INTERNET OF THINGS- BASED AUTOMATIC FEEDER AND MONITORING OF WATER TEMPERATURE, PH, AND SALINITY FOR LITOPENAEUS VANNAMEI SHRIMP

Falentina Lumban Toruan, Mia Galina[*]
Department of Electrical Engineering, President University, Bekasi, Indonesia
e-mail: falentina.toruan@student.president.ac.id, miagalina@president.ac.id

ABSTRACT

Aquaculture of Litopenaeus Vannamei shrimp is one of Indonesia's most crucial commodity export shrimp. Aquaculture feed management and environmental management are essential factors in determining shrimp sustainability. To maximize shrimp farming results, proper feeding, water quality control, and con-tinuous monitoring of three critical parameters: temperature, power of hydrogen (pH), and salinity levels in ponds are required. This study aims to feed the shrimp automatically at predetermined times (07.00, 11.00, 16.00 and 20.00). At the same time, it will monitor pond water quality parameters. Temperature, pH and salinity are all factors monitored. Every 10 minutes, monitored data is stored in ThingSpeak using IoT technology. The design goal has a specific threshold to avoid future problems. A Telegram notification is sent every 10 seconds when the water condition exceeds the threshold. The overall accuracy rate of 98.81%, pH of 96.6%, and salinity of 99.17% demonstrate that the system works correctly.

Keywords: automatic feeder, pH, salinity, temperature, vannamei shrimp, water monitoring.

I. INTRODUCTION

LITOPENAEUS Vannamei shrimp or white shrimp is widely used in aquaculture, and its optimal growth and survival require a stable and controlled environment. This is one of the leading commodities of Indonesian shrimp culture. In 2014, Vannamei shrimp production was about 411,729 tons, with an average increase of up to 13.83 percent per year [1]. In addition, Indonesia also participates in the International market for Vannamei shrimp. In 2018, Indonesia exported 197.43 thousand tons of Vannamei shrimp. Vannamei shrimp commodities significantly affect commodity exports [2]. Moreover, according to KKP data via statistic.kkp.go.id, West Nusa Tenggara (NTB) Province had the highest production volume in 2020, namely 159,013.10 tons, which made NTB Indonesia's main shrimp producer [3]. This means that the shrimp commodity has a significant role in the export performance of Indonesian fishery commodities.

Due to high local and international demand, Vannamei shrimp cultivation must be intensive. Several factors must be considered, including feeding accuracy based on Vannamei shrimp growth requirements and pond conditions. Farmers primarily feed shrimp by hand, though this method can be greatly improved. They continue to rely on human resources, for example, and the success of this method is dependent on the farmer's expertise, it takes longer time, and the portion given must be more precise. On the other hand, the pond's conditions should be closely monitored to prevent the Vannamei shrimp from dying. The temperature should be between 28 oC and 32 oC, pH between 7.5 and 8, and the salinity between 15-25 ppt [4].Water quality is critical to the growth and survival of shrimp reared in captivity [5]. Specific water conditions such as temperature, pH, and salinity must be maintained to ensure healthy shrimp growth and development. Furthermore, feeding is essential to shrimp farming, and manual feeding can take time and effort [6]. Many cultivators still use the manual method in Vannamei shrimp cultivation. When relying on human resources, it is possible that the shrimp will be ignored or delayed in being fed. Farmers, on the other hand, require assistance in monitoring the water pond conditions. If

the water quality is not carefully monitored, the shrimp may perish. Several studies on shrimp farming in Indonesia have also confirmed this. Some of them show that the importance of pond management is related to production capacity [7], [8]. If it is managed with a poor management function, this will have an effect on shrimp pond production [9].

Monitoring feeder systems and pond conditions are the best way to identify and solve the potential problems above. Therefore, developing an IoT-based automatic feeder and water monitoring system can assist shrimp farmers in optimizing their operations, lowering labor costs, and improving their overall health and productivity [10], [11]. With this technology, the system must be dependable, simple to use, and cost-effective, providing the farmer with accurate and real-time data for monitoring and control.

It is possible to continuously monitor pH, temperature, dissolved oxygen (DO), and total dissolved solids (TDS) in a fish pond using an IoT-based automation solution [10]–[12]. Several studies have discussed IoT technology for monitoring shrimp farms. In 2020, [13] developed a smartphone app to control shrimp feeders automatically. They created the application linked to an auto feeder and monitoring system. The application displays pH, temperature, DO, date and time measurements, and scheduled feed based on shrimp age and even allows the farmer to rename the pond. Furthermore, the application provides a PDF document, monitoring charts, monitoring history features, controlling the feeder, and warning notifications if certain conditions occur. Their study focused on how to configure the hardware for the application. To connect the network, they used an MQTT broker.

In 2018, [14] proposed a Vannamei shrimp farming system design with an automatic feeder and aerator system. They discussed the design of an auto feeder with a microcontroller that opens and closes the bowl cover with a servo and sends the food availability via SMS. When designing automatic aerators, temperature, salinity, and oxygen level are all factors to consider. They used dual-axis PV as a stand-alone power supply to power all components and the LCD to display the result.

