Smart Aquaponics System for Maximum Survival of Tilapia by Monitoring Water Quality

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ABSTRACT

Aquaponics hailed as an ideal technique consolidating hydroponics and aqua-farming, encourages water supportability. Imperative for fish wellbeing and endurance, water quality boundaries require observing and control through the turn of events and utilization of sensors. This study plans to bring issues to light among ranchers and Aquaculturists looking for improved yields of sound fish and hearty harvests by using sensors for observing water quality boundaries in Aquaponic frameworks. The exploration was directed with two Aquaponic medicines: a savvy framework outfitted with sensors and a control framework checked utilizing water testing units and instruments. Every treatment facilitated 20 Nile tilapia fingerlings (Oreochromis niloticus), with four plastic pots of *Mentha spicata* in every aquarium. Observing happened like clockwork for water quality boundaries and fish length-weight. The typical temperature stayed at 27.4±3.6, with a mean oxygen level of 7.2±0.6. Fish development rates found the middle value of 7.77±0.8 in the shrewd framework and 3.7±0.1 in the control. *Mentha spicata* flourished in this climate, adding to ideal water quality circumstances. Endurance rates were 100 percent in the savvy framework and 95% in the control, exhibiting the previous' effectiveness and eco-kind disposition through elevated creation and greatest endurance.

INTRODUCTION

The worldwide populace keeps on developing consistently, prompting expanded tension on normal assets like land, water, and supplements. There is a squeezing need to investigate reasonable and compelling strategies for food creation (Goddek *et al*., 2019). In the ongoing setting, buyers are progressively keen on practical and earth mindful food creation techniques (Ribeiro *et al*., 2017; Ali *et al.*, 2020). Around the world, there is a rising pattern in fish utilization, with per capita utilization surpassing 20 kilograms each year universally (FAO, 2016). Hydroponics is a quickly extending area in worldwide food creation, with critical development happening in different districts all over the planet (Subasighe *et al*., 2009). Hydroponics, a natural innovation that coordinates hydroponics with tank-farming plant developing frameworks, assumes a critical part in using supplements from water squander (Datta *et al*., 2018). It considers the creation of vegetables, plants, and organic products even in bone-dry and water-scant locales by reusing water productively (Jumper, 2000). Hydroponics arises as an imperative innovation, especially in parched regions, to further develop food security and adjust to environmental change (Conijn *et al*., 2018). While hydroponics has been drilled for quite a long time in numerous nations, it remains generally disagreeable contrasted with traditional food creation strategies and is prevalently completed for little scopes (Junge *et al.*, 2017). Be that as it may, progressions in plan and practices have worked with the change of this patio innovation into modern scale creation, essentially upgrading fish and yield creation efficiencies (Bernstein, 2011; Goddek *et al.*, 2019b). Aquaponic frameworks require support of water quality boundaries for the creation of solid fish and plants. These boundaries incorporate oxygen, pH, smelling salts, carbon dioxide, nitrate, and nitrite, which must all be inside ideal reaches for fish endurance (MacIntrye *et al*., 2008; Man Le Ruyet *et al.*, 2008). Unfortunate water quality can unfavorably influence fish wellbeing, development rates, taking care of effectiveness, and even lead to illnesses and demise (MacIntrye *et al.*, 2008; Man Le Ruyet *et al.*, 2008). The effectiveness of Aquaponic frameworks can be worked on through the proper determination of fish and plant species (Palm *et al.*, 2014). Hydroponics is picking up speed in Pakistan because of its eco-accommodating nature, requiring negligible water contrasted with regular agribusiness and disposing of the requirement for manures, pesticides, or herbicides (Sarfaraz *et al.,* 2020). It offers huge advantages for neighborhood ranchers, adding to advertise maintainability while limiting natural effects (Sarfaraz *et al.,* 2020). In Pakistan, major monetarily refined fish species incorporate tilapia, Chinese carp, normal carp, Indian significant carp, earthy colored trout, and rainbow trout (Girii *et al.*, 2019). Tilapia (Oreochromis niloticus) is especially preferred for its capacity to endure unfortunate water conditions and drink a wide assortment of food varieties (Amal and Zamri-Saad, 2011). Tilapia is likewise plentiful in protein, potassium, selenium, vitamin B-12, phosphorus, and niacin (Mjoun *et al.*, 2010). Plants display predominant development in aquaponic developing beds contrasted with tank-farming, with mint (Mentha spp.) being noted as a quickly developing spice with high monetary worth as of late (Rakocy *et al.*, 2012; Rakocy *et al.*, 2020). While research on Mentha spp. in hydroponics is restricted, it shows potential because of its low supplement prerequisites and hearty development (Somerville *et al.*, 2014). The current review expects to notice the development rate and endurance of Nile Tilapia (Oreochromis niloticus) and *Mentha spicata* in brilliant aquaponic frameworks and control aquaponic frameworks while keeping up with water quality boundaries inside their ideal reaches.

