Experimental IoT System to Maintain Water Quality in Catfish Pond

Adani Bimasakti Wibisono, Riyanto Jayadi

Information Systems Management Department-BINUS Graduate Program-Master of Information Systems Management,
Bina Nusantara University, Jakarta, 11480, Indonesia

Abstract—This study investigates the challenges in catfish aquaculture, mainly focusing on water quality, which is crucial for successful fish farming. This research aims to implement Internet of Things (IoT) technology with sensors connected to a microcontroller to monitor and control critical parameters such as temperature, pH, and oxygen levels in catfish ponds. Utilizing NodeMCU and specific sensors, the system provides real-time monitoring, enabling early detection of environmental changes that could impact fish health. The research findings indicate IoT technology in catfish aquaculture can enhance fish health and growth. Real-time monitoring reduces the risk of diseases by providing an optimal environment for the fish. Additionally, automatic control using fuzzy logic, which can adjust email notifications automatically, and actuators such as water pumps and pH regulators that work automatically based on conditions help maintain the stability of water quality. A comparison between conventional and IoT-based farming reveals that the IoT system can reduce catfish mortality by optimizing feed distribution and regulating pH levels. Thus, this study positively contributes to developing more efficient, sustainable and healthy catfish aquaculture methods through implementing IoT technology.

Keywords—*IoT; aquaculture; catfish cultivation; monitoring; controlling*

I. INTRODUCTION

Catfish is one of the favorite fresh fish foods for the people of Indonesia [1]. Not only in Indonesia, but freshwater fish farming is also becoming increasingly popular among urban and suburban residents in sub-Saharan Africa and Asia [2]. The development of freshwater fish farming is very positive in Indonesia because it coincides with the increase in population, which is also increasing every year. If the population of Indonesia does not match the growth in the amount of food production, then the need for and availability of food will not be met [3]. Freshwater farming these days is accessible because it can be done even in places and allows people who do not work as growers. Although easy, freshwater fish farming is highly dependent on the water quality. The main problem that freshwater fish farmers face is maintaining the water quality, as this is the main factor that can kill the fish being farmed [4]. Because optimal fish farming is highly dependent on the water's physical, chemical, and biological qualities [4], [5], some of the variables that determine the quality of water in freshwater fish farming are temperature, turbidity, carbon dioxide, pH, alkalinity, ammonia, nitrite, and nitrate.

Water quality directly affects the feed efficiency, growth rate and overall health of the fish [6]. For catfish, the most critical variables are the pH and temperature of the water. Catfish can live in extreme temperatures because the water temperature varies between 25°C to 34°C; catfish are in an excellent environment to grow [3]. The pH level in good catfish water is 7-9, with a pH value that does not experience unstable changes [7]. On top of that, the height or volume of the water is also essential because it affects the temperature and oxygen levels in the fishpond being grown [7].

Therefore, catfish farmers must perform water treatments by monitoring pH, temperature, and the water level. Today, catfish farmers use ubiquitous commercial tools such as pH meters and thermometers. Conventional checks are not adequate because the checks cannot be performed continuously. With technological advances, billions of objects can perceive, communicate, and share information through a systematic network [8]. With the mobile-monitored Internet of Things, it can be done anywhere, anytime. The researcher implemented the integration of Arduino, Wi-Fi, ph sensor, temperature sensor, and ultrasonic sensor to create a monitoring system. In addition, the researchers will also integrate the system into three water pumps as actuators to raise the water level, raise the pH, and lower the pH. This system will work automatically if the sensor captures a value not good for the catfish's health. This study also aims to compare conventional systems with systems using IoT. The conventional system will check the water quality twice a week.

In contrast, the IoT system will run automatically. The treatment will be carried out with the same face for variables other than pH, temperature, and height. In this research, we utilize relatively inexpensive hardware components with a total cost of approximately 30 dollars. Our study aims to analyze whether these IoT hardware components can operate efficiently and reliably over approximately 2.5-3 months. Through meticulous experiments, we will identify the performance and durability of these devices in real-world operational conditions. Thus, we want to significantly contribute to the understanding of utilizing cost-effective hardware devices in long-term IoT system implementations.

II. RELATED WORK

This study highlights various approaches and advances in aquaponic monitoring and control systems through several previous studies, as in Table I. Rozie et al. [3] focused on

integrating IoT and fuzzy logic for automation systems in aquaponic cultivation, providing a sophisticated approach to optimize processes.

