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IOT ENABLED WATER TANK MONITORING FOR SUSTAINABLE TILAPIA FARMING PROGRAM USING RECIRCULATING AQUACULTURE SYSTEM (RAS)

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Abstract

The goal of the study is to accomplish a Recirculating Aquaculture System (RAS) in a small-scale water tank setup for sustainable backyard/indoor fish farming for Nila tilapia fingerlings with alignment to Internet of Things (IoT) technology. The system improved water usage through continuous filtration and reuse, maintaining ideal conditions for tilapia fingerlings. Several IoT components were used including MQ-135 Gas sensor for ammonia detection, DS18B20 Temperature sensor and PH-4502C Liquid PH-Sensor for monitoring. Also the study featured automatic heating, cooling and aeration systems, and an automated feeding using DS1307 Real-Time Clock and servo motor. Early warning signs have been developed for real-time weather forecasting through the help of Open Weather API. These technologies work together to maintain optimal water conditions, ensure consistent feeding and adapt to weather changes, enhancing fish health and growth while conserving water. The system reached excellent satisfaction in different categories, as evaluated using ISO 25010 standards. A 4-point Likert scale has been used, it scored 3.72 for functional suitability, 3.67 for reliability, 3.74 for interaction capability, and 3.69 for performance efficiency. The overall mean of 3.71 demonstrates excellent satisfaction, claiming that the system successfully met its objectives and user standards.

Keywords: IoT, Aquaculture, Recirculating Aquaculture System (RAS), Tilapia, Weather forecasting.

Introduction

Nile tilapia is vital for global food security, but the Philippine tilapia industry faces challenges like low survival rates, disease, and slow adoption of aquaculture best practices. (Temesgen Tola Geletu & Zhao, 2022). Environmental factors greatly influence tilapia growth and profitability. (Silva et al., 2019). Solutions like Recirculating Aquaculture Systems (RAS) can enhance production and reduce pollution but maintaining water quality is challenging. Innovative automated feeding systems using IoT technology can improve feeding accuracy and fish health. Weather forecasts are also essential for effective farm management.

For backyard tilapia farming, both innovative technologies and best practices must be combined to solve the problems. This also involves using real-time weather data from APIs like the OpenWeatherMap, creating an automatic feeding system with a Real-Time Clock module DS1307 for regular feeding and implementing Recirculating Aquaculture System (RAS) to optimize water usage & fish health. They can allow you to create a sustainable, backyard fishing setup which provides an output without upkeep. This approach defines a possible blueprint for urban and suburban food production and provides an understanding of how technology might alleviate common difficulties in small-scale fish farming while promoting ethical aquaculture. These methods will be crucial in maintaining well-regulated sustainability of protein development by coming up with ecologically-sound solutions when preserving our food supply.

Conceptual Framework

Key components include the MQ135 Gas Sensor for air quality, Water Level Sensor, DS18B20 Temperature Sensor, and PH-4502C pH Sensor to monitor crucial farming conditions within three 50+ gallon containers. A DS1307 Real-Time Clock RTC Module provides precise timing for feeding and environmental control. The system also incorporates the OpenWeatherMap API, allowing for correlation between local weather conditions and internal tank parameters. Implementation focuses on real-time

