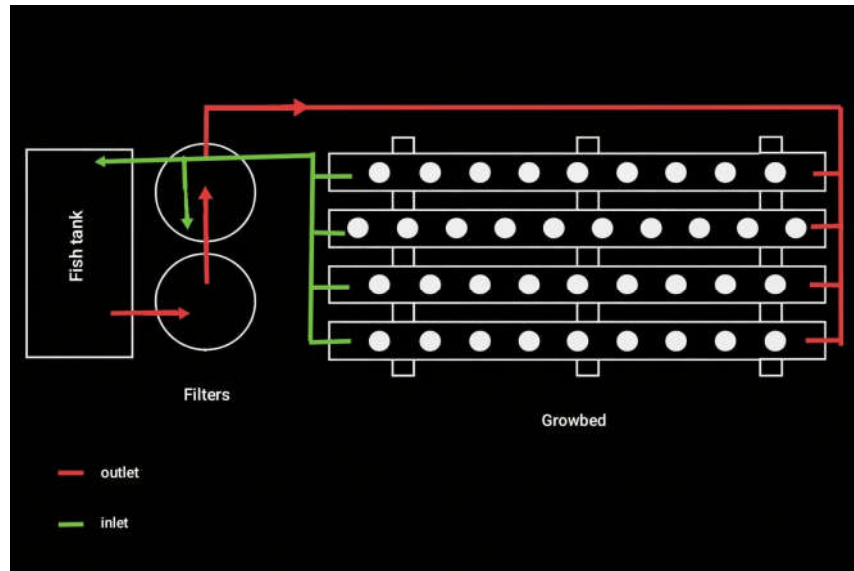


Figure 1. Schematic Representation of the Integrated Aquaponics System

Results and Discussion:

Table 1 shows the rate of time effect on water quality measurements in the parameters in the systems.

Water Temperature:

As shown in Figure 2, the water temperature after 45 days of cultivation and aquaculture ranged between 13.9 and 15.4 °C. This decrease is attributed to the low air temperatures during the winter season. Subsequently, the temperature began to increase gradually due to the installation of two small water heaters in each fish tank, which led to an increase in water temperature, in addition to the moderation of ambient temperatures after 105 days of cultivation and aquaculture. Consequently, the temperature in the systems ranged between 25.8 and 28.1 °C. The mean effect of time on the measured water quality parameters in the systems showed a significant relationship, with the highest value recorded at 18.84 ± 4.12 and the lowest value at 18.47 ± 0.16 , as presented in Table 1. In contrast, the mean water quality parameters at the growbed and tank sites did not show any significant values, as shown in Table (2)

Table 1. Shows the rate of the effect of time on the water quality measurement parameters in the systems.

		45 days	60 days	75 days	90 days	105 days	LSD at P=0.05
Temperature	Total mean	18.81	19.28	26.05	--	14.14	4.40*
	SD	± 2.03	± 0.13	± 0.19		± 4.71	
Dissolved Oxygen	Total mean	8.27	8.29	6.07	9.53	16.77	NS
	SD	± 2.43	± 1.45	± 1.74	± 1.37	± 3.63	
Electrical Conductivity (EC)	Total mean	5.11	7.09	7.38	7.92	9.16	1.238*
	SD	± 0.62	± 0.53	± 0.22	± 0.20	± 0.83	
Nitrate (NO ₃ ⁻)	Total mean	71.88	99.39	70.43	23.36	46.81	47.090*
	SD	± 31.23	± 35.14	± 42.23	± 25.62	± 48.75	
pH	Total mean	7.55	7.24	8.02	8.1	7.78	0.306*
	SD	± 0.49	± 0.28	± 0.28	± 0.15	± 0.1	

Table 2 shows the mean values of water quality parameters at the growbed and tank sites.

Table 2. Shows the mean values of water quality parameters at the growbed and tank sites.