TABLE I. RELATED WORK

Reference	Parameters	Automatic System	Media	Monitoring Method
Rozie et al. [3]	Temperature, Ammonia, Oxygen, PH, TDS, Water Level, Turbidity	Yes	Wi-Fi	Telegram, Web
Ahmad et al. [9]	Temperature, PH, Tinggi	Yes	LoRa	FRED application
Sukrismon et al. [1]	Temperature, PH, Water Level, Turbidity	No	Wi-Fi	Android application
Billah et al. [4]	Temperature, Oxygen, PH, Water Level	No	Wi-Fi	Android application
Ghulam Imaduddin et al. [10]	Temperature, PH, Water Level	Yes	Wi-Fi	Website
Salih et al. [11]	Temperature, PH	No	Bluetooth	Android application
Zougmore et al. [12]	Oxygen, PH	No	LoRa	Website
Tamim et al. [13]	Temperature, PH	No	Wi-Fi	Android application
Proposed system	Temperature, PH, Water Level	Yes	Wi-Fi	Website

Ahmad et al. [9] contributed by developing a comprehensive monitoring system integrated with data analysis applications, explicitly targeting detecting fishpond anomalies. Sukrismon et al. [1] addressed water quality monitoring for catfish farming through an Android application, emphasizing the importance of real-time data for effective management. Billah et al. [4] worked on a real-time water quality system dedicated to monitoring freshwater fish farming in ponds, enhancing the understanding of environmental conditions crucial for fish health.

Ghulam Imaduddin et al. [10] conducted tests on an IoT system for catfish farming, employing conventional measurement tools to validate the effectiveness of their implementation. Salih et al. [11] designed a Bluetooth-enabled IoT system to monitor water quality in fishponds, adding a wireless connectivity dimension to the monitoring infrastructure.

Zougmore et al. [12] implemented an IoT system with SMS, Twitter, and Facebook notification features, contributing to the accessibility and immediacy of information for fish farmers. Lastly, Tamim et al. [13] explored the integration of IoT in the fish farming industry, employing MIT Apps and Google Firebase for monitoring, showcasing the versatility of technological platforms in aquaculture management. Together, these studies showcase the dynamic landscape of technological interventions to enhance efficiency and sustainability in aquaponics and fish farming practice.

III. RESEARCH METHOD

This research focuses on developing an intelligent solution to oversee and regulate water conditions in catfish farming through aquaculture technology. The core idea of the resultant device involves the integration of multiple sensors and actuators with a microcontroller. This microcontroller is seamlessly linked to Wi-Fi and connected to a cloud-based information platform. The gathered data will be securely stored within a cloud database and presented through a website interface. This interface serves the purpose of visualizing the data and facilitating comprehensive analysis for research requirements. The system's control parameters are adjusted automatically by pre-programmed logical algorithms. The design system that has been created is shown in the Fig. 1.
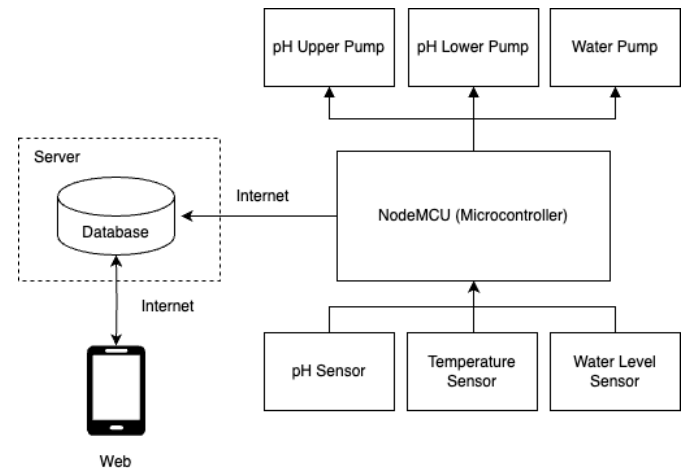

Fig. 1. System design.

The tools employed for this project encompass a set of essential components. Firstly, PhpMyAdmin serves as a pivotal tool, facilitating the management of the project's database efficiently. Secondly, Laravel, a robust framework, plays a vital role in building the project's web-based interface, ensuring seamless user interaction. Thirdly, Arduino IDE is instrumental in programming and configuring the microcontroller's functionalities, allowing it to communicate effectively with the various sensors and actuators. Lastly, MySQL is utilized as the database management system, working in tandem with the other tools to ensure efficient data storage and retrieval processes. The amalgamation of these tools forms a cohesive and comprehensive system for the intelligent control and monitoring of water quality in catfish farming.