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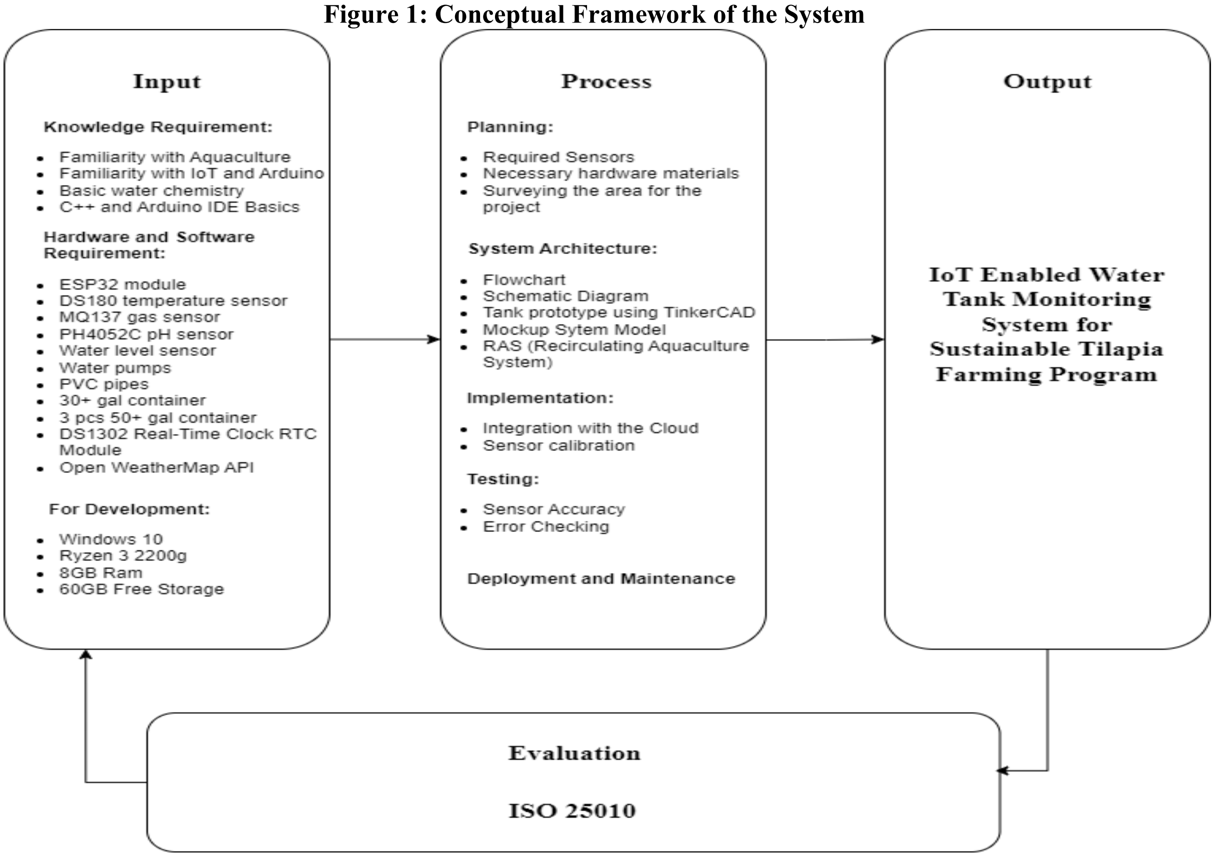
data collection and processing. The Blynk application platform offers enhanced visualization and control capabilities. Rigorous testing ensures system reliability and accuracy, with prompt issue resolution. Deployment follows a carefully planned process to minimize disruption to ongoing farming activities. Long-term success is supported by established maintenance protocols and an iterative development approach based on user feedback. The integration of these components creates a comprehensive monitoring and control system, tailored to the specific requirements of tilapia aquaculture in a recirculating environment.

Figure 1: Conceptual Framework of the System



Statement of the Problem

1. How does a backyard fishing setup achieve sustainable management to maintain a consistent fish supply while conserving local water resources?
2. How does the management of feeding intervals for fish ensure consistent and precise feeding to prevent underfeeding and overfeeding?
3. How does integrating real-time weather forecast data enhance water quality management and improve outcomes in sustainable tilapia farming?

Scope and Delimitation

The scope of this project encompasses the design, development, and implementation of a Recirculating Aquaculture System (RAS) within an indoor house located in Tondo, Manila. The project will focus on enhancing the efficiency and sustainability of backyard fish farming through advanced automation and monitoring technologies. Specifically, the project includes the creation of an automated feeding system utilizing the DS1307 Real-Time Clock (RTC) module and a servo motor to control feeding intervals and dispense fish feed at scheduled times. Additionally, an early warning system will be developed to integrate real-time weather forecast data from the OpenWeatherMap API, providing timely alerts to maintain optimal water conditions in the tank.

However, the implementation is restricted to an indoor environment, which may limit the scale and natural variability compared to outdoor systems. Additionally, reliance on the OpenWeatherMap API for weather data introduces dependency on internet connectivity and the accuracy of external data sources. The system's efficiency is also contingent on the correct calibration and maintenance of the automated components, which may require technical expertise.