In another publication, [15] proposed a new automation system design for the Vannamei shrimp feeder in 2018. To spread the feed, they employed a DC Gearbox motor as a valve mechanism and an ATMega32 as a microcontroller. In addition, they used a level sensor (TCRT5000) to detect the amount of feed and a temperature sensor (DS18B20) to detect the pond water's temperature. The food that the valve releases every 0.5 seconds is 40 g, 80 g, and so on. Lastly, [8] proposed a water quality monitoring system in high-intensity aquaculture systems in 2019. Their study was being carried out for a fishpond. They used the ESP32 as a controller on their systems and several sensors, including the SEN0161-V2 pH sensor, salinity sensor, Atlas Dissolved Oxygen Sensor, and LM35DZ temperature sensor. They displayed parameters on the Blynk app for farmers to check the real-time conditions of the pond and send notifications or alarms if the parameter exceeds the specified threshold.

Based on the comparison above, this study wanted to complement previous studies by focusing on combining two functions, monitoring water conditions such as temperature, salinity, and pH, as well as automatic feeding. Farmers can collect daily data from ThingSpeak and receive Telegram notifications when water conditions reach certain thresholds. The parameter will have a threshold value to keep the farm in good condition, and will send a Telegram notification when it exceeds the threshold. To feed shrimp automatically, the auto feeder will set a timer at 07.00, 11.00, 16.00, and 20.00. This study also aims to create a monitoring system that can receive notifications when water conditions exceed a certain threshold.

II. Research Method

As shown in Figure 1, this work combined experimental techniques and quantitative methodologies. The first step was to review the available literature, which included publications on the adoption of IoT technology that supports shrimp farming, IoT systems for smart farming, and IoT technology application literature relevant to this issue. This step of literature review was required to identify the required architecture, tools, tools, and theoretical and fundamental concepts that will aid in the analysis. Other major attributes and technical details of the sensor, microcontroller, and other supporting components were also detailed at this point. The second step was to create a design in the form of a system architecture design based on research solutions. In addition, design coding was done at this stage with
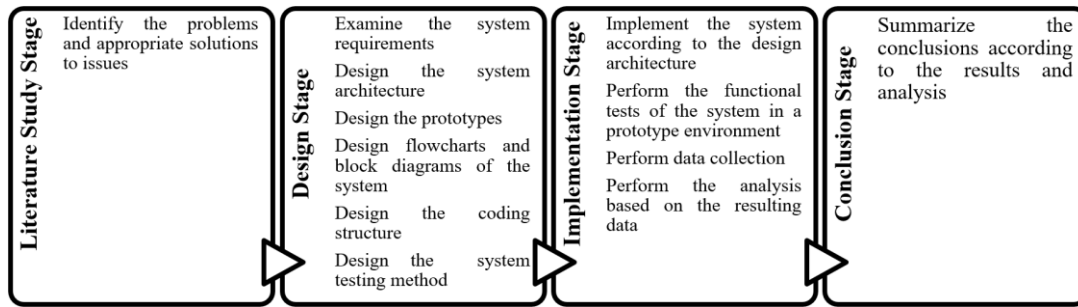
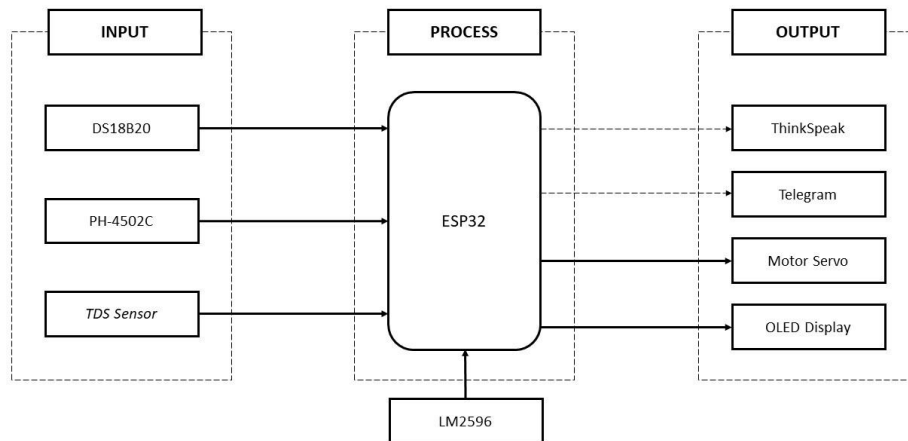Figure 1. The Research design of Automatic Feeder and Water Monitoring for Litopenaeus Vannamei Shrimp

Figure 2. Block Diagram of Automatic Feeder and Water Monitoring for Litopenaeus Vannamei Shrimp

the Arduino IDE developer environment.

The next stage was system implementation. At this stage, the design architecture was realized as a prototype. In addition, coding development has been completed, then continued with system testing. System testing included functionality testing to ensure all features and functions function according to system design specifications. Test results were derived from testing this functionality. The data were then analyzed according to the basic concepts explained in the research method section and finally concluded based on the data and results of the analysis.

A. Design System

The block diagram consists of input, process, and output (see Figure 2). The input system includes three sensors, and there are DS18B20 as the temperature sensor, PH-4502C as the pH sensor, and TDS sensor as the salinity sensor. The input, process, and output system configuration analysis ensured that the system would provide accurate measurements and appropriately dispense food to maintain shrimp growth. Temperature, pH, and salinity must also be monitored to ensure the shrimp thrive in the best possible conditions. The sensor data is analyzed by the ESP32 controller in order to keep track of these variables and design the appropriate feeding and water management systems. To ensure that food is delivered on time, servo motor performance is required.

Specifically, the study is divided into two flow charts: the automatic feeder function and the water monitoring system. Figure 3 depicts the flowchart of the automatic feeder system. When the system is turned on, it will first check for Wi-Fi connection availability. This function confirms that the Wi-Fi connection is compatible with the tool. If the connection is available, the system will proceed with its initialization. However, the system will return to the connection's initialization if there is no connection. The system will determine whether it is time to feed. If the answer is no, the system will be re-initialized; if the answer is yes, the food will be dispensed.

