Journal of Applied Science, Technology & Humanities
Volume 2, Issue 4, September, 2025, Pages 584-594

ISSN 3032-5765
DOI: https://doi.org/10.62535/wfkftp07

ESP32-Based Ornamental Fish Feeding Automation System with Sensor Utilisation and Fuzzy Logic Implementation

Muhammad Hafidz Fachrezi[1]
[1]Technology and Management of Applied Aquaculture Hatchery Study Program, College of Vocational Studies, IPB University
E-mail: mhafidzfachrezi@apps.ipb.ac.id

Darrell Juro Rudy Pradana[1], **Aulia Najiha Putri**[1], **Aisyah Rahmadiniyah**[1], **Dhaifan Rahadhian**[1], **Shalfa Hafizh Sulaiman**[1], **Atikah Safitri Siregar**[1], **Ahmad Akhdan Nur Ilyas**[1], **Berlinton Pandu Ajiguna**[1], **Fateh Nurabdillah Gunawan**[1], **Aqila Trisna Lutfi Nafisah**[1], **Az Zahra Khadijah**[1], **Panji Satrio Wibowo**[1], **Yassar Ariq Pradian**[1], **Muhammad Faiz Assariy**[2], **Daffa Zulqisthi**[2], **Naufal Auzan Ramadhan**[2]
[1]Technology and Management of Applied Aquaculture Hatchery Study Program, College of Vocational Studies, IPB University
[2]Computer Engineering Technology Study Program, College of Vocational Studies, IPB University
E-mail: darrelljuro@apps.ipb.ac.id

Abstract

The efficiency of ornamental fish feeding significantly influences fish health and water quality in aquaculture systems. Manual feeding often results in overfeeding or underfeeding, leading to water pollution and reduced fish productivity. This study aims to design and implement an automated ornamental fish feeding system using the ESP32 microcontroller integrated with temperature, pH, and dissolved oxygen sensors. The system employs Mamdani fuzzy logic to determine feeding quantities based on real-time environmental parameters. Research was conducted at the Aquaculture Production Laboratory and Hardware Laboratory 2, IPB University. The results show that the system is capable of dynamically adjusting feeding amounts, thereby reducing feed waste and maintaining water quality. The fuzzy logic approach allows for adaptive and efficient feeding management, outperforming fixed-timer systems. This automation technology supports sustainable and technology-driven ornamental fish farming.

Keywords: ESP32, fuzzy logic, water quality, automation, fish feeding.

INTRODUCTION

Feeding is an important factor in fish farming because food serves as the main source of energy and nutrients that support the growth and development process of fish (Sitanggang 2024). Good feeding management includes the selection of the type of feed, amount, frequency, time, and method of administration in accordance with the needs of fish and their life stages, so that feed efficiency can increase and feed waste that pollutes the environment can be minimized (Kurniawan 2019). The problem that is often faced by fish farmers is the efficiency of feed utilization that has not been maximized so that it is necessary to feed effectively and efficiently so that the feed given can be utilized properly by fish optimally for growth.

According to Warjono *et al.* (2022), technological progress is currently developing very rapidly, almost all the tools used are automatic. These tools can work quickly, effectively, and efficiently to make human work easier. The existence of an automation tool in various sectors has been proven to be able to increase work efficiency and effectiveness (Permana *et al.* 2023). Likewise, the application of automation technology for fish feeding can reduce the workload of manual feeders. Feeding can also be more scheduled and accurate, and eliminate the worry of dead fish due to not being able to feed when traveling far.

The use of automation technology in microcontroller-based feeding such as ESP32 has begun to be applied to optimise the time and amount of feed given to fish. These systems are generally equipped with water quality sensors, enabling feeding adjustments based on actual environmental conditions. This technology is considered capable of suppressing the amount of excess feed, reducing feed residue in water, and maintaining environmental parameters within optimal limits (Samara *et al.*

2022). The ESP32 is a microcontroller introduced by Espressif System and is the successor to the ESP8266 microcontroller (Santoso and Sitohang 2024).