		Fish tank 1	Fish tank 2	Fish tank 3	Growbed 1	Growbed 2	Growbed 3	LSD at P=0.05
Temperature	Total mean	18.84	18.61	18.80	18.47	18.59	18.61	NS
	SD	± 4.12	± 4.59	± 5.00	± 5.16	± 5.24	± 5.14	
Dissolved Oxygen	Total mean	11.16	10.73	10.27	9.09	10.47	9.48	NS
	SD	± 4.57	± 5.13	± 4.12	± 4.56	± 4.23	± 4.08	
Electrical Conductivity (EC)	Total mean	7.25	7.41	6.96	7.29	7.59	6.99	1.238*
	SD	± 1.49	± 1.51	± 1.44	± 1.42	± 1.54	± 1.14	
Nitrate (NO ₃ ⁻)	Total mean	46	52.09	37.13	44.73	45.8	31.72	47.09*
	SD	± 53.56	± 62.8	± 85.13	± 62.56	± 5.56	± 96.27	
pH	Total mean	7.53	7.69	7.76	7.65	7.64	7.67	NS
	SD	± 0.67	± 0.47	± 0.4	± 0.4	± 0.34	± 0.33	

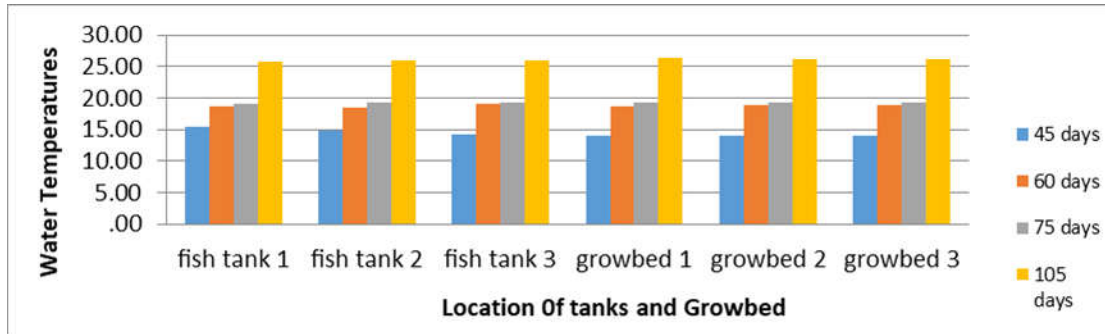


Figure2. Shows the interaction of water temperature (°C) across different time periods in the grow beds and fish tanks.

Dissolved Oxygen:

As shown in Figure 3, the dissolved oxygen concentration after 45 days of introducing fish and plants into the systems ranged between 7.8 and 8.4 mg L⁻¹ in both ponds and incubators. After 60 days, the dissolved oxygen levels increased, reaching values between 15.7 and 19.1 mg L⁻¹. However, a subsequent decline in dissolved oxygen concentration was observed after 75 days of plant cultivation and fish stocking.

The increase in dissolved oxygen within the systems may be attributed to the addition of aeration lines, where two aeration tubes were used instead of a single one. Air pumps are known to enhance dissolved oxygen concentrations in fish ponds and incubators, as reported by reference (stone and Thomforde, 2004). On the other hand, higher water temperatures can be blamed for the drop in dissolved oxygen concentration following 75 days of plant and fish rearing. Raising the temperature increases microbial activity and speeds up the breakdown of organic materials. Furthermore, because gases become less soluble at higher temperatures, there is an inverse relationship between water temperature and dissolved oxygen concentration.

As shown in Table 1, the results also showed a substantial correlation between time and the measured water quality parameters within the systems, with the maximum recorded value being 16.77 ± 3.63 and the lowest value being 6.07 ± 1.74. On the other hand, Table (2) indicates that there were no appreciable variations in the average values of water quality metrics between the incubator and pond locations.

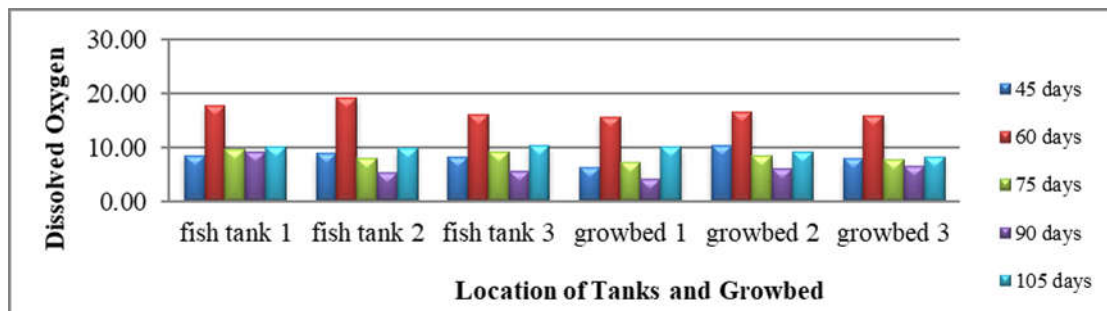


Figure 3. Shows the interaction between dissolved oxygen concentrations (mg L^{-1}) and time in the grow beds and fish tanks.