Figure 4 depicts the system flowchart of the shrimp pond's water monitoring system. Temperature, hydrogen power (pH), and salinity are all monitored in water. When the tool is activated, the device will
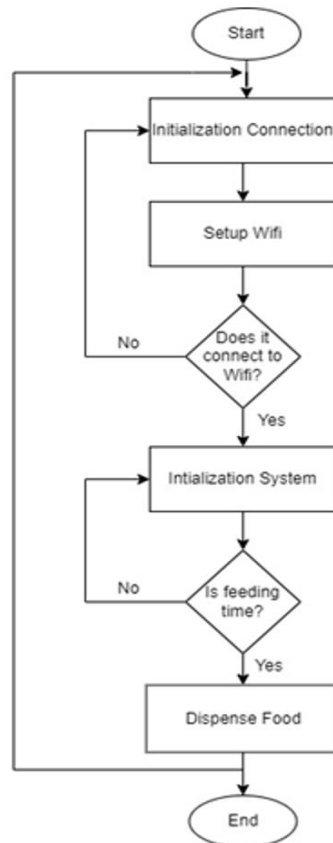
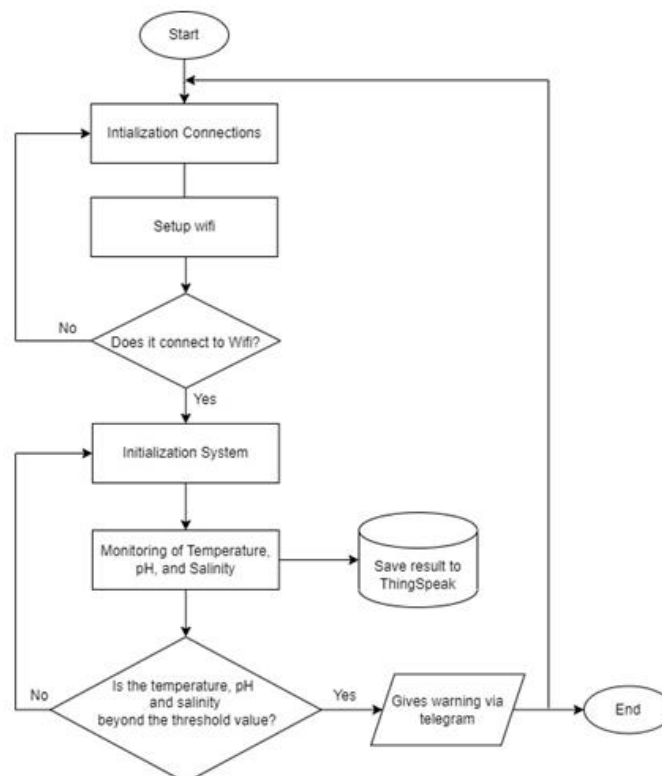Figure 3. Flowchart of Automatic Feeder for Litopenaeus Vannamei shrimp

Figure 4. Flowchart of Water Monitoring System for Litopenaeus Vannamei shrimp

initialize the Wi-Fi connection. If there is a connection, the system will continue to be initialized; otherwise, the system will return to the initialization process. All three sensors are active at the same time, detecting and monitoring the input based on its function. Every 15 minutes, the output data from each

TABLE 1
THRESHOLD VALUE OF WATER MONITORING

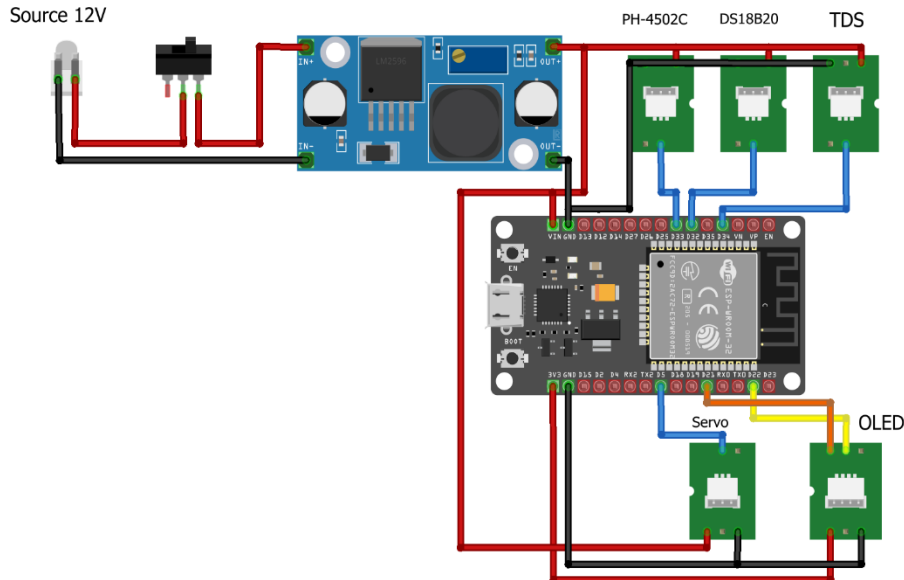| Parameter	Optimal
Temperature	28^0C - 32^0C
Power of Hydrogen (pH)	7.5 – 8
Salinity	15 ppt - 25 ppt

Figure 5. Schematic Design of Automatic Feeder and Water Monitoring for Litopenaeus Vannamei Shrimp

sensor will be sent and displayed on the ThingSpeak platform. Continue to the following function, the system will calculate the threshold value as shown in Table.1.

