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IoT-based device for water quality monitoring with mealworm feeding for vannamei shrimp

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ABSTRACT

The growth of vannamei shrimp is influenced by several factors, including feed and water quality. The type of feed provided can affect the quality of water in which white shrimp live. In this study, feeds with 20%, 40%, and 60% mealworms were used as three feeding treatments for vannamei shrimp. The main goal of this study was to determine whether mealworm feeding affects water quality. Temperature sensors, pH sensors, and total dissolved solid (TDS) sensors were used in this study by utilizing internet of things (IoT) technology to monitor the water quality. The sensors were placed in four tanks with three types of mealworm feed at different percentage levels. Readings were taken from the sensors every hour and monitoring was conducted for 14 days. This was performed to evaluate the system capabilities. ANOVA was used to compare the effects of the three feeding regimens. The findings indicated that the temperature variances in all tanks were generally similar. However, notable variances were observed in the pH and TDS values. This study revealed that feeding mealworms at any feed dose had no discernible effect on water quality.

Keywords: mealworm; water quality; vannamei shrimp

1. INTRODUCTION

The vannamei shrimp (*Litopenaeus vannamei*) lives in a sub-tropical climate and is generally cultivated in ponds. Farmers raise many vannamei shrimps because of the lucrative market (Muqsith et al., 2021). There is a growing demand for vannamei shrimp which can be sold domestically and internationally. Strong feed response, high survival rate, high stocking density, and disease resistance are advantages of vannamei shrimp (Widanarni et al., 2019). The growth rate of vannamei shrimp is strongly influenced by the feed given and the water environment in which they live, such as temperature, pH, and salt content of the water (Eddiwan, et al., 2020; Rakhfid et al., 2017). Numerous techniques have been used to boost vannamei shrimp production, including polyculture. This can lower the risk of water oxygen depletion (Susilowati et al., 2014), by providing various stocking densities that match the pond (Suwoyo and Hendrajat, 2021), limiting the number of shrimp in a pond with biofloc technology (Ali et al., 2020), and feeding in the form of prebiotics at various doses (Widanarni et al., 2019).

Research on water quality is typically conducted focusing on drinking water needs (Luvhimbi et al., 2022; Meride and Ayenew, 2016), benefits to the environment (Liu et al., 2021; Loi et al., 2022; Son et al., 2020), and placement of fish ponds (Munni et al., 2013; Sánchez and González, 2021). This research on water is crucial because water is a fundamental human need. Two methods are available for measuring the quality of water: transporting water samples to the laboratory and employing sensors to directly measure the water quality where the water is present. However, measuring the water quality is labor-intensive and complicated (Gazzaz et al., 2012).

The use of information and communication technology (ICT) applications, including the Internet of Things (IoT), has impacted many fields. One of the applications is water quality monitoring (Dhruba et al., 2022; Jan et al., 2021; Lakshmikantha et al., 2021; Moparthi et al., 2018). It is important to maintain the quality of water in shrimp ponds as shrimp development is very sensitive to water conditions in the ponds. Several variables that affect the water quality of shrimp ponds are temperature, degree of acidity, and the amount of dissolved solids or total dissolved solids (TDS). Water temperature in ponds affects the metabolism and appetite of shrimp (Adipu, 2019). This temperature is influenced by the weather and climate at the location of the pond. Low water temperatures can also render shrimp susceptible to diseases. Therefore, monitoring water temperature for 24 h is important to properly maintain the growth and development of shrimp. This is similar to the pH sensor, which is used to monitor the acidity of the water. Changes in the pH of pond water often occur for several reasons, such as feeding and stocking density. This results in fluctuations in the pH of water, which can lead to a decrease in the rate of shrimp feeding, which in turn causes poor growth (Larasati et al., 2021). With the pH sensor connected to IoT technology, it is hoped that monitoring the pH of shrimp pond water can be carried out in real time to maintain the pH of the water. Another sensor that is applied to shrimp ponds is the TDS sensor. This sensor assesses the levels of dissolved solids in both organic and nonorganic compounds. The TDS level can also affect shrimp growth; therefore, an application that can monitor changes in salinity in ponds is needed. With these three sensors in the shrimp pond waters, it is expected that the pond conditions can be accurately monitored for 24 h, allowing for the prevention of unforeseen events such as abrupt decreases in water temperature and shrimp deaths (Chowdury et al., 2019).