As in Fig. 2, this design connects components such as sensors, microcontrollers and electronic components needed to build a series of systems. This hardware design focuses on the microcontroller because the microcontroller is a device responsible for controlling and automatically reading data from connected devices according to the actions taken by the user. The microcontroller used is NodeMCU 1.0, which has Wi-Fi support, which allows the device to connect to a wireless network, making it an ideal choice for this research. Apart from that, the components that must be connected to the NodeMCU include:
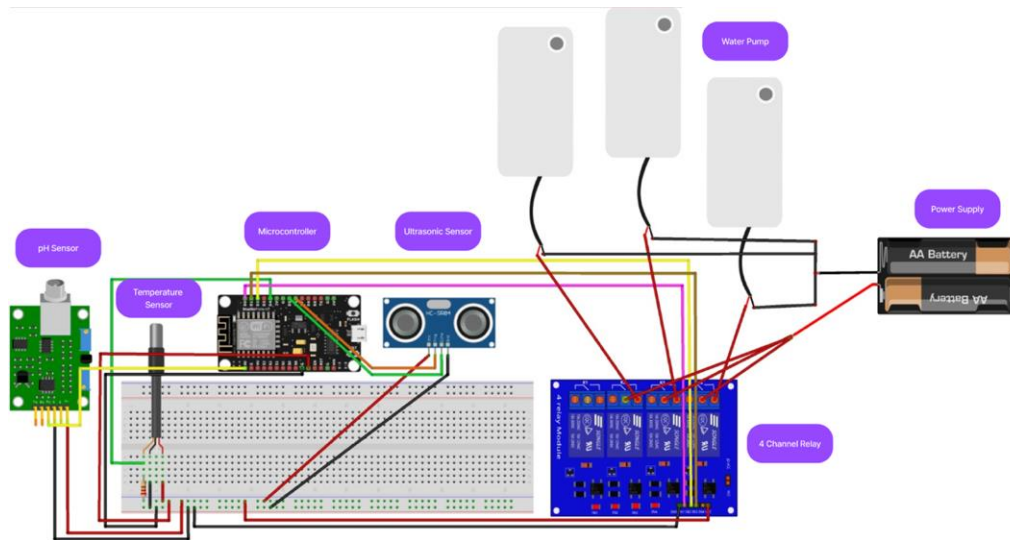
Fig. 2.   Hardware design.

1) PH Sensor (SEN0169): The pH sensor is used by dipping it in the water of the catfish pond that is being cultivated. The pH sensor will send the captured pH value to the microcontroller. The pH sensor used in this research is the same as the pH meter commonly used today: dipping it into the water to be tested.

2) Temperature Sensor (DS18B20): The temperature sensor used in this research is waterproof, so it is used by immersing it in the water of the catfish pond that is being cultivated. This temperature sensor will send the captured pH value to the microcontroller. The way to use this sensor is to dip it into the water you want to check.

3) Ultrasonic Sensor: This sensor is a distance-measuring sensor. This sensor will be placed above the pool and facing the water surface to measure the water level. The closer the water is to this sensor, the higher the water in the pool, and vice versa.

4) Relay Module 4 Channel: This relay works like a switch to turn on and off the electrical components connected to it. This research will connect three electric pumps to 3 channels on this relay. This relay works according to the microcontroller readings. If the microcontroller gets a value of 1 on relay one from the database, then relay one will turn on, and so will the other channels.

IV. Results and Discussion

In this section, we present the results of the pH sensor calibration experiment conducted to support the success of the IoT system in catfish farming. Additionally, we will explain the development of the website and database created as integral parts of this project. Furthermore, we will evaluate the outcomes of these experiments to understand how this system has positively contributed to enhancing efficiency and productivity in catfish farming.

A. Fuzzy Rule

The proposed model uses several fuzzy inference rules which are used to determine the conditions when the water pumps used must turn on. The fuzzy rule created in the fuzzy model considers the characteristics of catfish which require water quality with the pH level in water that is good for catfish is $7 – 9$ [10], the water temperature is 25°C-30°C and does not experience unstable temperature changes [10], and the water level in the first month is 20 cm, in the second month 40 cm, and the third month 80 cm. Fuzzy rules are created so that catfish can grow well and water quality can be maximized according to the needs of catfish, thereby increasing cultivation. The fuzzy rules used for the entire system such as for reminder notifications and the three pumps used in this research are as shown in the Table II.