Table 1 shows the threshold value of water monitoring. These parameters come from Vannamei shrimp water quality [4]. When the temperature, power of hydrogen (pH), and salinity reach this condition, it will send notifications through Telegram. The notification will be sent per 10 seconds and show the value of the latest data measured.

B. Hardware Implementation

Several sensors are used in the automatic feeder and water monitoring of temperature, pH, and salinity sensors. DS18B20 detects the temperature sensor of the water pond, PH-4502c detects the power of hydrogen (pH) in the water pond, and the salinity level of the water pond is detected by TDS (Total Dissolved Solid). In it there are also several supporting components, namely the DC to DC LM2596 voltage regulator to lower the voltage, the SG-90 servo motor to adjust the direction of rotation of the motor when mixing food, 0.96 Inch OLED to display measurement sensors, and Arduino Uno ESP32 as a microcontroller. All the parts are combined into one system to get the final result, as shown in Figure 5.

C. Software Implementation

The study employs the Telegram BOT function to receive a notification when the temperature, pH, and salinity exceed the threshold value [16], ThingSpeak stores daily data and displays it graphically, and Arduino IDE Wi-Fi updates all sensor data to the ThingSpeak server and Telegram. ThingSpeak receives the data and displays the outcomes of real-time parameters. When the sensors detect water conditions exceeding the threshold value, they send notifications via Telegram [17].

D. Hardware Implementation

As shown in Figure 6 and 7, four pipe functions dispense food. Automatic feeders and water monitoring will be implemented in the Vannamei shrimp pond measuring 2.5 m x 1.2 m x 1.5 m. Then, they are placed in the middle of the pond to distribute the food evenly. The food storage measures approx. 285mm x 75mm, and the lid is on top for farmers to refill food. A screen display is placed on the front to make it easier for farmers to see real-time water conditions.

Figure 6. Design of Automatic Feeder and Water Monitoring for Litopenaeus Vannamei Shrimp

Figure 7. Full Design Implementation
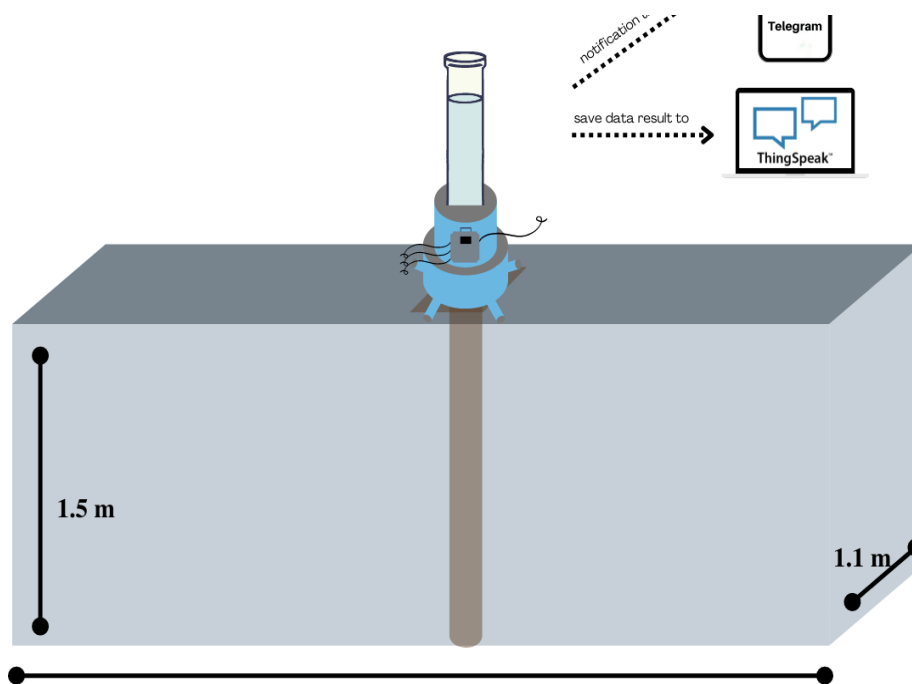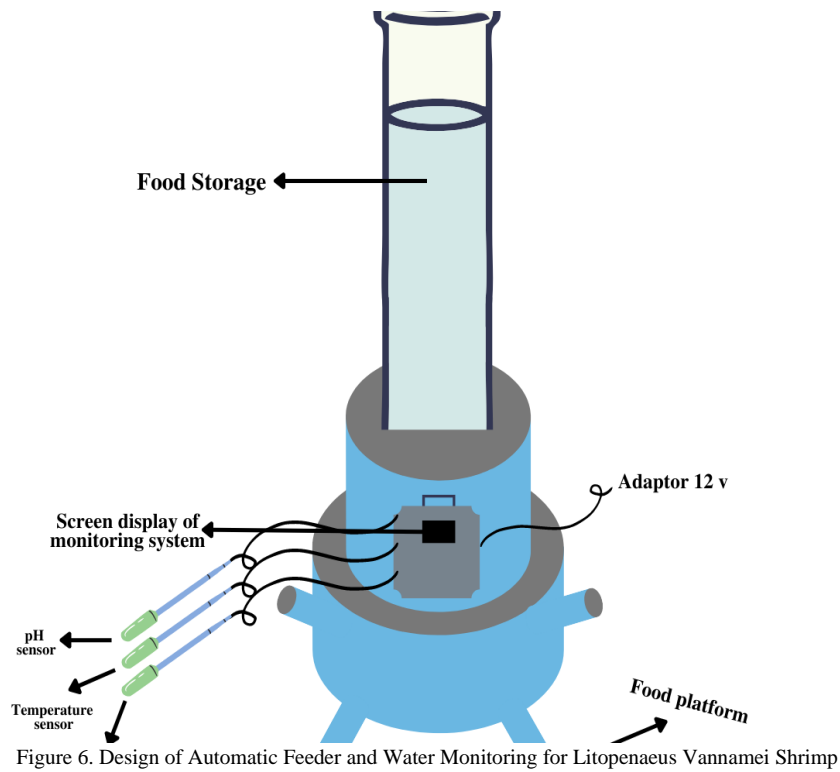
The Telegram will receive a notification if the conditions are beyond the threshold. The notification will display the latest parameter values that are outside the threshold. For example, a notification will appear **WARNING! WATER PH IS 6.41.** ThingSpeak is used as a cloud that can store data from sensor readings: temperature, power of hydrogen (pH), and salinity in the form of value and graph. The ThingSpeak platform can be accessed using a PC or Smartphone making it more practical.

