DESIGN AND DEVELOPMENT OF A SMART FEEDER BASED ON MICROCONTROLLER WITH FEATURES FOR AUTOMATIC FEEDING TIME AND PORTION CONTROL

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ABSTRACT
Catfish farming requires a regular and efficient feeding system to support fish growth and health. Common issues that often occur in the field include delayed feeding, improper feed quantities, and difficulties in monitoring leftover feed. This study aims to design and develop a microcontroller-based Smart Feeder using the ESP32, which can automatically control feeding time and portion sizes. The system development method uses the ADDIE approach, consisting of five stages: Analyze, Design, Development, Implementation, and Evaluation. The development of this tool involves key components, including the DS3231 RTC for time control, load cell + HX711 for feed weight measurement, servo and pump motors for the feeding mechanism, ultrasonic sensors to monitor leftover feed, and an I2C LCD to display information. Testing was conducted to evaluate the tool's functionality, including testing automatic feeding time, feed portion measurement, and monitoring leftover feed. Test results show that the tool functions as expected, being able to feed at the predetermined time, accurately measure feed portions, and monitor leftover feed in the container. Additionally, remote control via mobile applications adds comfort for users. User evaluations indicate positive results, although there are suggestions for further development, such as improving tool durability, adding a notification system, and advanced monitoring features. Recommendations from this research include adding automatic notification features so users can receive updates on feed status, as well as improving material quality and tool durability for long-term use..

Keyword : Smart Feeder, ESP32 Microcontroller, Automatic Feeding, Load Cell, Monitoring System, Catfish Farming.

1. INTRODUCTION

The development of automation technology in the fisheries sector has had a significant impact on improving efficiency and sustainability in fish farming. One of the main challenges in fish farming is providing feed at the right time and in the correct amount, which is often still done manually. Manual feeding has several drawbacks, such as inaccurate timing, feed wastage, and negative impacts on water quality, which can hinder optimal fish growth and increase operational costs [1]. Therefore, the use of automatic feeding systems based on technology, such as microcontrollers and the Internet of Things (IoT), has become a potential solution to address these issues. Automated systems allow for more accurate scheduling and portion control, reducing reliance on human intervention and optimizing resource use in fish farming. Recent studies have shown that this technology can reduce feed wastage, which is one of the main factors contributing to high operational costs [2]. With support from sensors and artificial intelligence-based algorithms, these systems can monitor fish behavior and adjust feed amounts according to the specific needs of the fish, leading to improved feed conversion and operational efficiency [3]. Furthermore, with the continued development of IoT and artificial intelligence technologies, these automatic feeding systems are expected to become more efficient, cost-effective, environmentally friendly, and support the sustainability of the fisheries industry in the [4].

The implementation of automated feeding systems in fish farming brings many benefits, such as increased efficiency and reduced dependence on manual intervention. However, its implementation is not without challenges. One of the main challenges is ensuring the accuracy of feed distribution according to the fish's needs, which is often affected by variability in the size and number of fish in a tank or pond. Some systems still struggle to adjust feed amounts based on the specific needs of the fish [5]. Additionally, automated feeding systems that rely on advanced technology often require stable infrastructure, such as reliable internet and power supply, which is not always available in remote fishing areas [6]. Dependence on hardware and software also adds complexity to maintenance, which is crucial for keeping the system functioning optimally in the long run. Another challenge lies in developing systems that can adapt to environmental changes, such as water temperature or oxygen levels, which can affect fish behavior and their feeding requirements. Therefore, more advanced algorithms are necessary to ensure that the feed is provided on time and in the correct amount according to fluctuating environmental conditions [7].