Methodology

The modern fish farming system uses a recirculating design that cleans and reuses water efficiently. The setup can be monitored remotely through a mobile app and website, letting farmers check tank conditions from anywhere. A microcontroller collects data from various sensors and sends alerts if water quality falls outside safe levels. The system records performance data over time, helping farmers improve their operations. This combination of water recycling, remote monitoring, and automated alerts makes fish farming more manageable, and data driven.

Figure 2: System Architecture

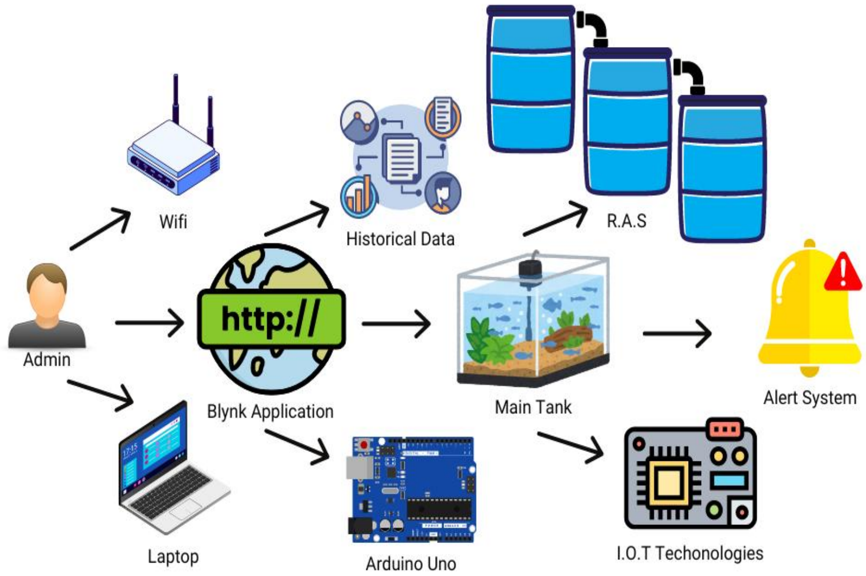


Figure 3: Schematic Diagram

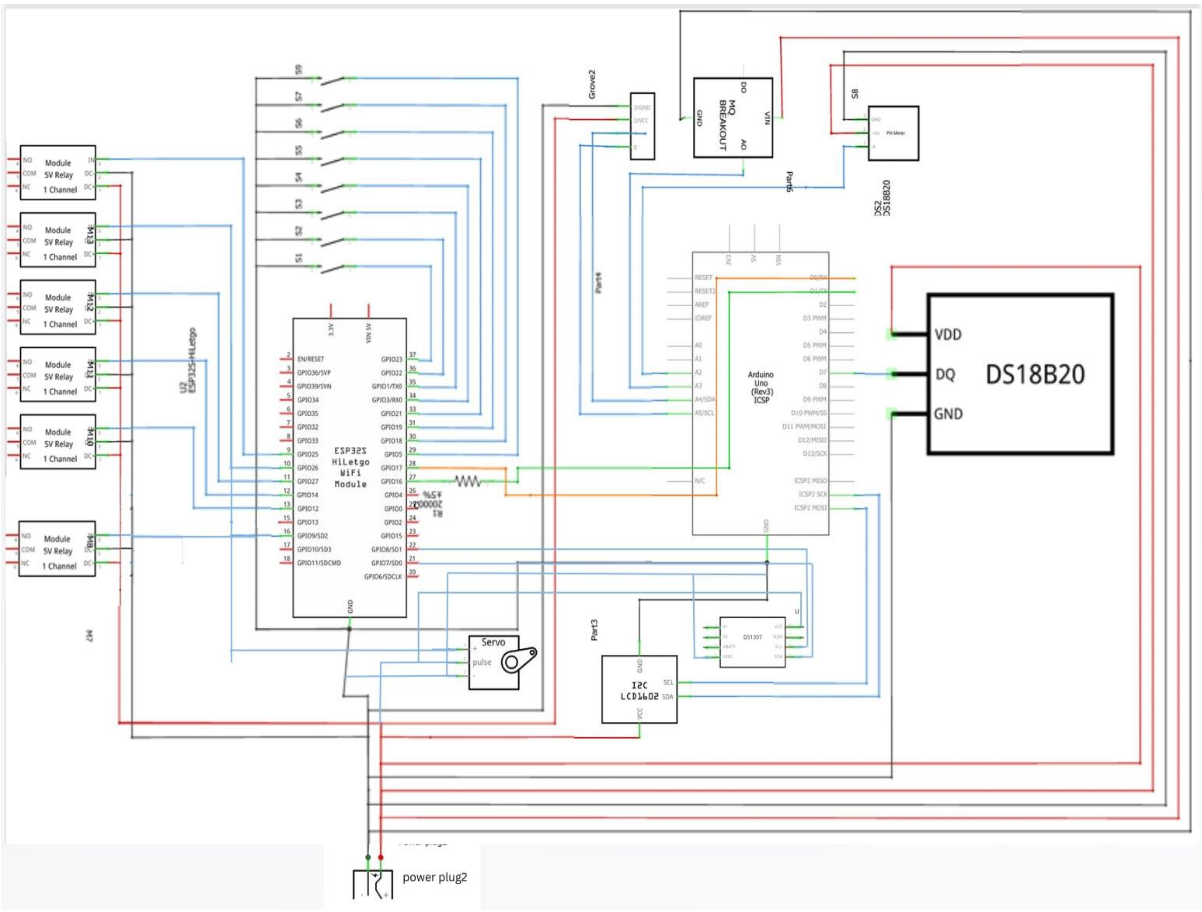
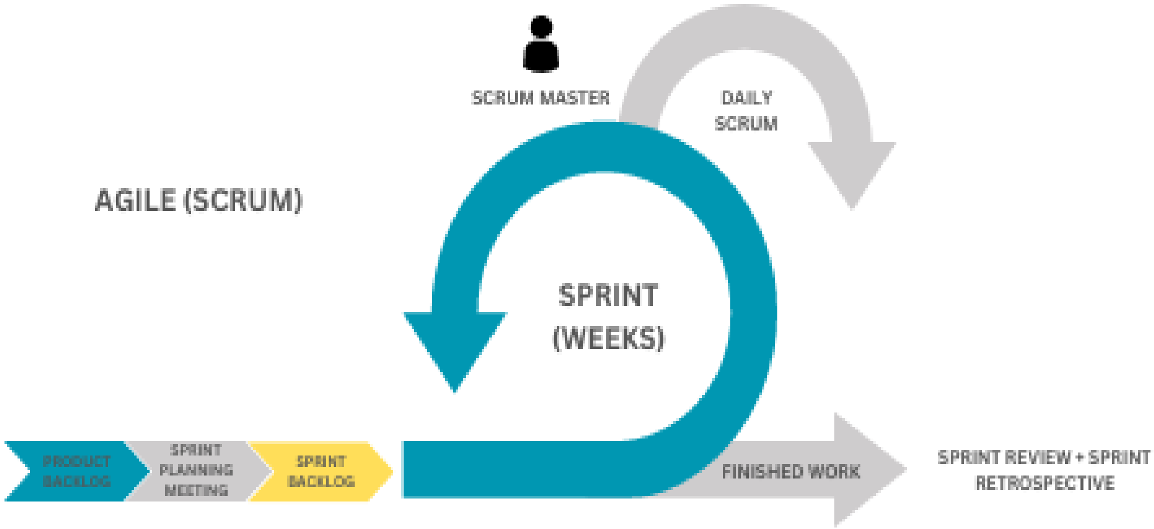


Figure 3 shows how our system's electrical components work together. A voltage regulator ensures steady power supply to all parts. The microcontroller connects to pumps through relays and receives data from sensors that track water quality, temperature, and ammonia levels. A timer-controlled motor handles automatic feeding. This setup allows the system to monitor conditions and respond automatically to maintain a proper tank environment.

Figure 4: Scrum Agile Framework



The figure 4 shows a Scrum Agile framework in the process of developing an "IOT Enabled Water Tank Monitoring System for Sustainable Tilapia Farming Program." The system allows for regular modifications using real-time information and stockholder suggestions for emphasizing iterative development and continuous feedback. Within the framework, every sprint is meant to provide small changes that add up over time to adapt a system to its specific needs. Thus, this methodology makes it easier for cross-functional teams to collaborate in order to maximize system functionality and increase project efficiency overall.