MATERIALS AND METHODS

Study Location

The research was conducted between October 2021 and March 2022 at the Fisheries and Aquaculture laboratory within the Department of Zoology at Jinnah University for Women.

Experimental Setup

Two glass aquaria, estimating 0.76 meters long, 0.47 meters in width, and 0.47 meters top to bottom, were used. Aquaponic frameworks were laid out, containing a savvy hydroponics framework furnished with sensors (Fig: 5) and a control hydroponics framework without sensors (Fig: 6). The two frameworks were outfitted with aerators and channels.

Selection of Fish and Plant Species

Every aquarium was supplied with 20 Nile Tilapia fingerlings (Oreochromis niloticus), at first averaging 0.95 grams in body weight. Taking care of happened two times day to day, with an eating routine containing 35-40% protein for fingerlings gauging somewhere in the range of 10 and 35 grams during the initial three months, and 30-35% protein for adolescents to grown-ups from the fourth month forward (Somerville *et al.*, 2014). Fish feed amounts were changed in light of normal body weight, with a fast increment of half in body weight like clockwork and feed changed between 5-30 grams.

Selection of Aquaponic Vegetables

The choice of aquaponic vegetables relied upon buyer interest, simplicity of development in the aquaponic framework, and supplement input comparability (Bosma *et al.*, 2017). Mint (Mentha spicata), a restorative and dietary spice with low supplement necessities, was picked (Knaus *et al*., 2020). Four mint plants were put in each aquaponic framework, obtained from a nursery and established in containers. Furthermore, four Drove bulbs, each appraised at 100 watts, were introduced to give light without even a trace of daylight.

Monitoring of Water Physicochemical Parameters

Water quality boundaries were checked involving sensors in the savvy aquaponic framework, while manual observing utilizing water testing units and meters was directed in the control aquaponic framework at seven-day spans. Smelling salts levels were observed utilizing Merck Smelling salts testing packs (Inventory no: HC032717), oxygen levels utilizing Merck Oxygen testing units (Index no: 1.14662.0001), temperature utilizing a thermometer, and pH utilizing a Benchtop pH meter from BANTE (Model no: FPH210-C) (Khodary *et al.*, 2023).

Fish Sampling Procedure

Five fish were haphazardly looked over each aquaponic framework utilizing a fish net to gauge their length and weight. The length of the fish was resolved utilizing an immediate estimation strategy, where each fish was set close by a steel ruler, and the estimation was taken from the head to the tip of the tail. Fish weight was estimated utilizing a computerized weighing machine. Estimations of fish length and weight were rehashed at seven-day spans (Villanueva *et al*., 2022).

Data Analysis

Data collected was inputted into Microsoft Excel and then analyzed using SPSS version 20 for statistical analysis. Descriptive statistics were applied to all variables, and normality was assessed using the Shapiro-Wilk test for variables such as length, weight, temperature, ratio, pH, oxygen, and ammonia. Results were presented as mean, standard deviation, median values, and interquartile ranges. The data was divided into two groups, and descriptive statistics were evaluated for each variable in both groups. Non-parametric Mann-Whitney U tests were performed to compare fish growth between the two groups, while an independent sample t-test was used to compare growth ratios. The Shapiro-Wilk test indicated that only the ratio variable was normally distributed.

Independent sample t-tests and non-parametric Mann-Whitney U tests were conducted to compare growth ratios and other variables between the two groups. Additionally, multiple linear regression analysis was performed to further analyze the growth of fish in both groups.