The use of fuzzy logic in an ESP32-based ornamental fish feeding automation system is an innovative approach to address the challenges of real-time feed and water quality management. The use of fuzzy logic in similar systems has shown positive results in a number of studies. For example, the study by Nagothu et al. (2025) utilised a fuzzy logic approach alongside IoT technology to enable immediate and continuous monitoring and adjustment of water quality conditions, improving fish productivity and health. A similar system was also implemented by Bokingkito (2017), who designed an IoT-based water quality monitoring system with fuzzy logic for real-time water quality assessment. In the context of feeding, fuzzy logic is used to determine the timing and amount of feed based on environmental conditions. For example, the system developed by Rathy (2024) uses temperature and pH sensors to automatically control feeding, ensuring fish receive feed according to their needs and environmental conditions.

The development technology and microcontrollers such as the ESP32 has opened up opportunities to create intelligent feeding automation systems. In addition, fuzzy logic can be implemented to overcome uncertainty in sensor data and provide more adaptive and accurate feeding decisions (Indrawati *et al*. 2024). The purpose of this research is to design and implement an ESP32-based ornamental fish feeding automation system, which uses water quality sensors as inputs and fuzzy logic as a decision-making method. Hopefully, this system can improve feeding efficiency, maintain water quality, and reduce dependence on manual intervention. It also supports more sustainable and technology-based ornamental fish farming, as suggested by previous research (Raihan, 2022; Jadhav *et al*. 2020).

METHODS

This research activity was conducted at the Aquaculture Production Laboratory and Hardware Laboratory 2 of the Vocational School of IPB University, Bogor, West Java, from April to May 2025. The research was designed within a laboratory setting with controlled environmental conditions to ensure system stability. An automatic feeding system was developed based on the ESP32 microcontroller as the main control unit. The selection of ESP32 was based on its ability to process data quickly, support wireless communication via Wi-Fi and Bluetooth, and have a dual-core 240 MHz processor and 520 KB memory, which is highly suitable for Internet of Things (IoT).

Additional devices used include push buttons and a keypad for user input, a DS1307 RTC module as a time recorder that remains active with backup battery support, a servo motor as a mechanical drive to regulate the opening of the feed container, and a 16×2 LCD to display real-time system information. The entire system was designed and tested using the Wokwi digital simulator, while fuzzy logic implementation was carried out using MATLAB software to generate control decisions based on environmental parameters.

Water quality parameters are used as system inputs, including temperature, pH, and dissolved oxygen. The DS18B20 sensor is used for temperature measurement, the pH-4502C sensor for detecting acidity levels, and the dissolved oxygen (DO) sensor for monitoring oxygen content in the water. These three sensors were selected because they are accurate, easy to integrate with the ESP32, and relevant for monitoring water quality in aquaculture systems. Data is collected automatically by the ESP32 with a reading interval of every five minutes.

Decision-making in this system uses the Mamdani fuzzy logic approach. Each input variable is classified into three linguistic categories (low, medium, high), then processed through IF-THEN rules formulated based on optimal water quality conditions for fish farming. The results of the process are then defuzzified using the centroid method to produce an output in the form of feed quantity, which is then converted into servo motor rotation movement. The obtained data are analysed descriptively and quantitatively, evaluating the relationship between environmental parameter values and system output results. The analysis is conducted using MATLAB and Microsoft Excel software to visualise the system's response to environmental dynamics.

This study has several limitations, as testing was only conducted on a laboratory scale, and the water quality parameters used did not include other substances such as ammonia or nitrite. All research procedures prioritised fish welfare principles, including optimal feed regulation to prevent stress and water quality degradation. No physical manipulation of the fish was performed that could disrupt their biological activities. This methodology aims to produce an automated feeding system capable of adapting to environmental conditions in real-time. The integration of water quality sensors and fuzzy logic is expected to improve feed utilisation efficiency, reduce waste, and support a more sustainable fish farming system.

RESULTS AND DISCUSSION

The results of determining the input fuzzy set can be seen in Figure 1, 2, and 3, as follows:

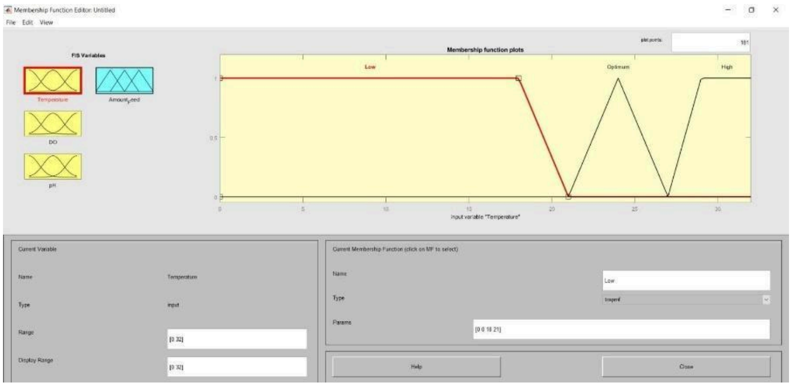

Figure 1. Input fuzzy of temperature

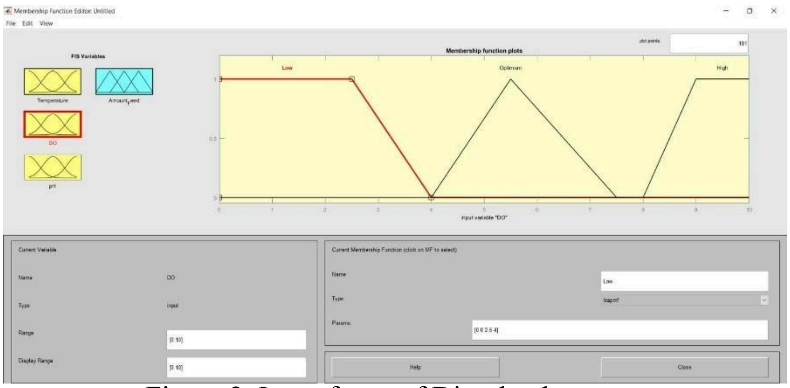

Figure 2. Input fuzzy of Dissolved oxygen

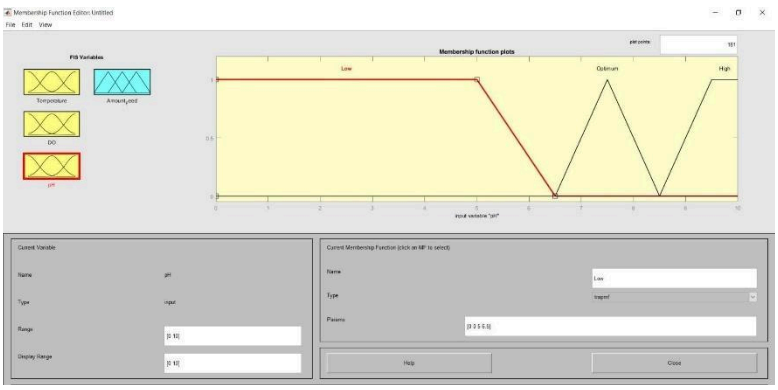

Figure 3. Input fuzzy of pH

For more details, the input fuzzy set can be seen in Table 1.

Table 1. Input fuzzy set

Input	Function	Range
Temperature	Low	0−21
	Optimum	22−27
	High	27−32
Dissolved oxygen	Low	0−4
	Optimum	4−7,5
	High	8−10
pH	Low	0−6,5
	Optimum	6,5−8,5
	High	8,5−10

Table 1 shows the fuzzy set classification for each input variable used in the automatic feeding system. The input variables include temperature, dissolved oxygen (DO), and pH, each of which is divided into three membership functions, namely Low, Optimum, and High. Each membership function has a certain range of values that are adjusted to the optimal conditions for the life of aquatic organisms. This classification is used to help the system determine the appropriate amount of feed based on sensor data in real-time.

The application of several inputs and functions by forming fuzzy rules using IF and THEN, fuzzy logic rules are obtained as follows:

Figure 4. Rules Viewer of Fuzzy Set

- If Temperature is low and DO is low and pH is low then Amount Feed is very low.
- If Temperature is low and DO is optimum and pH is low then Amount Feed is very low
- If Temperature is low and DO is high and pH is low then Amount Feed is low.
- If Temperature is low and DO is low and pH is optimum then Amount Feed is low.
- If Temperature is low and DO is optimum and pH is optimum then Amount Feed is low.
- If Temperature is low and DO is high and pH is optimum then Amount Feed is medium.
- If Temperature is optimum and DO is low and pH is low then Amount Feed is low.
- If Temperature is optimum and DO is optimum and pH is low then Amount Feed is medium.
- If Temperature is optimum and DO is high and pH is low then Amount Feed is medium.
- If Temperature is optimum and DO is low and pH is optimum then Amount Feed is medium.
- If Temperature is optimum and DO is optimum and pH is optimum then Amount Feed is medium.
- If Temperature is optimum and DO is high and pH is optimum then Amount Feed is high.
- If Temperature is optimum and DO is low and pH is high then Amount Feed is medium.
- If Temperature is optimum and DO is optimum and pH is high then Amount Feed is high.