Sampling Method

IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) used a non-probability sample technique called the "convenience sampling". Researchers will be having 100 respondents that are Indoor/backyard fisher, Aquaculture Employee, IoT Specialist/Electronics and Communication Engineer and Electrical Engineer who are willing to participate and answer the survey. These respondents will provide valuable insights for the success of the system study.

Instruments Used

Table 1: The four-point Likert Scale

Point	Scale Range	Explanation
4	4.00-3.00	Strongly Agree
3	2.99-2.00	Agree
2	1.99-1.00	Disagree
1	1.00-0.99	Strongly Disagree

Utilizing a four-point Likert scale for the IoT Enabled Water Tank Monitoring in Sustainable Tilapia Farming Program streamlines data collection and analysis. With concise options, clear opinions can be expressed, aiding precise feedback interpretation. This approach ensures efficient data gathering for informed decision-making to enhance tilapia farming sustainability through IoT-enabled monitoring.

Data Collection and Analysis

Sampling Method:

- Non-probability convenience
- Indoor/backyard fishers Aquaculture employees IoT experts/Electronics and Communication Engineers Electrical Engineers Total 100.

Survey Distribution:
- QR codes for quick access (in person)
- Online Survey using Google Forms (no open ends)

Data Collection:
- Structured Questionnaire with Close-ended Questions
- Use Likert scales, Multiple Choice and Rating Scale

Data Analysis:
- Express statistical analyses by descriptive statistics (mean, median, mode and standard deviation)
- Frequency analysis for each question in the survey.
- Cross-tabulation: comparing responses among different groups

Interpretation:
- Identify trends and patterns in the data through Tables and Bar graphs
- Analyze responses by different respondent types
- Examine the acceptance and perceived effectiveness of a IoT-enabled RAS system

Ethical Consideration
- **Welfare of tilapia**: Keep in mind that the IoT system keeps the water conditions perfect for tilapia to thrive well while also considering the health and well-being of the fish by balancing productivity and reducing stress levels.

- **Data privacy**: Crucial when safeguarding the sensitive production data of farmers gathered through devices. Particularly when sharing this information with government labs, for testing purposes.

- **Assets**: Let's ensure access for all farmers to this technology by addressing any differences, in resources needed for setups and their associated costs and technical requirements.

- **Sustainability**: Evaluate the effects, on a long term basis, for Recirculating Aquaculture Systems (RAS) considering the energy usage of Internet of Things (IoT) devices and the overall ecological impact of the system in relation, to aquaculture practices.

- **RA 10175**: Researchers used the Data Privacy Act of 2012 (RA 10175) for collection of data of the respondents.

Table 2: DAO Water Quality Guidelines for Primary Parameters

Parameter	Unit	Water Body Classification				
		AA	A	B	C	D
Ammonia as NH3	ppm	0-5	5-20	20-50	50-100	>100
Nitrate as NO3-N	mg/L	7	7	7	7	15
pH (Range)		6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.5-9.0
Temperature	°C	26-30	26-30	26-30	25-31	25-31

Table 2 shows the Department of Environment and Natural Resources, DENR Administrative Order No. 2016-08, Water Quality Guidelines and General Effluent Standards of 2016 *(pg. 6-8)*. It will be the primary parameters that will serve as the guidelines for the water quality. Class AA-C is the ideal range, making Class C as the maximum ideal for the propagation and growth of fish and other aquatic resources. Samples shall be taken from 9:00 AM to 4:00 PM in terms of data verification.

Table 3: BFAR Material for Tilapia in Feeding

Age (weeks)	Size	Avg Body	Number of	Feeding	Daily Feed	Feedings	Amount

	(inches)	Weight	Fish	Rate%	Ration (g)	per day	per feeding (g)
1-2	0.5-1.0	0.5-1	30	15	1.43-2.85	6	0.24-0.48
3-4	1.0-1.5	1-3	25	12	2.28-6.84	5	0.46-1.37
5-6	1.5-2.0	3-5	21	10	5.70-9.50	4	1.43-2.38
7-8	2.0-2.5	5-8	20	8	7.60-12.16	4	1.90-3.04
9-10	2.5-3.0	8-12	19	6	9.12-13.68	3	3.04-4.56
11-12	3.0-3.5	12-18	19	5	11.40-17.10	3	3.80-5.70

Table 3 outlines a 12-week feeding schedule for tilapia fingerlings, showing how food amounts change as the fish grow from small fingerlings to juveniles. While this schedule serves as a baseline for feeding management, farmers should adjust portions based on their specific conditions, including water temperature and fish behavior. This planned approach helps achieve the best growth results while using feed efficiently.