Automated feeding systems based on technology offer various advantages in enhancing the efficiency and sustainability of fish farming. One of the key benefits is the ability to control the timing and amount of feed more accurately, reducing the feed wastage that often occurs with manual methods. By minimizing waste, these systems not only improve productivity but also reduce the negative environmental impacts, such as water pollution caused by unused feed [8]. Additionally, this technology allows farmers to remotely monitor and control feeding through IoT-based applications, offering more operational flexibility and oversight. Another advantage of this system is its ability to adjust feed distribution according to the fish's needs based on their feeding behavior. For example, systems that rely on sensors to monitor the water movement generated by the fish can optimize the amount of feed provided, reducing waste and improving fish health. These systems can also be equipped with real-time water quality monitoring technology, which is vital for maintaining an ideal environment for fish growth [9]. Furthermore, this automated technology reduces reliance on human labor, not only saving costs but also improving the accuracy and consistency of feeding. By utilizing renewable energy sources, such as solar power, the system can become an environmentally friendly solution, reducing dependence on conventional electricity sources. Overall, automated feeding systems contribute significantly to operational efficiency and the sustainability of the fish farming industry, offering a more advanced, cost-effective, and environmentally friendly solution.

Several studies have been conducted to develop automated feeding systems to improve efficiency and sustainability in fish farming. For instance, an automated feeding system based on sensors has been developed using fish behavior as an indicator to determine the amount of feed given. This study showed that by utilizing the water wave changes generated by fish movements, the system could accurately feed according to the fish's needs based on their weight and activity. Additionally, IoT-based systems have been widely developed to facilitate remote monitoring and control of feed distribution. A study by [10] utilized Arduino and IoT to monitor and control feeding in real-time, as well as monitor water quality in the aquarium. However, research by [11] suggests that automated systems should also be equipped with water quality monitoring and pH detection technology to ensure the welfare of the fish and environmental quality in aquariums. With the development of this technology, automated feeding has become an efficient solution, reducing wastage and improving the quality of life for fish in modern farming systems.

The implementation of automated feeding systems in the fish farming industry faces some significant challenges. One of the main challenges is the limited infrastructure in certain areas, such as unreliable electricity and limited internet access. Some systems, such as those developed in research by [12], use IoT technology to monitor and control feeding in real-time; however, these systems are heavily dependent on a stable internet connection. Additionally, while automated systems offer convenience, the high initial investment cost for hardware and software development and installation is a barrier, especially for small-scale fish farmers. Research by [13] showed that while the initial cost of the system can be relatively low, maintenance and hardware upkeep pose a challenge for many farmers. Furthermore, technical challenges in controlling the exact amount of feed remain an obstacle. Most existing systems are still unable to dynamically adjust the feed amount based on the specific needs of the fish using their behavior to determine more efficient feeding amounts. The implementation of this technology requires technical expertise for installation and maintenance, which can be a barrier for those without sufficient technical knowledge. Therefore, developing systems that are easy to use and can be operated by fish farmers with minimal technical knowledge is crucial to overcoming these implementation challenges.

This research aims to design and develop an automated feeding system that optimizes the feeding process for fish in a more efficient and scheduled manner. One of the main objectives is to improve time efficiency and reduce dependence on manual intervention in feeding, which often leads to inaccuracies and feed wastage. This system is designed to regulate feed distribution based on a programmed schedule and can also be adjusted according to the fish's needs, which are measured based on their weight and feeding behavior. Additionally, this research aims to integrate the system with IoT technology, enabling remote monitoring and control of feeding via a mobile application. By utilizing sensors that can detect the remaining feed levels, the system can also provide alerts to the fish owner when a refill is needed. This research hopes that the implementation of this automated technology will not only improve the effectiveness of feed distribution but also enhance fish health and water quality in aquariums or fish farming ponds. Through this research, it is expected to contribute to the development of more user-friendly and cost-effective technology, particularly for small to medium-scale fish farmers, and support sustainability in the fish farming industry.

This research focuses on developing an automated feeding system that operates autonomously with high accuracy. The system developed prioritizes the use of the ESP32 microcontroller integrated with a real-time clock (RTC) module to ensure precise feeding times. The system is also equipped with a servo motor that functions as an actuator to dispense feed according to the programmed commands. The main focus of this system is to ensure that feed is distributed at the correct time and in the appropriate amount without human intervention, reducing feed wastage. Additionally, this research develops a system that can be integrated with mobile-based applications, enabling users to control feeding remotely. This provides convenience for fish farmers who may not have time to be present at the farming site. The primary goal of this system is to increase operational efficiency, reduce feed wastage, and ensure optimal fish growth in a more automated and controlled manner. Furthermore, by focusing on the use of simple but effective technology, this research aims to provide solutions for small to medium-scale fish farmers, who often face challenges in adopting advanced technologies.