- If Temperature is optimum and DO is high and pH is high then Amount Feed is high.
- If Temperature is high and DO is low and pH is low then Amount Feed is medium.
- If Temperature is high and DO is optimum and pH is low then Amount Feed is medium.
- If Temperature is high and DO is high and pH is low then Amount Feed is high.
- If Temperature is high and DO is low and pH is optimum then Amount Feed is high.
- If Temperature is high and DO is optimum and pH is optimum then Amount Feed is high.
- If Temperature is high and DO is high and pH is optimum then Amount Feed is high.
- If Temperature is high and DO is low and pH is high then Amount Feed is high.
- If Temperature is high and DO is optimum and pH is low then Amount Feed is very high.
- If Temperature is high and DO is high and pH is high then Amount Feed is very high.
- If Temperature is low and DO is optimum and pH is high then Amount Feed is medium.
- If Temperature is high and DO is optimum and pH is low then Amount Feed is medium.
- If Temperature is high and DO is high and pH is optimum then Amount Feed is high.

The output variable of fuzzy rules can be seen in Figure 5.

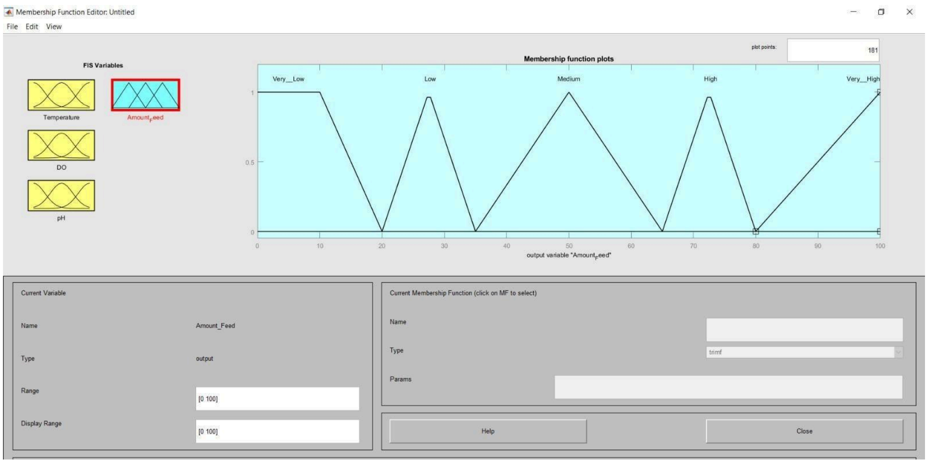

Figure 5. Output set Fuzzy of Amount Feed

Table 2. Output set fuzzy

Output	Function	Range (g)
Amount of Feed	Very low	0−20
	Low	20−35
	Medium	35−65
	High	65−80
	Very high	80−100

This table shows the Amount of Feed categories divided into five fuzzy membership functions, each with a range of values (in grams). This division is used to determine the feeding rate based on a fuzzy logic system, which is useful in automated decision-making, for example in feeding control systems.