TABLE II.   Fuzzy Rule

Action	Conditions
pH value < 7	The upper pH pump turns on and gives a notification alert via email
pH value > 9	The pH lower pump turns on and gives a notification alert via email
Water height in the 1st month < 10cm	The water pump turns on and gives a notification alert via email
Water height in the 2nd month < 25cm	The water pump turns on and gives a notification alert via email
Water height in the 3rd month < 45cm	The water pump turns on and gives a notification alert via email
Temperature < 25	Provides a notification alert via email
Temperature > 30	Provides a notification alert via email

B. IoT Device

The image in Fig. 3 represents the hardware implementation within a bucket intended for catfish farming. The image shows that the ultrasonic sensor component is placed on the bucket lid facing the bottom to ensure accurate water level measurement. The microcontroller is placed inside the bucket lid of a housing to prevent direct contact with water.

Like the microcontroller, modules for sensors and relays are placed inside a box to avoid direct contact with water, minimizing the risk of electrical short circuits. Meanwhile, the three water pumps are positioned within three separate bottles containing different solutions. Each pump has its designated task, from dispensing regular water to increasing water height, pH upper solution, and pH lower solution. Three water pumps with different solutions in separate bottles allow precise control of various environmental parameters in this catfish farm. This design aims to increase productivity and environmental health for effective catfish cultivation.

C. Web Dashboard

In this project, a dashboard has been developed to monitor and control IoT in devices Fig. 4, which can be accessed via the website. This dashboard uses PHP and Bootstrap programming languages for a responsive and aesthetic user interface. The primary function of this dashboard is to monitor and control IoT devices connected to the system. Through this dashboard, users can easily visualize data collected by IoT sensors, such as pH, temperature, and water level. This data, including graphs and tables, is presented in an informative and easy-to-understand format. The dashboard also displays the ON/OFF switch status of electronic devices controlled by relays.

This dashboard page also has a function for automatically sending emails based on the established logic. This functionality proves valuable for promptly notifying significant changes in the measured environmental conditions, enabling responsive actions to maintain the stability and quality of the sensor-monitored environment. The emails are directed to pre-registered email addresses using SMTP through phpMyAdmin, and a timer is implemented to prevent email spam. An example of the application of this email function can be observed in Fig. 5.

D. Experiments and Testing Cultivation Result

After the tool has been successfully created, the final step is to compare cultivation using IoT and conventional cultivation. Both cultivations are carried out as possible. Both cultivations will be carried out on the same media, seeds from the same supplier, the same type of food, and in the exact location. Cultivation is carried out using catfish seeds 7-9 cm in size. For conventional catfish cultivation, temperature, pH, and height parameters will be checked, and these parameters will be measured once every 1-2 days. The weight, height and number of remaining fish will be checked every three weeks.