TABLE 2
TEMPERATURE COMPARISON TABLE

No	Thermometer Digital (^{0}C)	DS18B20 (^{0}C)	Error (%)
1	30.4	30.00	1.30
2	30.3	30.00	1.00
3	30.3	29.94	1.20
4	30.3	29.94	1.20
5	30.3	29.94	1.20
6	30.3	29.94	1.20
7	30.3	29.94	1.20
8	30.3	29.87	1.44
9	30.2	29.87	1.10
10	30.2	29.87	1.10
Average of error (%)			1.19

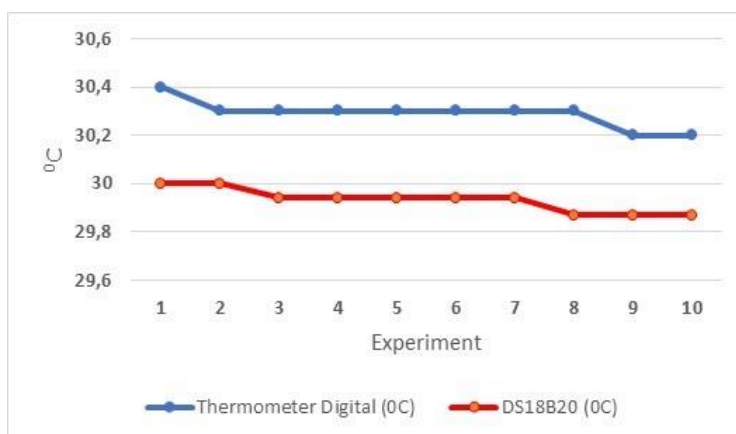Figure 8. Full View of Automatic Feeder and Water Monitoring for Litopenaeus Vannamei Shrimp

Figure 9. Temperature Graphic Comparison

III. RESULT AND DISCUSSION

The IoT technology-based automatic feeder and water monitoring system proposed for Litopenaeus Vannamei shrimp farms is a promising solution to overcome some of the main problems faced by shrimp farmers. The system's ability to automate feeding and water monitoring can assist in ensuring consistent feeding and optimal water conditions, which can improve shrimp growth and health. One of the system's key advantages is its ability to monitor and control in real-time. The system can continuously monitor water parameters like temperature, pH, and salinity, providing real-time water quality data for farmers. This data can be used to quickly adjust feeding and water conditions, reducing the risks of underfeeding or overfeeding, as well as water quality fluctuations, which can lead to higher mortality rates.

A. *Observation Data Result*

The following figure shows the application of an automatic feeder and monitoring system for temperature, pH and salinity in the Vannamei shrimp pond. The location of the implementation is in Karawang,

TABLE 3
POWER OF HYDROGEN (PH) COMPARISON TABLE

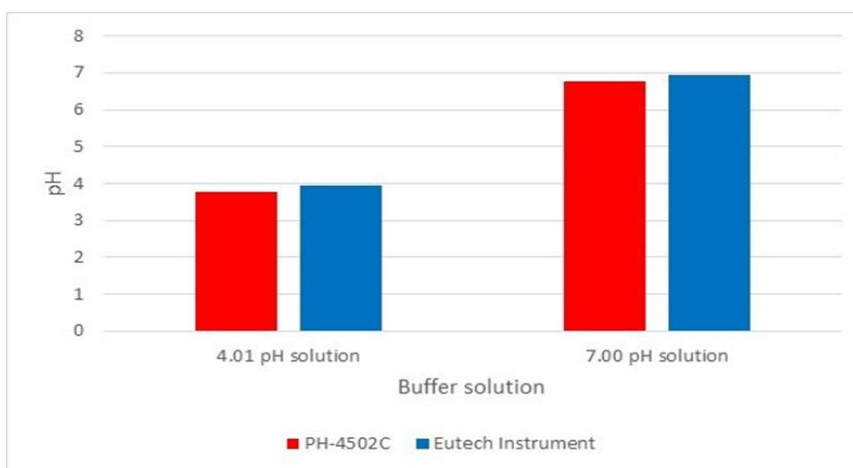| No	Buffer Solutions	PH-4502C (pH)	Eutech Instrument	Error (%)
1		3.76	3.93	4.32
2		3.76	3.93	4.32
3	4.01 pH solution	3.76	3.93	4.32
4		3.76	3.93	4.32
5		3.76	3.93	4.32
6		6.77	6.95	2.59
7		6.77	6.95	2.59
8	7.00 pH solution	6.77	6.95	2.59
9		6.77	6.95	2.59
10		6.77	6.95	2.59
	Average of error (4.01 pH)		4.32	
	Average of error (7.00 pH)		2.59	

Figure 10. Power of Hydrogen Graphic Comparison

West Java, at the home of a resident who manages a shrimp pond. The pool is approximately 2.5 meters wide, 1.2 meters long, and 1.5 meters high.