2. RESEARCH METHODOLOGY

The development methodology for the automatic fish feeding system uses a hardware and software-based approach with the ESP32 microcontroller. The process begins with a needs analysis to understand the issues involved in manual fish feeding. The results of this analysis are used to design a system that can automate the feeding process by utilizing real-time clock (RTC) technology to ensure accurate timing and a servo motor as an actuator to distribute the feed according to the specified amount. The next phase is system design, which includes the design of both hardware and software architecture. This design uses the microcontroller platform to control the necessary components, including sensors for detecting feed amounts and communication modules for integration with mobile-based applications.

During the implementation phase, the system is programmed with logic that ensures feeding occurs automatically according to the programmed schedule and can be adjusted based on the condition of the fish being farmed. After the system is implemented, functional testing is performed to ensure all components work according to the intended purpose. Testing also includes system performance tests to verify the accuracy of the feeding time and the precision of the feed quantity dispensed. With this approach, it is expected that the developed system can provide an efficient solution, reduce feed wastage, and improve fish farming productivity automatically.

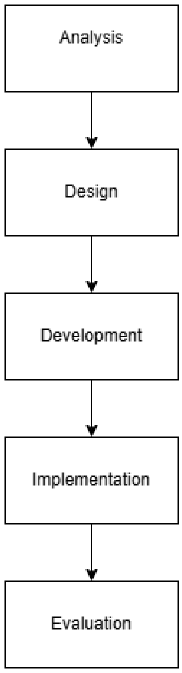

Figure 1 ADDIE Method

In the Analysis phase, a system needs analysis is conducted for the automatic fish feeding system with time and portion control features. This analysis includes a literature study related to catfish feed, the ideal weight of fish, and the feed percentage based on the age of the fish. Additionally, a review of similar existing systems is carried out, along with the identification of key components used in the system, such as the ESP32 microcontroller, RTC module, load cell, servo motor, and pump motor. During the Design phase, a comprehensive system design is created, including the design of electronic circuits (hardware schematic), system workflow (flowchart), LCD interface design, feeding schedule, and portion calculations based on the number of fish and their age using specific percentages. The Development phase involves implementing the system design. In this phase, the hardware components are assembled, and the microcontroller program is developed using Arduino IDE. The developed program includes the scheduling of feeding time using the RTC, reading the feed weight from the load cell, and controlling the servo motor and pump to dispense the feed. In the Implementation phase, the completed device is tested in a fish pond with 25 catfish. The testing includes verifying the accuracy of the feeding time, the conformity of the dispensed feed with the set portion, and the system's stability over a given period. Finally, the Evaluation phase is carried out to assess the performance of the device. If any shortcomings are identified, improvements are made to the hardware, software, or feeding settings. This evaluation also involves feedback from the supervisor or end users in the field to enhance the quality and effectiveness of the developed system.

3. RESULTS

3.1. Results of the Accuracy Test of the System in Providing Automatic Feed

The test results indicate that the ESP32 microcontroller-based smart feeder system successfully delivers feed automatically with a high level of accuracy. Although there was a slight difference between the scheduled feed weight and the recorded feed weight during testing, the variation was minimal, with a difference of no more than 0.1 grams. In the first test, the feed weight was recorded as 19.8g, followed by 19g in the second test and 20.1g in the third test. All of these tests showed a "successful" status, meaning the feeding process proceeded according to the predefined schedule. The system can read time accurately using the RTC DS3231 and ensures feeding occurs at the programmed time, as well as dispensing the correct portion, thanks to the use of a load cell sensor that measures the feed weight with precision.