Cultivation was compared for 15 weeks, and cultivation results were recorded every three weeks to monitor the cultivation process. The results of the comparison of catfish cultivation can be seen in Table III below.
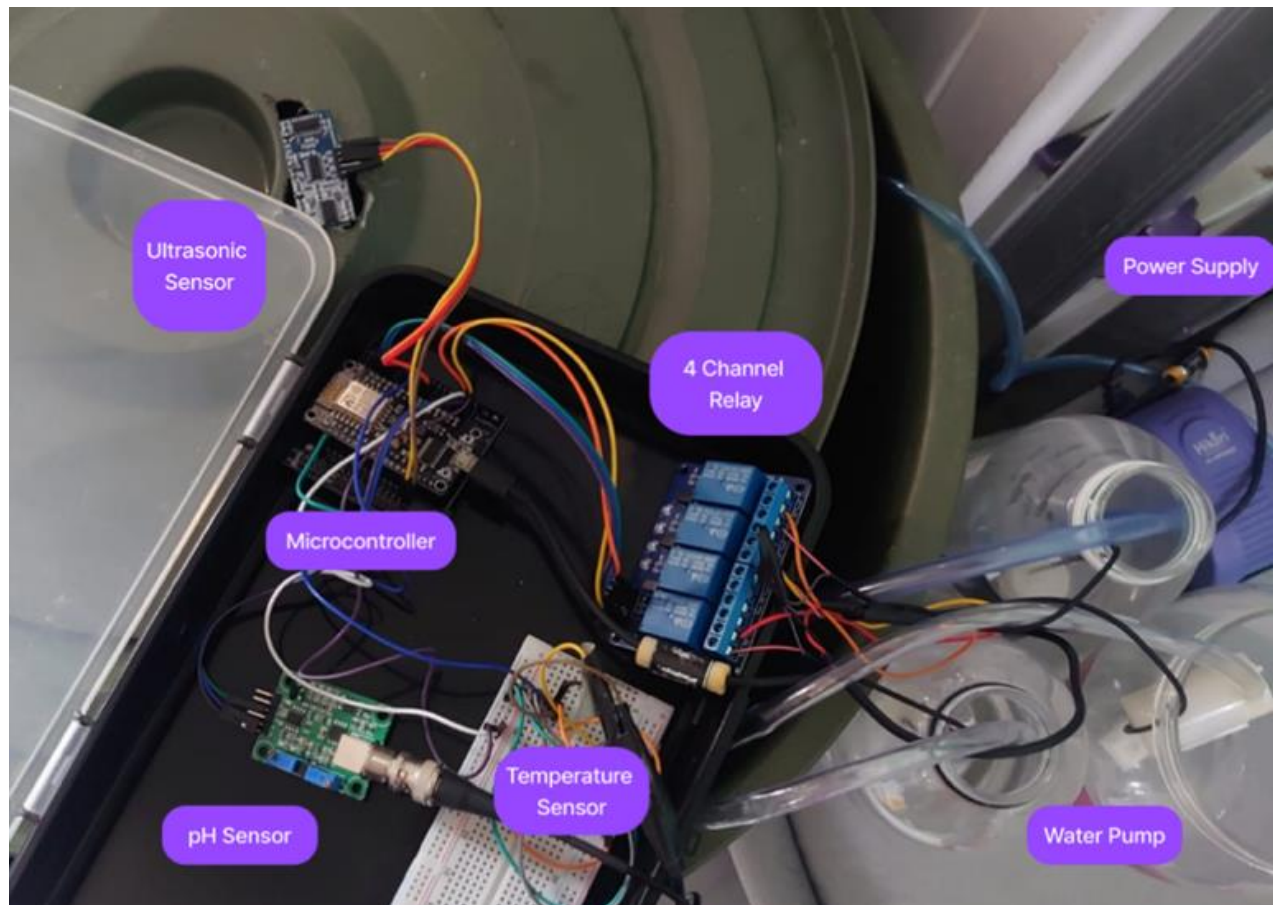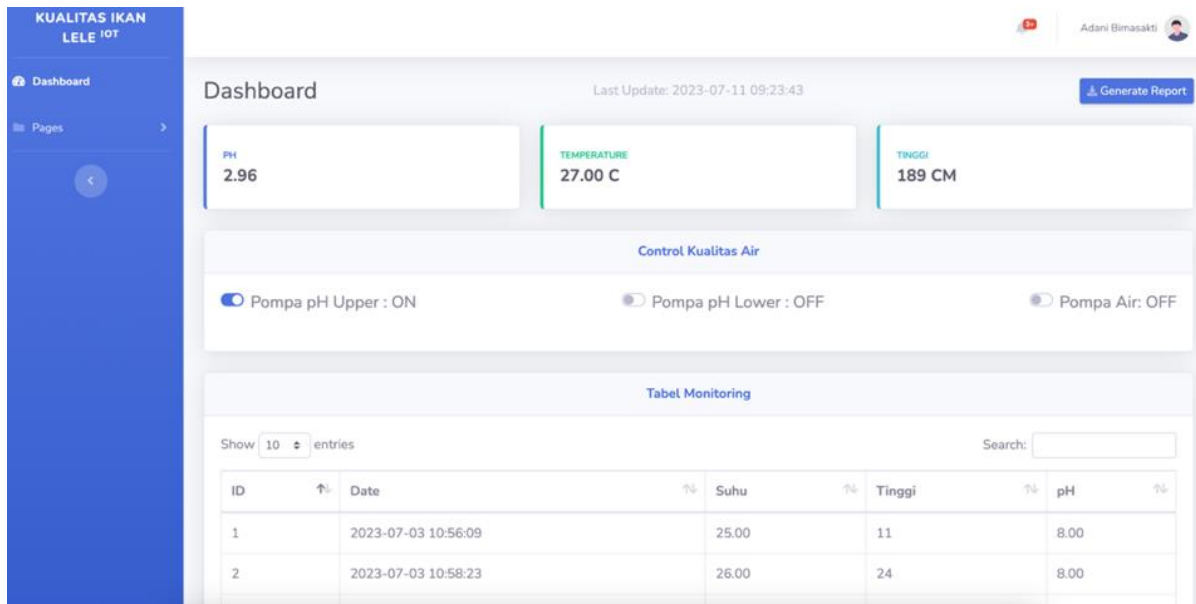