System Evaluation (ISO) In evaluating the effectiveness and quality of the "IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program" the developers will utilize the ISO/IEC 25010 standard to ensure the system meets high standards of quality in terms of functional suitability, reliability, usability, and maintainability. ISO/IEC 25010 is a quality model that serves as the foundation of a product quality evaluation system, determining which quality characteristics to consider when assessing a software product's properties (ISO 25000, 2022). This study specifically aims to evaluate the system in terms of the following characteristics.

Table 4: ISO 25010 Characteristics used for System Quality Evaluation

Characteristics		1	2	3	4
Functional Suitability	**Functional completeness** - IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) develops completely all the tasks from the stated objective that meets the user's expectations.				
	Functional correctness - IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) provides accurate function of the system, sensors and results with regards to the Recirculating Aquaculture System (RAS) ,water quality parameters, and precise feeding.				

Characteristics		1	2	3	4
Performance Efficiency	**Time behavior -** The system when operating responds efficiently and smoothly for overall positivity in terms of user experience.				
	Resource utilization - IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) constructively utilizes the resources for its operations achieving all the requirements.				
	Capacity - IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) can maintain and manage workloads responsively.				
Reliability	**Faultlessness -** IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) maintains the designated task properly during regular operations without any malfunctions or error.				
	Availability - IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) is available and functional when necessary for use without any interruptions.				
Interaction Capability	**Self-descriptiveness -** The system displays precise and appropriate details for easier navigation of the users.				
	Learnability - The system users can quickly learn and understand how to utilize the system's functionality.				
	Operability - The system has attributes that make it easy to operate and interact.				

Results and Discussion

Table 5 shows the data gathered such as average temperature, average pH level, average ammonia, and average nitrate from the sensors. It can be observed that the water parameters intended to detect were maintained on their desired values based on DAO-2016-08 Class C, which is the maximum ideal for the propagation and growth of fish and other aquatic resources. In conclusion, the average temperature gathered from 2 weeks was 27.87°C, 6.95 pH level, 18.05 ppm for ammonia level, and 0-5 mg/L nitrate.

Table 5: Average Temperature (°C), pH level, Ammonia (ppm), Nitrate (mg/L) per day

Day	Ave. Temp. (°C)	Ave. pH level	Ave. Ammonia (ppm)	Ave. Nitrate (mg/L)
1	27.33°C	6.88	21.51 ppm	0-5 mg/L
2	28°C	6.76	19.22 ppm	0-5 mg/L
3	27.88°C	6.93	15.39 ppm	5-10 mg/L
4	28.65°C	6.89	17.55 ppm	5-10 mg/L
5	28.15°C	7.05	17.02 ppm	0-5 mg/L
6	28°C	6.90	16.03 ppm	5-10 mg/L
7	27.17°C	7.10	18.12 ppm	0-5 mg/L
8	28.55°C	7.04	17.87 ppm	0-5 mg/L
9	27.43°C	7.11	17.34 ppm	0-5 mg/L
10	27.63°C	6.97	18.25 ppm	5-10 mg/L
11	28.15°C	7.1	18.44 ppm	0-5 mg/L
12	27.74°C	6.91	17.98 ppm	5-10 mg/L
13	28.12°C	6.87	19.21 ppm	0-5 mg/L
14	27.39°C	6.91	18.88 ppm	0-5 mg/L
Average	**27.87°C**	**6.95**	**18.05 ppm**	**0-5 mg/L**

Table 6: Data from the System of IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS) VS Sample Water Quality from Laboratory