As shown in Figure 8, the system is placed in the middle of the pond. It aims to spread the food all over the pond, which has four outputs to dispense it. It has food storage which can be opened and closed. Farmers will find it easy to refill their shrimp food. A screen display is placed before the system so farmers can quickly see water conditions.

B. Temperature Test and Discussion

The temperature sensor DS18B20 is used in automatic feeders and water monitoring systems. The temperature range of the DS18B20 is -55 °C to +125 °C, with an accuracy of 0.5 °C between -10 °C and +85 °C [18]. This means that the actual temperature reading from the sensor could be off by up to 0.5 °C in either direction. Several factors influence the accuracy of the DS18B20, including sensor quality, calibration, and the environmental conditions in which the sensor is used.

The Eutech PC450, on the other hand, is a pH and temperature sensor capable of measuring pH levels ranging from 0 to 14, with an accuracy of +/- 0.01 pH and temperature ranging from -10 °C to 110 °C [19]. As a result, it combines a pH electrode and a temperature sensor into a single probe. The pH electrode measures the acidity or alkalinity of a liquid solution, whereas the temperature sensor measures the temperature of the solution. The temperature sensor's measurement ability in this system was tested by comparing the measurement results of the DS18B20 temperature sensor with the measurement results of the Eutech Instrument PC450 sensor, a standard temperature-measuring device. As described in Table 2, the DS18B20 and Eutech PC450 probes were tested ten times in the same water situation.

Table 2 indicates that the DS18B20 temperature sensor still has an error compared to the digital thermometer. For example, DS18B20 is 30°C, and the digital thermometer is 30.4 °C; the percentage error calculation is shown in Equation 1. The result of *Error* (%) is 1.31%. The average of error is calculated by Equation 2. Based on Figure 9 and Equation 2, the result of average error is 1.19%.

TABLE 4
SALINITY COMPARISON TABLE

No	TDS sensor (ppt)	EutechIntrument (mS/cm)	EutechIntrument (ppt)	Error (%)
1	28	43.81	28.24	0.85
2	28	43.81	28.24	0.85
3	28	43.81	28.24	0.85
4	28	43.81	28.24	0.85
5	28	43.81	28.24	0.85
6	27	42.32	27.17	0.62
7	28	43.81	28.24	0.85
8	29	45.21	29.25	0.85
9	29	44.98	29.08	0.85
10	28	43.81	28.24	0.85
		Average of error (%)		0.83

TABLE 5
FEEDING TIME TEST

Times set up	Time (Telegram notification)	Time (system)	Delay (s)	Description
7:00 am	7:00 am	7.01	1 s	Success
11:00 am	11:00 am	11.03	3 s	Success
4:00 pm	4:00 pm	16.02	2 s	Success
8:00 pm	8.00 pm	20.02	2 s	Success

Figure 11. Telegram Feeding Notification

Figure 12. Telegram pH Notification

$$Error(\%) = \frac{|(DS18B20\ value) - (Thermometer\ value)|}{Thermometer\ value} \times 100\% \tag{1}$$

$$Average\ of\ Error(\%) = \frac{\sum error}{\sum testing} \tag{2}$$

The average error in DS18B20 testing represents the average deviation between the measured temperature values obtained by the DS18B20 sensor and the actual temperature values obtained by the reference sensor, the Eutech Instrument PC450 sensor. In this case, the average error of 1.19% indicates that the temperature readings from the DS18B20 sensor deviate from the actual temperature values by approximately 1.19% on average, as measured by the Eutech Instrument PC450 sensor. This information is critical for determining the DS18B20 sensor's accuracy and reliability and whether it is suitable for use in a specific application. The data above shows that the accuracy is 98.81%, meaning the error rate is not significantly different.
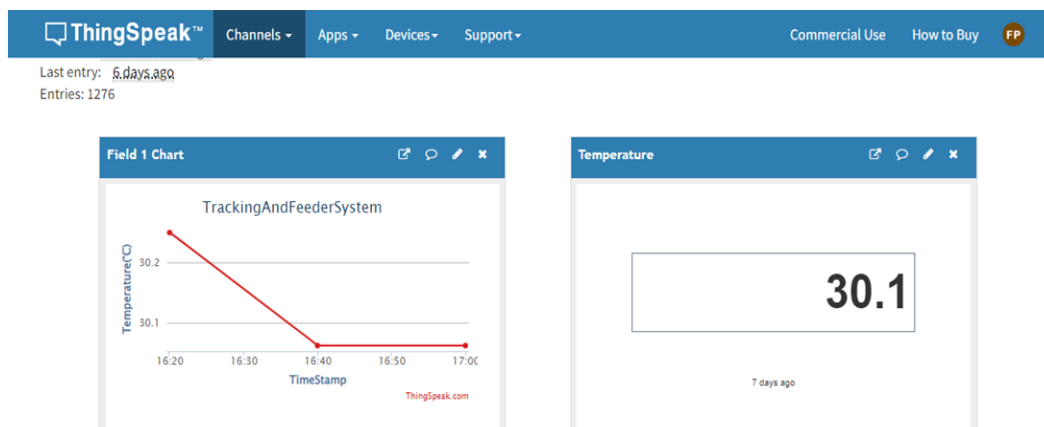
Figure 13. ThingSpeak Temperature Display

C. *Power of Hydrogen Test and Discussion*

The pH testing method is basically the same as the first test method, namely by comparing the measurement results of the pH sensor with an industrial-scale reference pH sensor. pH calibration was performed ten times on the sensor at room temperature 32°C using a buffer solution of pH 0.01 and 7.00. The data from the pH meter and pH-4502c calibration are shown in the Table.3.