Fig. 3. IoT device.
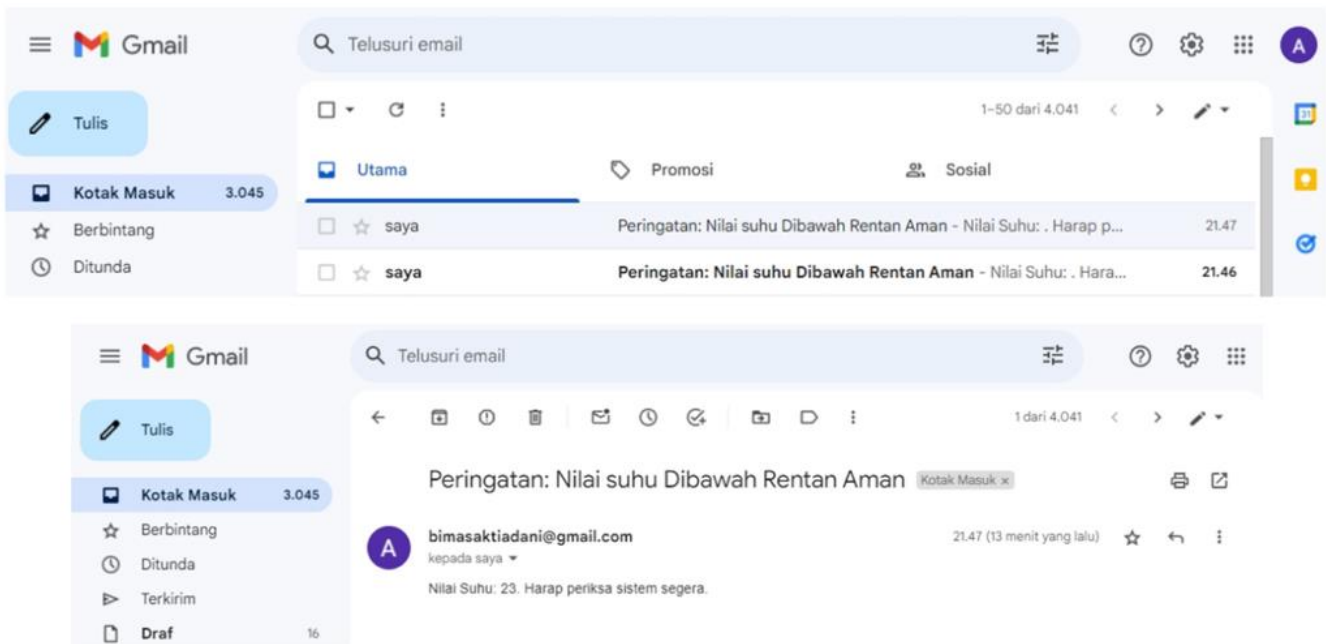
Fig. 4. Web Dashboard.

Fig. 5. Automation email.

TABLE III. CULTIVATION RESULT

Time	Conventional Cultivation			Cultivation using IoT		
	Weight	Height	Total Fish	Weight	Height	Total Fish
Early Seeds	3-6 gr	7 – 9 cm	25	3-6 gr	7 – 9 cm	25
Week 3	8,34 gr	10,7 cm	17	8,57 gr	11,5 cm	22
Week 6	15,34 gr	13,5 cm	7	16,57 gr	12,5 cm	16
Week 9	26,91 gr	16, 0 cm	4	28,34 gr	17,5 cm	16
Week 12	68,88 gr	21,4 cm	3	70,95 gr	22,2 cm	16

Internet of Things (IoT) technology in fish cultivation has profoundly transformed fish welfare. Apart from facilitating rapid growth and increasing numbers, IoT-based farming creates an optimal environment for fish. One crucial aspect is ensuring the health of the fish itself. In conventional farming, health problems often manifest as white spots on the fish's skin, signaling disease or stress that can compromise the fish's health and quality. IoT technology allows for close monitoring of the cultivation environment, enabling real-time tracking of critical parameters such as temperature, pH, and water quality. This system ensures precise control, promoting faster and healthier fish growth. Maintaining optimal temperature, balanced pH, and good water quality is essential for fish fitness and disease prevention. Early detection of environmental changes, such as declining water quality, allows for prompt preventive action.