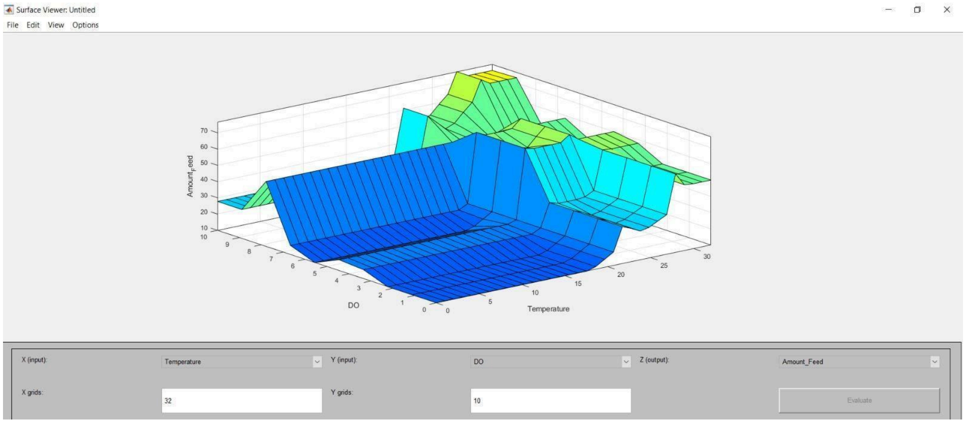

Figure 6. Surface display of Temperature and DO

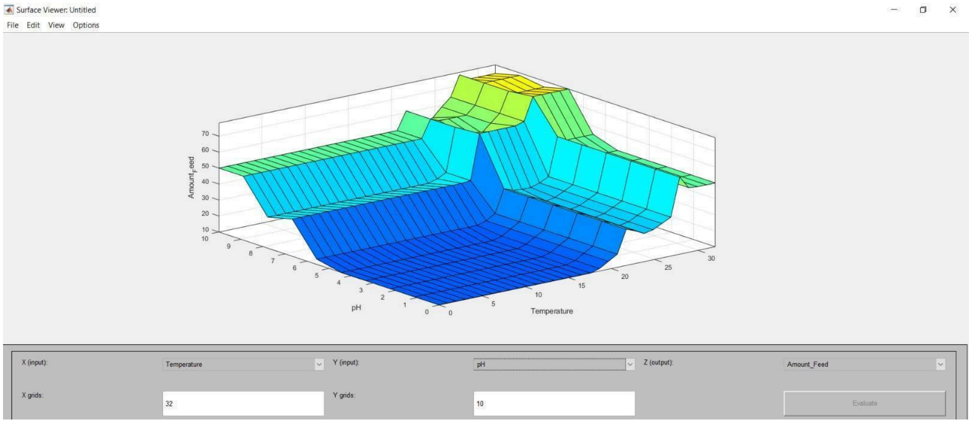

Figure 7. Surface display of Temperature and pH

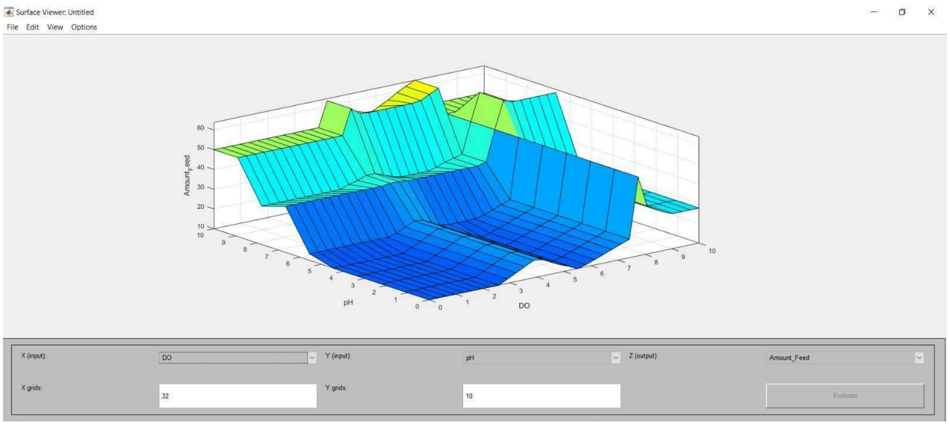

Figure 8. Surface display of DO and pH

Water quality plays a very important role in the success of ornamental fish farming, especially in terms of feeding efficiency and fish growth. Water quality parameters such as temperature, pH, and dissolved oxygen (DO) directly affect appetite, metabolism, and feed conversion in ornamental fish. Keeping the water temperature at an ideal level is essential to support the metabolic activities of the fish. For example, temperatures that are too low can reduce fish appetite, while temperatures that are too high can cause stress and increase oxygen demand. Research by Irawan *et al*. (2019) showed that water temperature ranging from 26-28°C is the optimal range for seluang fish growth, with higher or lower temperatures disrupting metabolic processes and feed efficiency. Water pH also affects feed efficiency. pH that is too low or too high can cause stress in fish and disrupt the digestive process.

According to research by Siregar *et al*. (2017), a stable water pH in the range of 6.5-8.0 is important for maintaining fish health and feed utilisation efficiency.

Based on the figure displayed, it shows the use of a fuzzy logic system to assess water quality through the parameters of temperature, dissolved oxygen (DO), and pH. This fuzzy method is very relevant in aquaculture because aquatic environmental conditions are often dynamic and uncertain. According to Kristiantya *et al*. (2022), fuzzy logic is effective in integrating various water quality parameters to determine feeding decisions automatically. fuzzy input on the water temperature parameter is categorised into several levels (low, medium, high). Optimal water temperature is very important for fish metabolism. If the temperature is too low or too high, the fish's appetite will decrease (Ratnasari 2019).