RESULTS

Data Analysis Procedure

Data was collected via Microsoft Excel and incorporated in SPSS version 20 to apply statistical analysis. The ratio of growth was evaluated by the formula: (Table:1)

$$Ratio = \frac{Length}{Weight}$$

Descriptive statistics were applied to all the variables in the study and the normality was assessed for the length, weight, temperature, ratio, Ph, oxygen, and ammonia through the Shapiro Wilk test of normality. The variables were presented as the mean, standard deviation, median values, and interquartile ranges. Data were divided into two groups and the descriptive statistics of non-parametric data were evaluated in both groups for each variable. To compare the growth of fish in both groups a non-parametric Mann Whitney U test was performed. The growth ratio between both groups was compared by an independent sample t-test. A significant level of less than 0.05 was considered significant.

Statistical Analysis on Length-Weight Ratio

All of the 52 observations, data was equally divided in both groups having 26 observations in each group. The mean length and weight of all the fishes were 7.76±0.8 and 11.29±0.1 respectively. The overall temperature was 27.4±3.6 on average and the mean oxygen level was 7.2±0.6. The normality check by the Shapiro Wilk test showed that only the ratio variable was normally distributed. (Table: 1)

Independent sample t-test and non-parametric Mann Whitney U test was performed for the comparison of growth ratio and other variables in both groups. The details are given in the table.

Table: 1 Showing the Statical Analysis of Length – Weight Ration And Water Quality Parameters

Variables	**Smart AP (n=26)**	**AP (n=26)**	**p-value**
Ratio (mean±SD)	0.61±0.2	0.71±0.1	**0.024^***
Temperature Median (IQR)	29 (6)	29.2 (7)	0.57#
Oxygen Median (IQR)	7.6 (0.3)	7 (0.6)	**0.001#***
Ph Median (IQR)	7.3 (0.3)	7.1 (0.4)	0.23#
Ammonia Median (IQR)	0.06 (0.07)	0.03 (0.1)	0.31#

*Significant value

^Independent sample t-test was applied

#Mann Whitney U test was applied

Statistical Analysis of Growth Rate

Data Analysis procedure

Data was collected via sensors linked with a computer through read-only memory removable device and incorporated in excel data ToolPak statistical analysis. The growth was evaluated by the formula:

$$Percentage\ Growth\ Rate = \frac{Final\ Weight - Initial\ Weight}{Initial\ Weight} \times 100$$

Descriptive statistics were applied to all the variables in the study and the normality was assessed for the percentage Growth Rate. Data were divided into two groups and the descriptive statistics of non-parametric data were evaluated in both groups for each variable. To compare the growth of fish in both groups a multiple linear regression analysis was performed:

Multiple linear regression was calculated to predict the Growth rate based on Weight and Time. A significant equation was found:

$(F(1,24) = 0.0034$ Sig $F < 0.95)$, with R^2 of 0.000141787

Results

For all of the 52 observations, data was equally distributed among both groups having 26 observations in each group. The mean growth rate of all the fish was7.77±0.8 and 3.7±0.1 for Smart and AP respectively. Regression Statistics and ANOVA is performed in order to determine the standard errors and variation between sample means/variation within the samples between both groups. (Table: 3)

	Coefficients	Standard Error	t Stat	**P-value**	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	3.74214288	0.810645	4.616253	**0.00011***	2.069053772	5.415232	2.069054	5.415232
X Variable 1	-0.008752354	0.150027	-0.05834	0.953962	-0.318393008	0.300888	-0.31839	0.300888

*Significant value

The P-Value < 0.05 (P-Value = 0.00011) shows the significance of automation on the growth rate of Aquaponics

Table 3 Regression Statistics and ANOVA

Regression Statistics	
Multiple R	0.011907452
R Square	0.000141787
Adjusted R Square	-0.041518971
Standard Error	1.934618617
Observations	26

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.012738	0.012737999	0.00340338	0.953962029
Residual	24	89.8259806	3.742749191		
Total	25	89.8387186			

Absolute Growth Rate Radar.

As seen on the web, The Smart Aquaponics system has far greater performance than the Conventional AP system, as Smart ha as greater peak and far greater reach at the circumference, while Conventional AP has close circle reach and near center approach, this shows the performance evaluation of both system in terms of Absolute Growth (Fig:2)