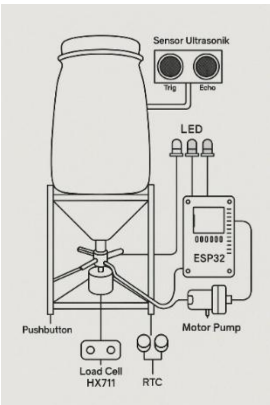

Figure 2 Tools Design

This design represents a smart feeder system based on the ESP32 microcontroller, specifically developed to provide feed automatically to fish. The system integrates several key components to ensure efficient and timely feeding. The ESP32 microcontroller serves as the main control unit, managing the entire process from reading input from sensors to controlling the servo motor and pump motor. The RTC (Real Time Clock) DS3231 module is used to provide accurate time information, allowing the system to feed the fish at the scheduled time automatically. Additionally, an ultrasonic sensor installed above the feed container detects the remaining feed level, providing a warning when the feed stock is low, ensuring timely refills. To measure the portion of feed dispensed, the system uses a load cell connected to the HX711 module. This load cell ensures that the amount of feed dispensed is consistent with the pre-programmed portion, improving the accuracy of the feeding process. The servo motor is used to open the feed channel, and the pump motor is responsible for spraying the feed evenly into the pond. A pushbutton allows the user to manually activate or adjust the system, while the LED provides a visual indication of the system's status, such as whether the system is active or waiting for a command. All relevant information, such as time, system status, and feed weight, is displayed on the LCD I2C, providing clear feedback to the user about the system's condition. With this design, the system operates automatically, delivers feed with accuracy, and provides information that helps the user monitor the system's performance in real-time.

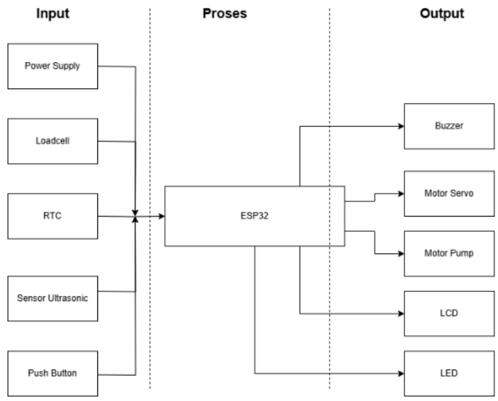

Figure 3 Flowchart System

In this system, the components are categorized into three main categories: input, process, and output. The input consists of several devices, including the Pushbutton, Loadcell, and RTC (Real Time Clock). The Pushbutton functions as a manual control to activate the system directly, set the time, or perform calibration on the system. The Loadcell is used to measure the weight of the feed dispensed, and the data obtained from this sensor ensures that the feed provided matches the pre-determined portion. The RTC, on the other hand, provides accurate time information to the microcontroller, ensuring that feeding occurs at the programmed time. In the Process category, the ESP32 microcontroller plays a central role as the controller for the entire system. This microcontroller reads inputs from the RTC, Pushbutton, and Loadcell, then processes the data and adjusts the outputs accordingly. The ESP32 processes this data to ensure that each component operates according to the specified objectives. For the Output, the system is equipped with several components that aid in the feeding process. The servo motor is used to open and close the feed container lid, ensuring that the feed is dispensed at the correct time. Once the feed is dispensed by the servo motor, the pump motor functions to spray the feed evenly across the pond, ensuring efficient distribution of the feed throughout the entire pond area. Additionally, the LCD I2C is used to display important information such as the feeding time, system status, the weight of the feed dispensed, and other notifications that are useful for the user to monitor the system's performance in real-time.