Manual feeding of ornamental fish often faces challenges such as schedule irregularities, overfeeding, and underfeeding, which can negatively affect fish health and aquarium water quality. To overcome these problems, this research develops an ESP32 microcontroller-based ornamental fish feeding automation system, equipped with environmental sensors and fuzzy logic implementation for adaptive decision-making. The ESP32 was chosen as the control centre of the system due to its data processing capabilities, Wi-Fi connectivity, and efficient power consumption (Widyati *et al*. 2025).

Advances in electronics technology in fisheries have resulted in various devices available on the market. However, automatic fish feeding devices on the market generally have not been able to adjust the amount of feed to the specific needs of fish. So, the solution to overcome the existing problem is to develop an automatic fish feeding device by collaborating technology with Fuzzy Logic Controller (FLC) to automatically feed fish according to fish needs based on pond water quality which includes parameters of temperature and pH (Ramadani *et al*. 2021). The three parameters in the form of temperature, pH and dissolved oxygen measured can represent the level of water quality, combining the Fuzzy Logic Controller method can provide effectiveness in feeding, where this technology can regulate feed automatically and according to needs (Sobri *et al*. 2021).

Fish mortality due to pond pollution caused by excess uneaten feed is a common problem in fish farming. The uneaten feed settles to the bottom of the pond and decomposes, which is the main cause of many complex problems. These include reduced water quality, increased turbidity, low oxygen levels, uncontrolled algae growth, and high levels of ammonia and nitrate that can cause fish poisoning. These conditions make fish susceptible to disease, resulting in many dying before harvest. In addition, poor water quality, such as temperature, pH, and DO that do not meet the needs of fish, can reduce fish appetite, worsen their health conditions, and inhibit growth (Hamid *et al*. 2020). Over time, technology also has a major impact on the progress of the fisheries sector, especially technology in the field of electronics, where electronics plays a role in the manufacture of sophisticated equipment that can work automatically with a high level of precision, efficiency, and quality results in the fisheries sector (Nurhadi *et al*. 2020); Pratama 2023; Somantri *et al*. 2023; Sulistiani *et al*. 2023).

Inefficient feeding will affect the accumulation of residual feed and fish excretion, which can result in a decrease in the quality of the fish pond, which can indirectly affect the productivity of the fish aquarium. When the water temperature does not match the optimal temperature for fish to live, the fish appetite will decrease. The optimal water temperature for freshwater fish is 25−28 °C, while the pH value (>8) will increase the ammonia content in the water and cause the fish to have no appetite, while the appropriate water pH is between 6−8. For this reason, setting the dose of fish feed is very necessary so that the dose of fish feed given is in accordance with the level of fish appetite. One way or method to make the feed dose in accordance with the level of fish appetite is to use the fuzzy method to determine how much fish feed should be given (Hendrawati *et al*. 2022).

The results of this study are in line with research conducted by Maryam (2023) who designed an automatic feeding device for tilapia as well as temperature and pH monitoring using the Telegram application. However, there are differences in the approach to the decision-making system. Maryam (2023) set a fixed feeding time, namely at 08.00 and 17.00, without considering the actual condition of the pond environment. In this study, a Mamdani fuzzy logic approach is used which allows the system to feed automatically by adjusting the parameter values of temperature, pH, and dissolved oxygen in real-time. This makes feeding more precise and efficient, while maintaining stable water quality. This approach is proven to be able to reduce the potential for overfeeding that can reduce water quality, as explained by Kurniawan (2019) that feed efficiency is directly proportional to the health of the aquaculture environment.

The implementation of fuzzy logic in this system allows adjustments to the amount of feed based on the environmental conditions detected by the sensors. For example, if the water temperature is within the optimal range and the light intensity indicates morning time, then the system will provide a larger amount of feed. Conversely, if the temperature is too low or high, and the light intensity indicates night time, then the amount of feed will be reduced or not given at all. This approach has proven effective in previous studies, such as that conducted by Syah *et al*. (2020), who developed an automatic feeding system with temperature and pH control using fuzzy logic in an aquarium. A similar implementation has been carried out by Sugiarto *et al*. (2024), who developed an automatic ornamental fish feeding system based on ESP32.