pH :

All systems had a pH of 7.5 at the start of the experiment. The pH started to drop after 60 days of cultivation; it ranged from 6.7 to 7.3 in all systems Figure 4. Fish respiration and nitrifying bacterial activity are blamed for this decrease (Kim *et al.*, 2023). Subsequently, the pH values showed an increasing trend, which may be attributed to algal growth in the fish tanks and growbed units, as algae are known to elevate pH levels within such systems.

Overall, the recorded pH values remained within the tolerance limits for fish and bacteria but were higher than the optimal range for plants. The pH values ranged from 6.7 to 8.1. Regarding the effect of time on water quality parameters within the systems, the mean values showed a statistically significant relationship, with the highest recorded value being 8.10 ± 0.28 and the lowest value being 7.24 ± 0.28 . as presented in Table 1. In contrast, the mean values of water quality parameters at the growbed and fish tank sampling sites did not show a statistically significant difference, as illustrated in Table 2.

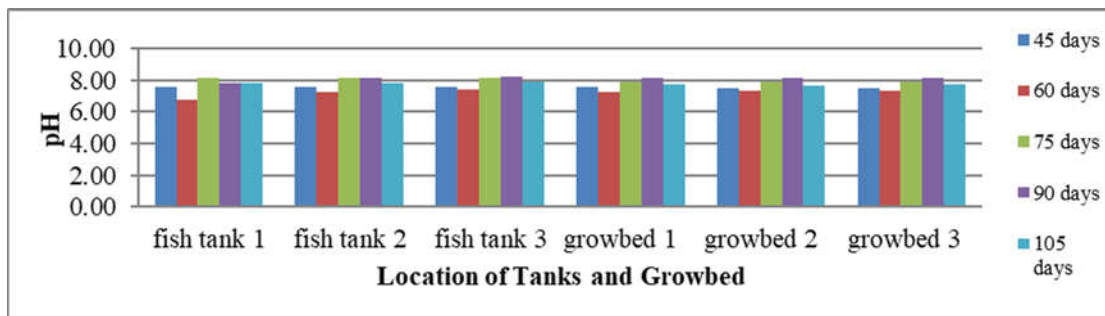


Figure 4. Shows the interaction between pH concentrations and time in the grow beds and fish tanks

Nitrate (NO_3^-):

After 45 days of fish stocking and plant cultivation, nitrate concentrations ranged between 61.9 and 99.1 mg L^{-1} . Subsequently, nitrate levels increased to a range of 95.6–103.3 mg L^{-1} after 60 days of cultivation Figure 5. This increase is attributed to the rise in fish feeding rates from 3% to 5%, as higher feeding levels contribute to elevated nitrate concentrations in the water, in agreement with the findings of study (Anonymous, 2007).

After this period, Nitrate levels started to drop, which could be because of plant roots absorbing it. One of the nitrogen types that plants can absorb the easiest is nitrate. Nitrate concentrations stayed within the advised ranges during the trial, which is in line with the findings provided by (Aslanidou *et al.*, 2023). Nitrate concentrations were found to drop more significantly in growbed units 1 and 2 than in growbed unit 3.

Given that pepper plants have somewhat shorter root systems and tomato plants have longer fibrous root systems, this could be the result of changes in root morphology. Nitrate concentrations in the fish tanks remained within the recommended range of 0–200 mg L⁻¹, which is in agreement with the limits reported by (Goddek and Keesman, 2020). As shown in Table 1, the mean values for the impact of time on water quality parameters within the systems demonstrated a statistically significant association, with the highest recorded value being 99.39 ± 35.13 and the lowest value being 23.36 ± 25.62. The mean water quality parameters at the Grow bed and fish tank sample sites also showed statistically significant values; Table 2 displays the greatest value of 96.27 ± 31.72 and the lowest value of 53.56 ± 46.00.