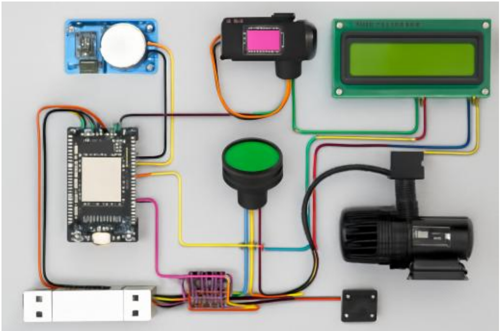

Figure 4 Hardware

Various interconnected components form a system that operates integratively. The ESP32, serving as the central microcontroller, controls the entire process of this system. This microcontroller is connected to various input and output components that work together seamlessly. The RTC (Real Time Clock) is connected to the ESP32 to provide accurate time information, enabling the system to dispense feed according to the scheduled time. Additionally, the ultrasonic sensor connected to the ESP32 is used to detect the remaining feed level in the container. Data from this sensor helps the system issue a warning when the feed is nearly depleted. The LCD I2C is also connected to the ESP32 to display important information such as the feeding time, system status, the weight of the feed dispensed, and warnings when feed needs to be replenished. The Pushbutton, also connected to the ESP32, allows the user to manually control the system, such as turning the device on or off and making other adjustments. Other components connected to the system include the servo motor and pump motor. The servo motor is used to open and close the feed channel, while the pump motor is responsible for spraying the feed into the pond after the channel is opened by the servo. The system automatically adjusts the feeding time and quantity based on data from the **load cell**, which is connected to the ESP32, ensuring accurate portion control. With all components interconnected, the system can automatically and efficiently dispense fish feed according to the pre-set schedule and requirements.

Table 1. Component Connection

No	Component	Pin Esp 32	Description
1.	Load Cell (HX711)	GHD: G DT: D0 SCK: D4 VCC: 3V	Feed weight data communication
2.	RTC DS3231	SCL: D1 SDA: D2 VCC: + GND: -	I2C communication
3.	LCD 12C	SDA: D2 SCL: D1 VCC: + GND: -	I2C communication, displays device status information
4.	Sensor Ultrasonic	D7: Echo D3: Trig VCC: + GND: -	Measuring the feed height in the container using ultrasonic waves
5.	Motor Servo	PWM: DS MERAH: + COKLAT: -	Opening and closing the feed channel
6.	Relay	IN: D8	Digitally controlling the pump motor on/off via ESP32

The table explains the connections between various components and the ESP32 microcontroller in the smart feeder system. First, the Load Cell (HX711) is connected to the ESP32 through the DT (D0) and SCK (D4) pins for data communication, enabling the ESP32 to read the weight of the dispensed feed. The GND (G) pin connects to the ground, while the VCC (3V) pin provides the necessary power for the load cell. Next, the RTC DS3231 is connected to the ESP32 via the SCL (D1) and SDA (D2) pins for I2C communication, allowing the microcontroller to read the accurate time from the RTC and automatically schedule the feed dispensing. The RTC is also connected to the power source through VCC (+) and GND (-) to ensure the time keeps functioning even if the device is powered off. The LCD 12C also uses I2C communication with the ESP32 through the SDA (D2) and SCL (D1) pins to display important information to the user, such as time, feed status, and the weight of the dispensed feed. The VCC (+) and GND (-) pins provide power to the LCD for clear information display. The Ultrasonic Sensor connected to the D7 (Echo) and D3 (Trig) pins measures the remaining feed level in the container using ultrasonic waves. This data is used to issue a warning when the feed is nearly depleted. The VCC (+) and GND (-) pins supply power to the sensor for proper functionality. For mechanical control, the Servo Motor is connected via the PWM (DS) pin of the ESP32 to control the movement of the motor that opens and closes the feed channel. The Red (+) and Brown (-) pins are used for supplying power and ground to the servo motor. Finally, the Relay, connected to the IN (D8) pin, is used to control the Pump Motor digitally. The relay regulates the pump motor, which sprays the feed into the pond, ensuring the feed is evenly distributed. All of these components work together integratively, enabling the system to automatically dispense feed with high accuracy based on time, weight, and the remaining feed in the container.

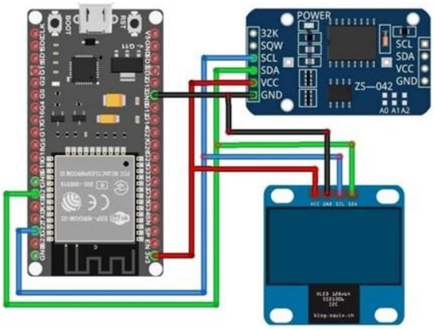

Figure 4 RTC circuit

The RTC DS3231 module is used to provide accurate time information to the ESP32 microcontroller. This module is connected to the ESP32 via I2C communication, enabling efficient data exchange between the two components. The VCC pin on the RTC module is connected to the VCC on the ESP32 to supply the necessary power for the RTC module to function, while the GND pin on the RTC is connected to the GND on the ESP32 for grounding. Meanwhile, the SCL and SDA pins on the RTC DS3231 are connected to the SCL (D1) and SDA (D2) pins on the ESP32, allowing data communication between the components. The RTC DS3231 module is equipped with a backup battery that maintains time accuracy even when the system is powered off or loses power, ensuring the time remains accurate. In the context of the smart feeder system, the time information received from the RTC is used by the ESP32 to schedule the automatic feeding process based on the pre-programmed time. With this RTC integration, the system can operate automatically at the specified time without requiring manual supervision, thus enhancing operational efficiency and reducing reliance on human oversight.