<table>
<tr><th colspan="4">IOT Enabled Water Tank Monitoring for Sustainable Tilapia Farming Program using Recirculating Aquaculture System (RAS)</th><th colspan="4">Sample Water Quality test</th></tr>
<tr><td>Temperature (°C)</td><td>pH level</td><td>Amonia (ppm)</td><td>Nitrate (mg/L)</td><td>Temperature (°C)</td><td>pH level</td><td>Amonia (ppm)</td><td>Nitrate (mg/L)</td></tr>
<tr><td>26.90 °C</td><td>7.29</td><td>0.87 ppm</td><td>0-5 mg-L</td><td>….</td><td>….</td><td>….</td><td>….</td></tr>
<tr><td colspan="4">Test Method</td><td colspan="4">Test Method</td></tr>
<tr><td>DS18B20 Temperature Sensor</td><td>PH-4502C Liquid pH Sensor</td><td>MQ-135 Gas Sensor</td><td>API Nitrate test kit</td><td colspan="4">……………………………………..</td></tr>
</table>

Table 6 shows the data gathered such as average temperature, average pH level, average ammonia, and average nitrate from the sensors. It can be observed that the water parameters intended to detect were maintained on their desired values based on DAO-2016-08 Class C, which is the maximum ideal for the propagation and growth of fish and other aquatic resources. In conclusion, the average temperature gathered from 2 weeks was 27.87°C, 6.95 pH level, 18.05 ppm for ammonia level, and 0-5 mg/L nitrate.

Table 7: Average Length Growth of Nile Tilapia Per Week

Week	Ave. Length Growth of Nile Tilapia (cm)
0	3.2 cm
1	4.9 cm
2	6.2 cm
3	8.5 cm
4	9.3 cm
5	11.5 cm

Table 7 shows the average length growth of Nile Tilapia per week. From Week 0, the average length of the Tilapia fingerlings is 3.2 cm which had a 1.7 cm increase going to Week 1. Week 2 recorded an average length of the fingerlings of 6.2 cm which had a 1.3 cm increase. Week 3 has a 2.3 increase from the previous week. Week 4 had a .80 cm increase in length of the tilapia fingerlings. Week 5 showed a significant growth averaging 2.2 cm increase. Lastly, By Week 6, the fingerlings reached a length of 12.7 cm which had a 1.2 cm increase from the previous week.

Figure 5 Arduino box

Figure 6 Indoor Setup

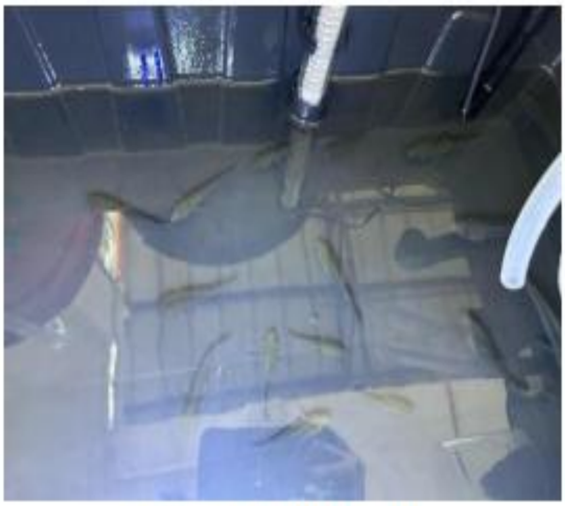


Figure 7 Tilapia Fingerlings

Figure 8 Blynk Application

Figure 5, 6, 7 and 8 shows the whole set-up of the system which includes the Arduino box, Whole Setup, Tilapia Fingerlings and Blynk Application. Recirculating Aquaculture System (RAS) is the system developed to maintain the good quality of life of the Oreochromis Niloticus (tilapia). The Arduino box includes materials and sensors that were used to monitor water quality parameters (pH, temperature, ammonia) and automated feeding. The Blynk Application is used to display the status of the said essential parameters which serve as the basis whether the ammonia, pH and temperature are maintaining its standard requirement.

Table 8: Overall Mean for Characteristics in 25010 Evaluation

Criteria	Criteria	Interpretation
Functional Suitability	3.72	Excellent
Reliability	3.67	Excellent
Interaction Capability	3.74	Excellent
Performance Efficiency	3.69	Excellent

The table shows the IoT-enabled water tank monitoring system achieved satisfaction in different categories. Using a 4-point Likert scale, with a score of 3.72 for functional suitability, 3.67 for reliability, 3.74 for Interaction Capability, and 3.69 for performance efficiency. The system demonstrated its effectiveness in order to meet users' standards and is interpreted as Excellent. The overall mean of 3.71 shows that the system has excellent satisfaction, asserting its functional suitability, performance suitability, usability, and reliability. This means that the system is successful in achieving its objectives.