A Power of Hydrogen sensor measures a liquid or solution's pH (acidity or alkalinity) (pH-4502C). The pH probe is typically inserted into the solution being tested and detects the concentration of hydrogen ions in the solution being tested to determine the pH level. A glass electrode that is sensitive to changes is usually included in the probe. According to the data presented above, there is still some difference in measurement results compared to the pH-4502 output. For example, the percentage error when PH-4502c is 3.76 and the pH meter is 3.93. The calculation is shown in Equation 1. The result of *Error* (%) is 4.32%. The average of error is calculated by Equation 2. Based on Figure 10 and Equation 2, the result of average error is 3.4%.

Both sensors were tested in the same way, by immersing them ten times in each solution. The sensor probe is sterilized with distillation solution before each test so that the next measurement value is not affected by the pH conditions in the previous test. The accuracy of the sensors used in this study was evaluated based on the results of these measurements by comparing the readings obtained from the two buffer solutions with known pH values. Within acceptable error limits, the reading should ideally correspond to a known value. The calibration test yielded an average error of 3.4%, indicating that the pH-4502 sensor used is accurate to 96.6%. This is because the Eutech PC450 is an industrial standard pH sensor designed to measure a solution's acidity or alkalinity accurately.

D. *Salinity Test and Discussion*

The first step in analyzing TDS sensor data is properly calibrating the sensor. Calibration involves immersing the sensor in a known salinity solution and adjusting the sensor's output to match the expected value. In this study, the authors conducted a salinity test by comparing the measurement results of the TDS sensor with the results of the Eutech Instrument PC450 sensor as a standard digital measurement.

According to Table 4, the TDS sensor still has an error compared to the Eutech Instrument PC450. For example, when the TDS sensor is 28.00 and the Eutech Instrument is 28.24, the percentage error is 0.85% with the average of error 0.83%. Based on the data presented above, a conclusion accuracy of 99.17% is calculated, indicating that the sensor used in this study is nearly as capable as the manufacturer's standard reference sensor.

E. *Feeding System Test and Discussion*

Feed testing determines whether the automatic feeder's success rate is satisfactory. "Feeder active" in Figure11 indicates that the system has been activated and has begun dispensing food. Based on the test results (Table 5), the system performs well and is similar to the system developed for Telegram notification. However, the system takes a while to start feeding. It indicates that the delay is between 1-3 seconds.

F. Telegram Notification Test and Discussion

Telegram allows users to access information using a smartphone linked to an access point or Wi-Fi and presents it in plain, concise text. Telegram notifies users when the water quality exceeds the threshold number. With this feature's support, farmers can assess the value of the data and move preventatively quickly. In this work, the Telegram notifications are set to deliver reports every 10 seconds.

The Telegram notification is shown in Figure 12, describing when the Power of Hydrogen (pH) parameters are outside the threshold value. Hydrogen power (pH) has a threshold of 7.5-8. When the threshold is exceeded, Telegram displays the most recent data on water conditions.

G. Temperature Test and Discussion

Using the K-Means technique, particular data properties are retrieved as part of the consumer segmentation process. Invoice, StockCode, Description, Quantity, InvoiceDate, Price, Customer ID, and Country are some of these properties. In this study, the LRFM approach was used to choose qualities or features.

H. ThingSpeak Test and Discussion

ThingSpeak will display temporary data storage as a graph with data as a number. ThingSpeak is accessible via PC or smartphone. The accuracy of a sensor is typically expressed as a percentage of the difference between the measured salinity value on the used sensor and the value from standardized reference instruments such as hydrometers or refractometers.

Based on Figure 13, the ThingSpeak temperature display appears between 16:20 and 17:00 West Indonesia Time. At 16:20 the temperature was above 30.2 $^{\circ}$C, then dropped below 30.2 $^{\circ}$C starting at 16:40. It happened because of cloudy weather. The numeric display shows the current temperature condition. The test is successfully uploaded to ThingSpeak. The readings that appear from sensors attached to the ESP32 are sent to ThinkSpeak. ThingSpeak displays the latest water condition data for the data updating process.

IV. CONCLUSION

Based on the design and testing of the automatic feeder and its monitoring system, it is possible to conclude that the Automatic Feeder and Water Monitoring for Litopenaeus Vannamei Shrimp were successful. These systems can optimize shrimp growth, health, and survival rates by continuously monitoring and controlling key parameters such as temperature, pH and salinity while lowering labor costs and potentially providing significant benefits to Litopenaeus Vannamei shrimp culture. Analysis of the DS18B20 temperature sensor, PH-4502C pH sensor, and TDS salinity sensor shows that these sensors can provide accurate and reliable measurements of related parameters with low error rates and good linearity, sensitivity, and response time. The overall accuracy rate for temperature is 98.81%, 96.6% for the power of hydrogen (pH), and 99.17% for salinity. This percentage remains acceptable, indicating that the monitoring system works appropriately. However, it is critical to properly calibrate and maintain these sensors and consider any factors that may affect their accuracy, such as temperature, pressure, and other dissolved solids. The Telegram notification is delivered at the time specified. The system sends a Telegram notification if the parameter exceeds the threshold.