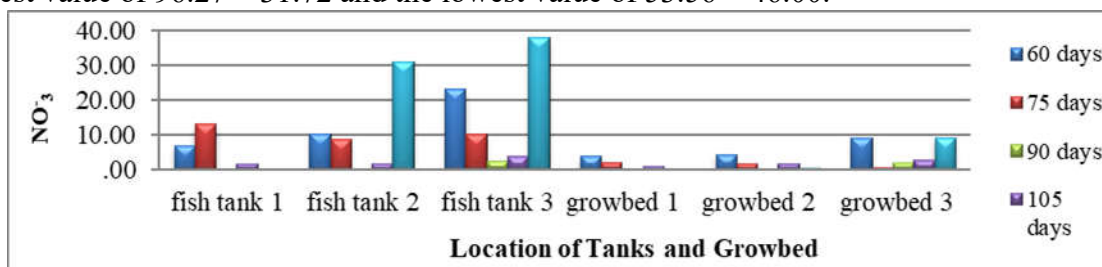


Figure 5. Shows nitrate concentrations (mg L⁻¹) over time in the grow beds and fish tanks

Electrical Conductivity (EC)

After 45 days of cultivation, Figure 6 shows that electrical conductivity values ranged between 4.9 and 5.1 mS cm⁻¹. After 105 days of growing and stocking, EC values steadily rose across the systems, peaking at 9.6 mS cm⁻¹. The water used in the systems, which came from the Shatt Al-Arab River, where high electrical conductivity levels have been documented, could be the cause of this increase (Lee *et al.*, 2026). According to Table 1, the mean effect of time on water quality metrics within the systems showed a statistically significant association, with the lowest recorded value being 5.11 ± 0.62 and the highest being 7.92 ± 0.20. However, as shown in Table 2, there were no statistically significant variations in the mean water quality metrics at the Grow bed and fish tank locations.

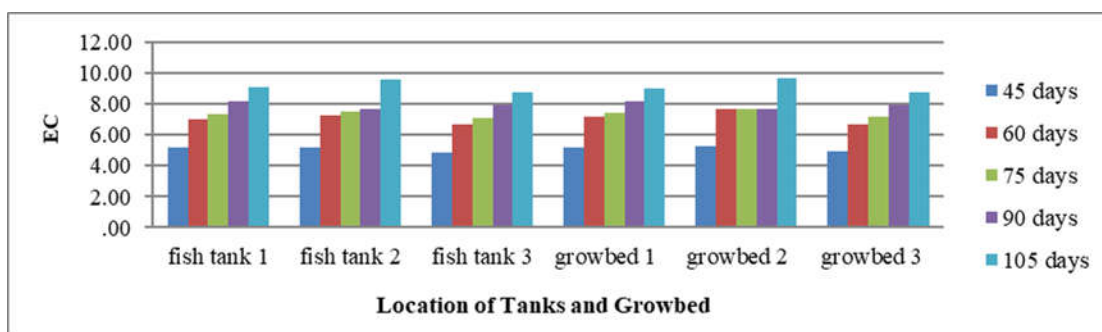


Figure 6. Shows the interaction between electrical conductivity (mS cm⁻¹) and time in the grow beds and fish tanks

The correlation coefficients between fish weight and water quality attributes within the systems are shown in Table 3. Fish weight was found to be positively correlated with electrical conductivity, water temperature ($p < 0.01$).

Table 3. correlation coefficients between fish weight and water quality parameters in the systems

Water parameters	Fish weight
DO (mg L ⁻¹)	0.03
EC (mS cm ⁻¹).	.83**
W. T (°C)	.81**
pH	0.27
(NO ₃ ⁻) (mg L ⁻¹)	-0.46

**Correlation coefficient is significant at the 0.01 probability level.

*Correlation coefficient is significant at the 0.05 probability level.

Conclusions

1. An examination of the water quality is necessary to gauge the sustainability and effectiveness of aquaponic systems.
2. In order to maintain appropriate water quality conditions, filtration devices in aquaponic systems are essential to the nitrification process and the removal of solid wastes.
3. To guarantee the best possible system performance and efficient operation of every component, a suitable balance between fish biomass, plant density, and the surface area available for bacterial colonization must be achieved.
4. The findings showed that fish mortality could result from even a little rise in nitrate concentrations over the advised thresholds.
5. Long-term operation and ongoing research over a number of years are necessary for aquaponic systems because short-term studies may yield an inadequate or ambiguous understanding of system dynamics and performance.

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