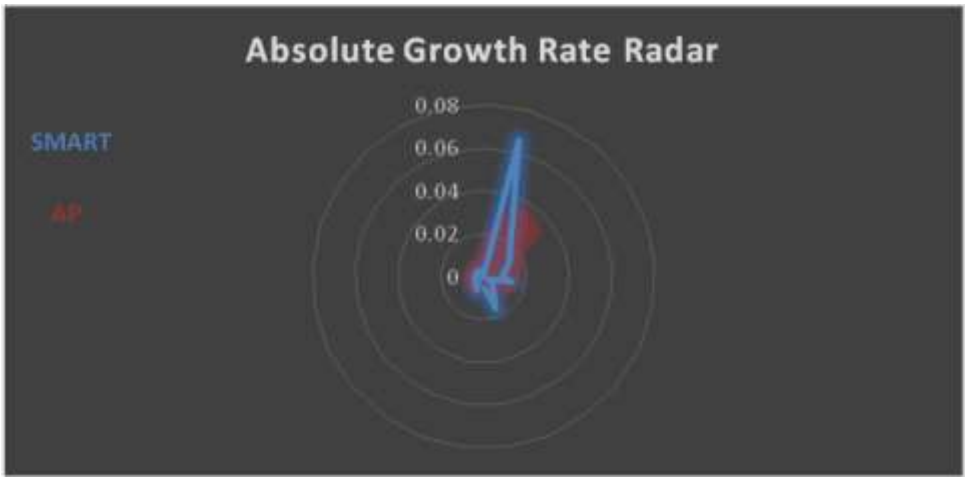

Fig: 2 Absolute Growth Rate Radar of Smart and Control Aquaponics system

Relative Percentage Growth

RP, short for relative percent, is a measure of the change in a value relative to the average of that value, For a given data, this is a representation of the growth rate of each fish with reference to the growth rate of all fishes in that group. The graph shows that Smart AP has more peaks and a higher area covered by Smart AP than Conventional AP. (Fig: 3)

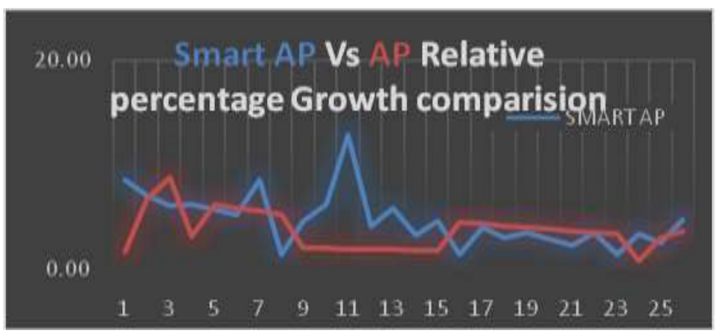

Fig: 3 Graph of Relative Percentage Growth Comparision of Smart Aquaponics Vs Control Aquaponics system

Mortality Vs Weeks

The survival rate in smart Aquaponics system was 100% and in Control Aquaponics system the rate of survival rate was found to be 95% as shown in Fig:4

Fig: 4 Graph of Mortality Rate in Smart Aquaponic system and Control Aquaponic system

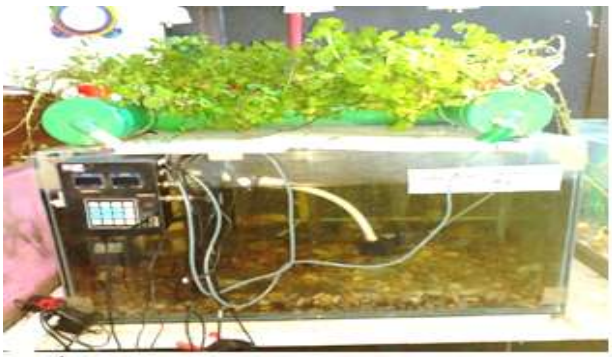

Fig: 5 Smart Aquaponics System

Fig: 6 Control Aquaponics System

DISCUSSION

The current study highlights the use of Aquaponics in fish production to achieve maximum survival and optimal growth. Fish growth and survival are directly correlated with the water quality characteristics, which are vital to fish growth. There is the possibility to achieve the significant growth and high survival rate when the water quality parameters are closely maintained and evaluated.

Fish growth and a healthy system dependent greatly on the factors of water quality being maintained (Sunny *et al.,* 2017). Fish health and growth are frequently affected by water quality parameters such as temperature, pH, dissolved oxygen, and ammonia (Islam *et al.*, 2018). Temperature, pH, dissolved oxygen, and ammonia levels in both control and smart Aquaponics systems were measured for the present study.