REFERENCES

[1] Direktorat Jenderal Perikanan Budidaya (DJPB), "Udang Vaname dan Udang Windu Masih Andalan Ekspor Indonesia," 2014. http://www.djpb.kkp.go.id/arsip/c/246 (accessed Feb. 20, 2023).

[2] Balai Perikanan Budidaya Air Payau Situbondo, "Budidaya Udang Vaname Di Tambak Milenial (Millenial Shrimp Farming/MSF)," 2021. https://kkp.go.id/djpb/bpbapsitubondo/artikel/34255-budidaya-udang-vaname-di-tambak-milenial-millenial-shrimp-farming-msf (accessed Feb. 23, 2023).

[3] E. Y. Setyawan, "Produksi Budi Daya Udang di Indonesia," Balai Besar Riset Sosial Ekonomi Kelautan dan Perikanan, 2022. https://kkp.go.id/brsdm/sosek/artikel/39265-produksi-budi-daya-udang-di-indonesia

[4] Supito, Teknik Budidaya Udang Vaname (Litopenaeus vannamei). Balai Besar Perikanan Budidaya Air Payau Jepara, 2017.

[5] H. S. Suwoyo and E. A. Hendrajat, "High density aquaculture of white shrimp (Litopenaeus vannamei) in controlled tank," in IOP Conference Series: Earth and Environmental Science, 2021, vol. 777, no. 1, p. 12022.

[6] Khushbu, R. Gulati, Sushma, and P. Sharma, "Shrimp Culture (Litopenaeus Vannamei) and Its Management," Bhumi Publishing, 2022.

[7]   O. Juarno, R. Oktaviani, A. Fauzi, and N. Nuryartono, "Kinerja Produktivitas dan Faktor yang Berpengaruh Terhadap Total Factor Productivity (TFP) Tambak Udang Indonesia," J. Sos. Ekon. Kelaut. dan Perikan., vol. 6, no. 2, pp. 149–168, 2017.

[8]   I. Kurniawan, A. B. Witarto, and Z. Zulkiflienmansyah, "Kewirausahaan Sosial Sebagai Landasan Transfer Teknologi (Studi Kasus Tambak Udang Sumbawa)," JMM UNRAM-Master Manag. J., vol. 10, no. 1A, pp. 21–32, 2021.

[9]   F. J. Rizky, R. S. Hari, H. Supendar, and I. Budiawan, "Tambak-Ku: Sarana Penunjang Dalam Industri Udang Untuk Mengkuti Pekembangan Era Industri 4.0," J. Infortech, vol. 2, no. 2, pp. 145–152, 2020.

[10]   K. R. S. R. Raju and G. H. K. Varma, "Knowledge based real time monitoring system for aquaculture using IoT," in 2017 IEEE 7th international advance computing conference (IACC), 2017, pp. 318–321.

[11]   M.-C. Chiu, W.-M. Yan, S. A. Bhat, and N.-F. Huang, "Development of smart aquaculture farm management system using IoT and AI-based surrogate models," J. Agric. Food Res., vol. 9, p. 100357, 2022.

[12]   A. Abu-Khadrah, G. F. Issa, S. Aslam, M. Shahzad, K. Ateeq, and M. Hussain, "IoT Based Smart Fish-Feeder and Monitoring System," in 2022 International Conference on Business Analytics for Technology and Security (ICBATS), 2022, pp. 1–4.

[13]   F. Darmalim, A. A. Hidayat, T. W. Cenggoro, K. Purwandari, S. Darmalim, and B. Pardamean, "An integrated system of mobile application and IoT solution for pond monitoring," in IOP Conference Series: Earth and Environmental Science, 2021, vol. 794, no. 1, p. 12106.

[14]   I. Arditya, T. A. Setyastuti, F. Islamudin, and I. Dinata, "Design of Automatic Feeder for Shrimp Farming Based on Internet of Things Technology," Int. J. Mech. Eng. Technol. Appl., vol. 2, no. 2, pp. 145–151, 2021.

[15]   T. S. Mukti and H. Boedinugroho, "Rancang Bangun Sistem Otomatisasi Pemberian Pakan pada Budidaya Udang Vaname (Litopenaeus Vannamei) Menggunakan Mikrokontroller ATMEGA 32," Institut Teknologi Sepuluh Nopember, 2018.

[16]   S. T. John, B. K. Roy, P. Sarkar, and R. Davis, "IoT enabled real-time monitoring system for early-age compressive strength of concrete," J. Constr. Eng. Manag., vol. 146, no. 2, p. 5019020, 2020.

[17]   J. Fahana, R. Umar, and F. Ridho, "Pemanfaatan Telegram Sebagai Notifikasi Serangan untuk Keperluan Forensik Jaringan," Query J. Inf. Syst., vol. 1, no. 2, 2017.

[18]   E. Ponciano, "What is Calibration?," Calibrationawareness.com, 2017. https://calibrationawareness.com/calibration-awareness-what-is-calibration (accessed Sep. 09, 2022).

[19]   Components101, "DS18B20 Temperature Sensor," 2018. https://components101.com/sensors/ds18b20-temperature-sensor (accessed Sep. 09, 2022).

[20]   Fisher Scientific, "Thermo ScientificTM EutechTM PC 450 Multi-parameter Meter Kit," 2023. https://www.fishersci.co.uk/shop/products/eutech-pc-450-multi-parameter-meter-kit/15347063 (accessed Sep. 09, 2022).