Moreover, IoT technology facilitates accurate fish diet and nutrition monitoring, ensuring optimal growth by providing the right amount of feed at the right time. As in conventional methods, failure will regulate pH manually to avoid uneven growth and health issues. For example, overfeeding without pH regulation between weeks three and six resulted in significant fish mortality. This research significantly enhances fish farming efficiency and sustainability. By employing IoT technology for real-time monitoring, farmers can optimize environmental conditions more effectively, thereby increasing productivity and reducing losses due to unfavorable conditions. In conventional cultivation, pH control is not automated, leading to uneven growth and poor health in some fish. For instance, overfeeding during the third to sixth week caused the death of 10 catfish in non-IoT systems, while IoT-based pH regulation resulted in only five catfish deaths.

Additionally, IoT technology enables accurate monitoring of fish diet and nutrition, providing the right amount of feed at appropriate intervals. Excessive feeding can increase the pH of the water because the remaining feed contains amino acids unsuitable for catfish growth. Unlike conventional methods, where pH control is not automated, IoT-based systems ensure uniform growth and better health outcomes for fish populations. As evidenced by the results of conventional cultivation in Fig. 7, many white spots indicate unhealthy fish. It is different from Fig. 6, which is one of the results of cultivation using IoT, which does not have white spots.

Fig. 6. Week-12 IoT cultivation.

Fig. 7. Week-12 Conventional cultivation.

Future research in this area could explore integrating advanced machine learning algorithms with IoT technology to predict and prevent disease outbreaks based on water quality data and feeding intervals. Additionally, studying the long-term impacts of IoT-based agriculture on ecosystem sustainability and biodiversity can provide valuable insights into broader environmental impacts. However, it is essential to acknowledge some limitations of current research. One significant limitation is the potential cost barrier associated with implementing IoT technology in fish farming operations, particularly for small-scale farmers. Additionally, technical challenges such as sensor reliability and connectivity issues in remote agricultural locations must be overcome for widespread adoption. Fish cultivation using IoT technology yields abundant production results and creates a healthy and optimal environment for fish. By minimizing the risk of disease, enhancing growth, and ensuring adequate nutrition, this method represents an innovative way to breed fish efficiently, sustainably, and healthily.

V. CONCLUSION

The findings of this research contribute significantly to new knowledge in aquaculture, particularly in the context of catfish cultivation. The integration of Internet of Things (IoT) technology represents a novel approach to monitoring and controlling water quality in catfish ponds, offering farmers unprecedented levels of access and control. By utilizing IoT devices such as pH sensors, temperature sensors, and ultrasonic sensors, farmers can continuously monitor crucial parameters in real time, regardless of their physical location. Accessing and analyzing data remotely via a web interface enhances convenience and efficiency, enabling prompt action to respond to deviations from optimal conditions.

The research demonstrates that the IoT-based method leads to significantly higher survival rates among catfish than conventional methods. The substantial difference in survival rates (16 fish remaining with IoT-based methods versus three fish remaining with conventional methods) underscores the transformative impact of IoT devices on aquaculture practices. This result highlights the effectiveness of IoT-enabled monitoring and control and suggests that these technologies can revolutionize the industry by improving productivity and profitability.

Furthermore, the research emphasizes the importance of real-time monitoring and precise control in creating optimal conditions for fish growth. By maintaining parameters such as pH and water level within the appropriate limits, IoT systems contribute to the overall health and well-being of the fish, ultimately leading to more significant, healthier harvests. This aspect is crucial for addressing the growing demand for sustainable and efficient food production, aligning with broader societal goals.

In conclusion, the study demonstrates the synergy between accessibility and effectiveness in IoT technology, offering a promising solution to enhance the sustainability and profitability of aquaculture. The results prove that IoT solutions can significantly increase yields while improving overall practices. Future research in this area could explore additional applications of IoT technology in aquaculture, investigate optimal sensor configurations, and assess long-term impacts on ecosystem health and resource management. Additionally, studies could focus on the scalability and affordability of IoT solutions to ensure widespread adoption among catfish farmers and other stakeholders in the aquaculture industry.