The current study's control and smart Aquaponics systems' average temperature ranges fell within the same ranges as those reported by Osman (2021) for Aquaponics systems, and Maulini et al. (2022) for sensor-based temperature recording. The temperature of both Aquaponics systems in the current study was within tolerable range, as indicated by Bhatnagar and Devi (2013) and Kohinoor (2000).

Furthermore, Kohinoor (2000) and Bhatnagar and Devi (2013) reported that fish may encounter stress conditions if the temperature is below 12 ºC and above 35 ºC.

The Aquaponics system's pH indicates how basic and acidic the water is. The pH range in the smart Aquaponics system by sensor application was higher during this study, whereas Maulini et al. (2022) found the lower pH range monitoring by sensors. The pH in the control Aquaponics was lower during the present study than as reported by Kumar et al. (2023). Both pH limits are suitable for fish growth. The pH range that DeLong et al. (2009) recommends for tilapia culture is 6 to 9.

According to Caldini et al. (2015), ammonia is produced in Aquaponics systems by the nitrogenous excreta of fish and the breakdown of remaining feed. The high concentration of this waste can be detrimental. The ammonia range for tilapia growth is 0.17 - 3.87 mg/l (Kumar et al., 2023). While Maulini et al. (2022) determined the permissible range of ammonia by using sensors, the ammonia ranges in the current study were monitored by using sensors, and the concentration was lower than optimum range, which indicates good water quality management. The ammonia ranges in the control aquaponics system were also lower than the ammonia monitor by Tamim *et al*. (2022).

In contrast to Anantharaja et al. (2017), who discovered that fish in an Aquaponics system had an average length and weight of 9.02±0.54, the current study's fish had an average length and weight of 7.76±0.8 and 11.29±0.1, respectively. While the average growth attained in the present study in both the smart Aquaponics system and the control Aquaponics was higher than that of observed by Valiente et al. (2018), the length and weight of Nile tilapia in the smart Aquaponics system was significantly higher than that of the traditional system.

It was discovered that the smart Aquaponics system had a 100% survival rate and that there was no mortality at the period of observation. Selek *et al.* (2017) stated that Nile tilapia (*Orechromis niloticus*) in control Aquaponics systems had a 100% survival rate; however, the present study observed a 95% survival rate. Fish and plants will eventually grow healthily as a result of the system's reduced nitrogenous compound levels and improved water quality. (Oladeji & Associates, 2020). The current study's growth of *Mentha spicata* yields positive results. Knaus *et al.* (2020) state that the physicochemical characteristics of the water and the fish stocking density influence the *Mentha spicata* growth. *Mentha spicata* grows most efficiently in air temperatures between 4.6°C and 35.3°C (Ju *et al.*, 2021). The current study maintained the aquaponics system and laboratory temperature within the ideal range for *Mentha spicata* to grow at a high rate. The pH of both aquaponics systems in the current study was in the ideal range for *Orechromis niloticus* and *Mentha spicata*, which exhibit optimal development at this range. Knaus et al. (2020) also observed that the ideal pH range for *Mentha spicata* and *Orechromis niloticus* growth is 7.9–8.0.

Mentha spicata regulates the levels of nitrate and nitrite by absorbing these nutrients, as evidenced by the ammonia ranges in the current study being lower than allowable range in both systems. Plants act as a biological filter in Aquaponic systems by absorbing nutrients, according to Syafiqah et al. (2015). Fish and plants grow healthily as a result of the system's reduced nitrogenous compound levels, which also contribute to excellent water quality.

Proper monitoring of the water quality parameters can enhance fish growth and survival rates. Comparative growth and survival rates were noted in this study between the control and smart aquaponics systems.

The current study indicated that, in comparison to the control Aquaponics system, which was controlled by water testing kits and meters, the smart Aquaponics system was very efficient, with high survival and maximum growth rate since its water quality was being monitored by sensors. It was shown to be more effective since the sensors monitored water quality parameters more effectively and were kept up to date by controllers. It was also noted that the best and healthiest growing plants were mint (*Mentha spicata*), and that mint growth is correlated with clean, well-maintained water.

CONCLUSION

It is found that appropriate monitoring of the water quality indicators can enhance fish and plant development and survival. This study establishes the importance of using sensors in aquaponics systems and offers assistance to fish farmers who are interested in starting small-scale aquaponics businesses. It suggests that these farmers use smart aquaponics systems to achieve high yields and healthy production. It is possible to carry out additional research by cultivating various crops with various fish species.

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