Table 2. Test Results

No	Date	Time Feed	Portion Scheduled	Weight Actual	Status
1.	8-7-2025	07:00	20g	19,8g	Berhasil
2.	8-7-2025	13:00	20g	19g	Berhasil
3.	8-7-2025	19:00	20g	20,1g	Berhasil

The automatic testing was conducted on July 8, 2025. The table records three tests performed at different times: 07:00, 13:00, and 19:00. Each test recorded a scheduled portion of 20g; however, the actual recorded weight varied slightly at each time. In the first test at 07:00, the actual weight recorded was 19.8g, in the second test at 13:00 it was 19g, and in the third test at 19:00 it was 20.1g. All tests were recorded with a "Successful" status, indicating that the testing process proceeded as scheduled.

3.2. Test Results of Warning System Through Ultrasonic Sensor and LCD

This system is also equipped with an ultrasonic sensor that functions to monitor the remaining feed in the container and provide a warning when the feed is nearly depleted. The sensor detects the remaining feed height in the container, and when the detected distance reaches 6 cm, the LCD displays a warning "Refill Feed!" notifying the user that the feed stock is running low. Additionally, the attached I2C LCD displays various important information in real-time, including feeding time, feeding status, and the weight of the feed dispensed. This clear display helps users monitor the system's condition directly without further interaction. Information displayed on the LCD includes the "Feeding Completed" status after the feeding process is finished, making it easier for users to oversee and manage the automatic feeding process. In the software and application section, this smart feeder system was developed using the Arduino IDE with C/C++ programming language. The program is responsible for managing the workflow of all components connected to the ESP32 microcontroller, such as the servo motor, load cell, RTC, ultrasonic sensor, pump motor, and LCD display. The program is structured modularly, with each component having its own specific function and code, and all components work synergistically to achieve the main goal of efficient automatic feeding.

To ensure the system dispenses feed at the specified time, the program uses the RTC DS3231 to read the time and compare it with the programmed feeding schedule. When the set time is reached, the program activates the servo motor to open the feed channel, then the pump motor to spray the feed into the pond. Furthermore, the ultrasonic sensor detects the remaining feed in the container. If the sensor detects that the feed is nearly empty, the code triggers the LCD display to show the "Refill Feed!" warning. This LCD provides visual feedback to the user, displaying information on feeding time, the amount of feed dispensed, and the system's status. The function of the ultrasonic sensor is crucial, as it allows the system to monitor the remaining feed and provide a warning before the feed runs out, ensuring that the user can refill the feed without needing to monitor it directly. With this software, the system can operate automatically, controlling all functions from dispensing feed to monitoring the remaining feed in real-time. This ensures that the system functions effectively and dispenses feed with accuracy based on the fish's needs.

The test results of various components in the smart feeder system were conducted to ensure that each component functions as expected, supporting the automatic feeding system. In the first test, the ultrasonic sensor was tested to detect the remaining feed in the container with a distance greater than 6 cm. The expected result was the display of the "Refill Feed" warning, and the actual result showed a detected distance of 6.4 cm, which met expectations, indicating the sensor's good performance in detecting the remaining feed level. The second test evaluated the **RTC module**, which provides a time signal according to the scheduled 07:00. The system was expected to start dispensing feed automatically at this time. The test results showed that the system was activated at the desired time, confirming the functionality of the RTC in providing accurate time. In the third test, the **load cell** was tested to ensure the accuracy of feed dispensing with a target weight of 20 grams at 07:00. The actual result showed a detected weight of approximately 19.9 grams, indicating successful feed dispensing with a very high level of accuracy. Next, in the fourth test, the **servo motor** was tested to open and close the feed channel according to the PWM signal received from the ESP32. The expected result was a 90° opening and 0° closing. The test showed a quick and accurate response from the servo motor, ensuring that the feed channel could be opened and closed correctly. The fifth test evaluated the **pump motor**, which is responsible for spraying the feed into the pond. With a trigger input from the relay controlled by the ESP32, the test results showed that the pump motor worked well, distributing the feed evenly across the pond. Finally, in the sixth test, the **LCD** was tested to display feeding time and the amount of feed dispensed based on data from the RTC. The test results indicated that the LCD worked properly, displaying information clearly and helping the user to monitor the system status in real time. Overall, the results of these tests demonstrate that all components in the system function properly and as expected, supporting the implementation of an efficient and accurate automatic feeding system.