REFERENCES

[1] Y. Sukrismon, Aripriharta, N. Hidayatullah, N. Mufti, A. N. Handayani, and G. J. Horng, "Smart Fish Pond for Economic Growing in Catfish Farming," Proceedings - 2019 International Conference on Computer Science, Information Technology, and Electrical Engineering, ICOMITEE 2019, pp. 49–53, Oct. 2019, doi: 10.1109/ICOMITEE.2019.8921233.

[2] C. N. Udanor et al., "An internet of things labelled dataset for aquaponics fish pond water quality monitoring system," Data Brief, vol. 43, p. 108400, Aug. 2022, doi: 10.1016/J.DIB.2022.108400.

[3] F. Rozie, I. Syarif, and M. U. H. Al Rasyid, "Design and implementation of Intelligent Aquaponics Monitoring System based on IoT," IES 2020 - International Electronics Symposium: The Role of Autonomous and Intelligent Systems for Human Life and Comfort, pp. 534–540, Sep. 2020, doi: 10.1109/IES50839.2020.9231928.

[4] M. M. Billah, Z. M. Yusof, K. Kadir, A. M. M. Ali, and I. Ahmad, "Quality Maintenance of Fish Farm: Development of Real-time Water Quality Monitoring System," 2019 IEEE 6th International Conference on Smart Instrumentation, Measurement and Application, ICSIMA 2019, Aug. 2019, doi: 10.1109/ICSIMA47653.2019.9057294.

[5] A. Bhatnagar and P. Devi, "IPA-Under Creative Commons license 3.0 Water quality guidelines for the management of pond fish culture," Int J Environ Sci, vol. 3, no. 6, 2013, doi: 10.6088/ijes.2013030600019.

[6] F. E. Idachaba, J. O. Olowoleni, A. E. Ibhaze, and O. O. Oni, "IoT enabled real-time fishpond management system," World Congress on Engineering and Computer Science 2017, vol. 1, pp. 42–46, 2017.

[7] K. Samaun, . H., and . S., "The Effect of Different Water Levels on the Growth and Survival of Sangkuriang Catfish Seeds at the Gorontalo City Fish Seed Center(Pengaruh Ketinggian Air yang Berbeda terhadap Pertumbuhan dan Kelangsungan Hidup Benih Ikan Lele Sangkuriang di Balai Benih," vol. 3, 2015, [Online]. Available: http://ejurnal.ung.ac.id/index.php/nike/article/view/1299

[8] A. R. Al-Ali, I. A. Zualkernan, M. Rashid, R. Gupta, and M. Alikarar, "A smart home energy management system using IoT and big data analytics approach," IEEE Transactions on Consumer Electronics, vol. 63, no. 4, pp. 426–434, Nov. 2017, doi: 10.1109/TCE.2017.015014.

[9] I. Ahmad, N. I. S. N. Ridzuan, W. N. H. A. W. Hassan, and M. R. R. Maz, "Water quality monitoring using wireless sensor networks," AIP Conf Proc, vol. 2291, Nov. 2020, doi: 10.1063/5.0025040.

[10] Ghulam Imaduddin and Andi Saprizal, "Automation of Monitoring and Setting Solution Acidity and Fish Pond Water Temperature in Catfish Hatcheries (Otomatisasi Monitoring Dan Pengaturan Keasaman Larutan Dan Suhu Air Kolam Ikan Pada Pembenihan Ikan Lele)," Jurnal Sistem Informasi, Teknologi Informatika dan Komputer, vol. 7, no. 2, pp. 28–35, Mar. 2017, doi: 10.24853/JUSTIT.7.2.28-35.

[11] N. A. J. Salih, I. J. Hasan, and N. I. Abdulkhaleq, "Design and implementation of a smart monitoring system for water quality of fish farms," Indonesian Journal of Electrical Engineering and Computer Science, vol. 14, no. 1, pp. 44–50, Apr. 2019, doi: 10.11591/IJEECS.V14.I1.PP44-50.

[12] T. W. Zougmore, S. Malo, F. Kagembega, and A. Togueyini, "Low cost IoT solutions for agricultures fish farmers in Afirca: A case study from Burkina Faso," ICSCC 2018 - 1st International Conference on Smart Cities and Communities, Dec. 2018, doi: 10.1109/SCCIC.2018.8584549.

[13] A. T. Tamim et al., "Development of IoT Based Fish Monitoring System for Aquaculture," Intelligent Automation and Soft Computing, vol. 32, no. 1, pp. 55–71, 2022, doi: 10.32604/IASC.2022.021559.