Numerous studies have been conducted to evaluate the water quality of vannamei shrimp ponds (Kilawati et al., 2020; Palupi et al., 2022; Ritonga, 2021; Santanumurti et al., 2019). However, the water quality of shrimp ponds with mealworm feed has never been investigated. Therefore, the purpose of this study was to determine how the provision of mealworms at different quantities affects the quality of water and, ultimately, the growth of vannamei shrimp. IoT technology is used with sensors to continuously check water quality via a smartphone app.

2. MATERIALS AND METHODS

2.1 Location

The research was conducted at the Brackish Water Cultivation Center, Galesong, Takalar Regency, South Sulawesi, Indonesia (-5.331603, 119.357315). Takalar Regency has a tropical monsoon climate (Am) with temperatures ranging from 23 °C to 32 °C and rainfall in the range of 10–400 mm. The research was conducted in the first week of August 2022.

2.2 System

The monitoring system hardware consisted of an ESP 32 Dev kit V1, which was an ESP 32 One Chip (SoC) platform system. The ESP 32 developer toolkit V1 also had WiFi capabilities to send and receive data. The ESP32 Dev kit V1 was connected to several sensors, namely the pH-4502C sensor module board, sensor Ds18b20, which was used to detect the level of water temperature in the tanks, and the TDS sensor which was used to measure the amount of dissolved substances in the water, as shown in Figure 1. Data were generated from sensor readings each hour and received by the microcontroller. This was relayed through the IoT service, to be further displayed on the water monitoring app, as shown in Figure 2. There were four stryfoam tanks containing vannamei shrimp seeds named A, B, C, and D. Each tank had three sensors, namely temperature, pH, and TDS sensors. The pH sensor was calibrated using solutions with pH levels of 4 and 6. Calibration of the TDS sensor was performed using the sensor manufacturer's software. The tanks were placed outside in a roofed area so that they were not exposed to rain, as shown in Figure 3. The foam tanks had dimensions of 75(l)x42(w)x32(h) cm and a water level of 26–27 cm. Each tank was equipped with an aerator to maintain the oxygen levels in the water. The water quality monitoring application was developed using Kodular with five main displays: a login screen, dashboard screen, temperature data screen, pH data screen, and TDS data screen.

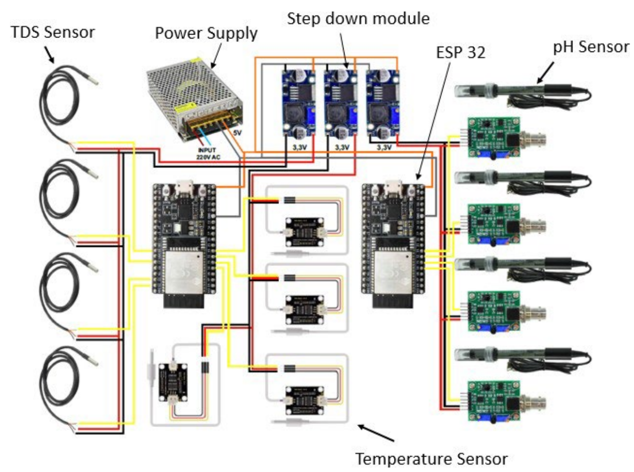


Figure 1. Wiring diagram of the monitoring device

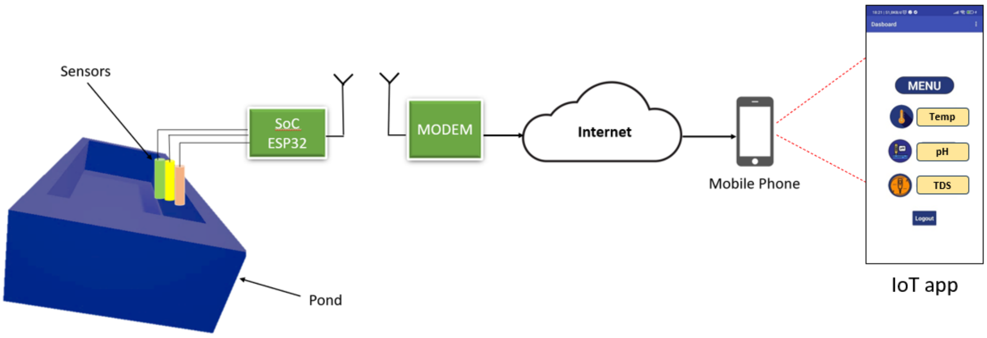


Figure 2. Diagram of the system which consist of sensors, microcontroller and IoT module