4. DISCUSSION

4.1. Discussion of the Results of the Accuracy Test of the System in Providing Automatic Feed

The test results of this smart feeder system show that all components are functioning properly and according to their intended purposes. In the first test, the ultrasonic sensor successfully detected the remaining feed height at 6.4 cm, which met expectations. This indicates that the ultrasonic sensor works well in providing the "Refill Feed" warning when the feed stock is low, enhancing the efficiency of feed management. The second test with the **RTC module** showed that the system operated according to the programmed schedule at 07:00, demonstrating good time accuracy and ensuring that the automatic feeding occurred on time. Next, the test of the **load cell** showed excellent feeding accuracy with a very small weight difference, recorded at 19.9 grams, almost matching the target portion of 20 grams, highlighting the high precision in measuring the dispensed feed.

The test of the **servo motor** showed a quick and accurate response in opening and closing the feed channel according to the PWM signal from the **ESP32**, ensuring precise feed distribution. In the **pump motor** test, the results showed that the motor worked well in spraying the feed evenly across the pond, ensuring efficient feed distribution. Lastly, the **LCD** test successfully displayed clear information about feeding time, the amount of feed dispensed, and the system status in real time, making it easier for users to monitor the system's condition directly. Overall, the test results demonstrate that all components in the system work well and support the implementation of an efficient and accurate automatic feeding system.

4.2. Discussion of Warning Test Results Through Ultrasonic Sensors and LCD

The test results of the smart feeder system show that all components work properly and according to their intended functions, supporting efficient automatic feeding. In the first test, the **ultrasonic sensor** successfully detected the remaining feed in the container with excellent accuracy at 6.4 cm, which aligned with the expected value. This indicates that the sensor performs well in providing the "Refill Feed" warning, which is crucial to ensure that the feed does not run out unnoticed by the user. In the second test, the **RTC module** demonstrated excellent performance by providing time signals according to the programmed schedule at 07:00. The system activated at the desired time, proving the RTC's accuracy in scheduling the automatic feeding. Next, the **load cell** test showed a very high level of accuracy, with a minimal difference between the target weight (20 grams) and the actual weight recorded (19.9 grams). This demonstrates that the system dispenses feed with high precision, in line with the programmed portion.

In the **servo motor** test, the motor's response to open and close the feed channel was fast and accurate. This ensures that the feed is dispensed at the correct time as scheduled. The **pump motor** test also yielded good results, as the pump motor successfully sprayed the feed evenly across the pond, ensuring efficient feed distribution. Finally, the **LCD** test showed that the display of information such as feeding time, the weight of feed dispensed, and the system status was clear and helped the user monitor the system's performance directly. Overall, the results of these tests demonstrate that the system operates efficiently and accurately, supporting automatic feeding and enhancing the productivity of fish farming.

4. CONCLUSION

This research successfully designed and developed an automatic feeding system based on the **ESP32 microcontroller** with features for time and portion control, improving efficiency in fish farming. The system utilizes key components such as the **RTC DS3231 module**, ultrasonic sensors, load cell, servo motors, and pump motors, all working integratively to ensure timely and accurate feed dispensing. Test results show that all components perform well and as expected. The system successfully manages automatic feeding times, accurately measures feed portions, and provides warnings through the ultrasonic sensor and LCD display when the feed stock is nearly depleted. While there are some challenges related to infrastructure dependency and the development of additional features, this system provides an efficient and cost-effective solution to improve fish farming productivity. Recommendations for future research include enhancing the durability of the system, adding automatic notification features, and developing more advanced monitoring capabilities.

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