Figure 9: Age of Respondents

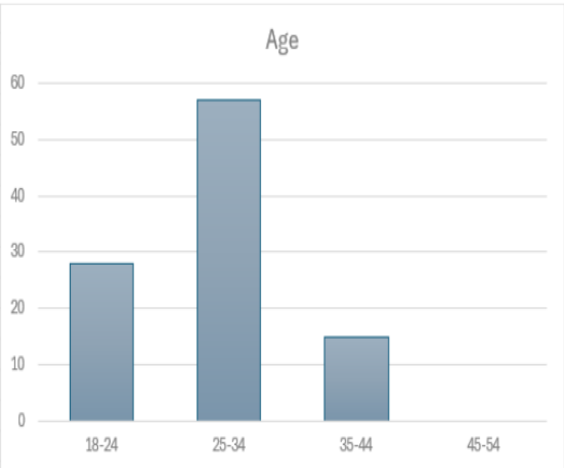
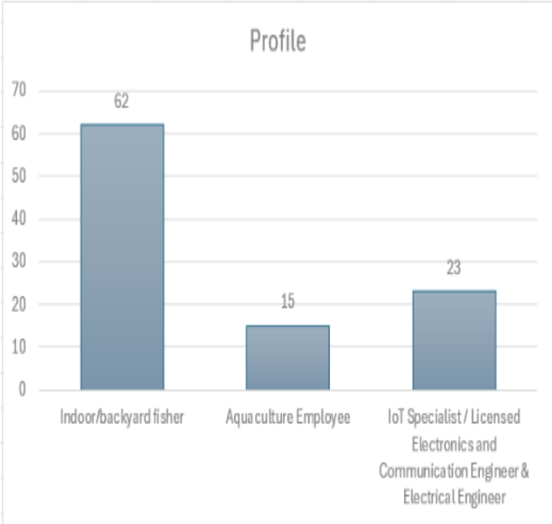


Figure 9 shows the range of age of the respondents. Age is one of the important factors in the demographic profile as respondents might have more experience and knowledge in aquaculture, which can give a lot of perception regarding practicality and usability of the IoT system

Figure 10: Profile of Respondents



The chart illustrates the profile of the respondents, with sixty-two (64) respondents for indoor/backyard fisher. Meanwhile, twenty-three (23) are either IoT Specialist / Licensed Electronics and Communication Engineer & Electrical Engineer, and 15 are Aquaculture employees. Choosing the perfect respondents for this survey is important as they can give insights about challenges and benefits of using IoT systems in smaller-scale and home-based setups. Likewise, an IoT Specialist / Licensed Electronics and Communication Engineer & Electrical Engineer is essential for evaluating the system's overall functionality. While the Aquaculture Employees can provide rulemaking perspectives.

Conclusion

The aquaculture system uses three interconnected tanks to raise tilapia efficiently. The setup includes sensors to monitor water temperature and pH levels, along with a system to detect ammonia. Water flows through a filtration process: first removing solid waste, then through bacteria-rich filters that break down harmful compounds, and finally into a clean water tank.

An automated feeder, controlled by a timer, provides food at set intervals to prevent over or underfeeding. The system connects to weather monitoring services to track environmental conditions.

Farmers can check water quality and system status remotely through a mobile app, helping maintain ideal conditions for fish health and growth. This practical design promotes sustainable fish farming while reducing labor and resource costs.

Recommendations

By enhancing the tilapia tank's performance, we recommend upgrading the temperature control system using smart automation. This would manage heating and cooling equipment more precisely based on sensor readings. While we currently use manual testing kits for nitrate levels, installing specialized electronic sensors would provide continuous monitoring and allow faster responses to water quality changes.

The weather alert system helps farmers prepare for environmental changes. Adding real-time weather forecasts to the mobile monitoring app would give users more time to adjust tank conditions before weather events affect water quality.

These improvements would help maintain optimal conditions for tilapia growth while reducing the need for constant manual monitoring.

Conflict of Interest

There is no conflict of interest between the authors in this manuscript.

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