The research by Liu *et al*. (2020) developed a fuzzy model to control feeding based on real-time temperature sensor data and dissolved oxygen levels, and the results showed an increase in feed efficiency of up to 25% and improved fish health. Similar systems integrating ESP32 as the main controller have also been widely applied in modern aquaculture to automate feeding and water quality monitoring simultaneously (Singh *et al*. 2022). In addition, fuzzy logic allows for more refined decision-making than binary logic, especially in situations where sensor values are at a threshold, thus keeping the balance of the aquarium ecosystem optimised (Zhao *et al*. 2019). Therefore, the integration of fuzzy logic in ESP32-based automation systems not only improves ornamental fish productivity, but also contributes to more sustainable water resource management (Patel & Mehta 2023).

CONCLUSION

This study successfully designed and implemented an automatic feeding system for ornamental fish using the ESP32 microcontroller integrated with temperature, pH, and dissolved oxygen sensors, controlled through the Mamdani fuzzy logic method. The system is capable of determining the appropriate amount of feed based on real-time water quality conditions, thereby increasing feeding efficiency and reducing the risk of water quality deterioration due to overfeeding. Compared to previous systems that relied on fixed feeding schedules, this fuzzy logic-based approach proved to be more adaptive to environmental changes and supports more sustainable aquaculture practices.

REFERENCES

Barathi SA, Cheryl CB, Rajagopalasamy A, Uma B, Ahilan, Aanand S. 2019. Functional feed additives used in fish feeds. *International Journal of Fisheries and Aquatic Studies*. 7(3): 44–52.

Bokingkito PB. 2017. Using fuzzy logic for real-time water quality assessment monitoring system. *Proceedings of the 2017 International Conference on Information Technology and Electrical Engineering (ICITEE)*: 1–6.

Fahmizal, Mayub A, Arrofiq M, Ruciyanti, F. 2022. Mudah Belajar Arduino dengan Pendekatan berbasis Fritzing, Tinkercad, dan Proteus. Yogyakarta: Deepublish.

Hamid S A, Abdullah S, Rahim AMA, Muhammad Z, Fadhlullah S, Leh NAM. 2020. IoT based water quality monitoring system and evaluation. In International Conference on Control System, Computing and Engineering (ICCSCE2020), August. 21–22.

Indrawati EM, Suprianto B, Kartika UT. 2024. Pemberi pakan ikan otomatis berbasis IoT dengan FLC berdasarkan kualitas air (suhu, pH, kekeruhan). *JST (Jurnal Sains dan Teknologi)*. 13(3): 383−394.

Jadhav MA, Raut PK, Kakde RB. 2020. IoT based automatic fish feeder system. *International Research Journal of Engineering and Technology (IRJET)*. 7(6): 3212–3216.

Kristiantya YN, Setiawan E, Prasetio BH. 2022. Sistem kontrol dan monitoring kualitas air pada kolam Ikan air tawar menggunakan logika fuzzy berbasis arduino. *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer*. 6(7): 3145−3154

Kurniawan DW. 2019. Analisa pengelolaan pakan ikan lele guna efisiensi biaya produksi untuk meningkatkan hasil Penjualan. *Iqtisha Dequity*. 2(1): 54–67.

Liu H, Wang Z, Li S. 2020. Real-time fuzzy control for automated fish feeding system based on water quality monitoring. *IEEE Access*. 8: 127840–127849.

Maryam. 2023. Pemberian pakan ikan nila otomatis serta mengecek suhu dan kadar pH air berbasis Internet of Things (IoT). *JITET (Jurnal Informatika dan Teknik Elektro Terapan)*. 11(3): 665–675.

Nagothu SK, Bindu SP, Anitha G, Vincent S, Kumar OP. 2025. Advancing aquaculture: Fuzzy logic-based water quality monitoring and maintenance system for precision aquaculture. *Aquaculture Internasional*. 33(1): 1−21.

Nurhadi E, Arinal V, Patricia A, Wati SS, Bila S. 2023. Implementasi alat pemberi pakan ikan otomatisasi menggunakan IoT. *Journal of Information Technology and Computer Science*. 6(1): 171–176.

Patel R, Mehta P. 2023. Development of IoT and Fuzzy Logic-based automated fish feeding system for sustainable aquaculture. *Journal of Environmental Management*. 320: 116041.

Permana DC, Ferdiansyah R, Safira FP, Gumilang ZTA, Pangestu AJ, Rozak RWA. 2023. Otomasi industri sebuah peluang atau ancaman. *Jurnal Pengabdian Masyarakat: Pemberdayaan, Inovasi dan Perubahan*. 3(3): 139−145.

Pratama RP. 2023. Desain alat pemberi makan ikan otomatis berbasis ESP32. *Elektriese: Jurnal Sains Dan Teknologi Elektro*. 13(1): 74–82.

Raihan R. 2022. Perancangan sistem monitoring kualitas air menggunakan ESP32 dengan Fuzzy Logic Sugeno berbasis Android. *JIMIK (Jurnal Ilmiah Mahasiswa Informatika Komputer)*. 7(2): 88–95.

Ramadani ME, Raafi'u B, Mursid M, Ash-shiddieqy RH, Zain AT, Adziimaa AF. 2021. Design and development of monitoring system on carp farming ponds as IoT-based water quality control. International Conference on Research and Academic Community Service (ICRACOS, 148–153.

Rathy PAA. 2024. IoT based automatic fish feeder using mobile application. *IIP Series*. 3(8): 19–25.

Ratnasari D. 2019. Identifikasi jenis ikan air tawar di Pasar Masuka Sintang Kalimantan Barat. *Jurnal Keguruan dan Ilmu Pendidikan*. 3 (2): 82−87.

Samara RW, Iskandar EL, Grandiossa R. 2022. The Effect of the different types plants on the *Recirculating Aquaculture System* (RAS) on the growth performnace of carp seed (*Cyprinus carpio*). *Jurnal Perikanan Dan Kelautan*. 12(1): 20−33.

Santoso SP, Sitohang JN. 2024. Perancangan alat kendali penabur pakan ikan otomatis berbasis mikrokontroler ESP32 firebase. *Jurnal Elektro*. 12(1): 90–103.

Singh A, Gupta N, Kaur P. 2022. IoT-based aquaculture monitoring and automated feeding system using ESP32 and Fuzzy Logic. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 11(2): 712–721.

Sobri H, Nurdiansyah Y, Istiyadi DR, Infantono A. 2021. Implementasi fuzzy logic control untuk pemberi pakan ayam otomatis pada ayam broiler dengan menggunakan teknologi IoT. In Prosiding Seminar Sains Teknologi Dan Inovasi Indonesia (Vol. 3, pp. 179–190).

Somantri, Insany GP, Olis S, Kamdan. 2023. Perancangan sistem otomatisasi pemberi pakan ikan lele berdasarkan suhu air menggunakan logika fuzzy sugeno. *Jurnal Edukasi Dan Penelitian Informatika*. 9(2): 289–298.

Sugiarto MAR, Muhtarom M, Asri AAK. 2024. Implementasi sistem pemberian pakan ikan hias otomatis menggunakan ESP32 berbasis IoT (Internet of Things). *Jurnal Indonesia Manajemen Informatika dan Komunikasi*. 5(3): 2781–2791.

Sulistiani H, Saputra W, Darwis D, Isnain AR, Putra AR, Khairunisa Y. 2023. IoT: Monitoring temperature, water pH, and automatic water drainage systems for gurami cultivation. 2023 International Conference on Networking, Electrical Engineering, Computer Science, and Technology (IConNECT. 19–23.

Syah AAP, Salamah KS, Ihsanto E. 2020. Sistem pemberi pakan otomatis, pH regulator dan kendali suhu menggunakan Fuzzy Logic pada aquarium. *Jurnal Teknologi Elektro*. 10(3): 194.

Tiarto EH, Mansur S, Kinasih A. 2024. Rancang bangun purwarupa mekanik alat pemberi pakan ikan otomatis. *Sebatik*. 28(1): 202–212. doi: 10.46984/sebatik.v28i1.2458.

Warjono S, Sandhi EK, Riqulloh FD. 2022. Akuarium dengan pemberi pakan otomatis dan pergantian air via aplikasi telegram. *Orbith*. 18(1): 76–81.

Widyati MAS, Anshori Y, Laila R, Joefrie YY. 2025. Automatic fish feeding and temperature control system for aquariums ased on Internet of Things (IoT). *Journal of Applied Informatics and Computing*. 9(1): 146−152.

Zhao X, Li Y, Wang T. 2019. Fuzzy Logic control of fish feeding system based on water quality sensors. *Aquaculture Engineering*. 85: 75–82