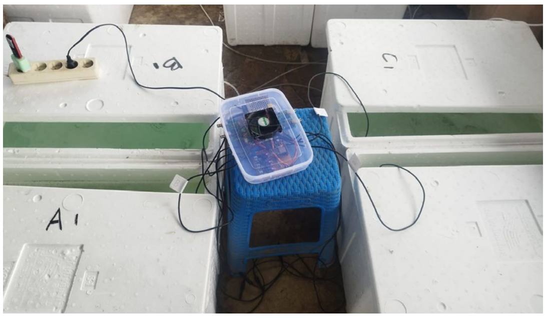


Figure 3. The four tanks system

2.3 Feeding

Shrimp stocked into the tank with the size of Post Larva (PL) 12 and a weight of approximately 0.001 g/tail totaled 50 tails. This type of feed was made from mealworm flour (Tenebrio molitor) and various other ingredients, namely fish meal, crab meal, bran, flour tapioca, sago, sargassum flour, salt, calcium carbonate ($CaCO_3$) 3%, magnesium oxide(mgO) 0.2%, methionine 0.2%, and 0.3% vitamin-mineral mix. The feed consisted of four treatments: A (20%), B (40%), C (60%), and D (Control). Feed was administered up to 0.1 gram at a time, three times per day, in all ponds at 7:00, 13:00, and 19:00. On day four and day eleven, the water was adjusted to protect the water quality.

2.4 Statistic analysis

One-way analysis of variance was used to compare the results for each group. Furthermore, Levene's test (LT) was used for the equality of variance and the Kruskal-Wallis test (KWT) was used for non-parametric alternatives.

3. RESULTS AND DISCUSSION

Measurements were carried out for 14 days to determine the variables of temperature, pH, and TDS during feeding. Figure 4(a) shows the temperature changes in the four tanks. The temperature was in the range 24–27 °C. Low temperatures occurred at night and high temperatures occur during the day. The four tanks show the same pattern of temperature changes, increasing until day 3 and then decreasing until day 6. The pattern repeated for the remaining days. The average minimum temperature was observed on days 1 and 14, and the average maximum temperature was observed on days 3 and 10. Days 4 and 11 had changes in average temperatures because of the scheduled water changes in all tanks, as shown in Figure 4(b).

Based on the pH readings, the average pattern of pH values in tanks A, B, and C was extremely varied with values ranging from around 6.5 to 8.5 as shown in Figure 5(a). In tank A, it can be seen that within two weeks, the average pH value was at the level of 6.5–8.5. This indicates that the pH level was good and did not experience significant changes due to mealworm feeding. Similar results were observed in tank B, where the average pH level was between 7.0 and 8.5. Some of the readings showed unusual levels of deviation. A transient fault or data transmission error could be responsible for this. Tank C appeared slightly different, was classed as similar to the other two tanks with an average pH around 7.5. It can also be seen that a pH value of approximately 5 was the outlier value as shown in Figure 5(b). This is also believed to be the result of a data-transmission fault or a brief incorrect reading from the sensor. However, it can be seen that the pH values were comparatively similar in tank D, which served as the control tank.

For the TDS sensor, the results generally showed different trends in the four tanks, as shown in Figure 6(a). In tank A, the average measurements showed a decrease from day 1 until day 3, then an upward trend to day 8, followed by a gradual decline to day 11. Similar patterns occurred in tanks B and C during day 1 to day 6, where there were slight decreases from day 1 until day 3, then increases on the day 4 as the water changes. However, there were slight decreases from day 6 to day 8 and an increase on the day 9 and they decreased again from day 10 to day 13 and increased again on day 14. In tank D, similar pattern was also similar to other tanks during the first 6 days but decreased and increased with a different pattern afterward. The average measurements showed a TDS that typically ran between 500–650 ppm as shown in Figure 6(b). It appears that there were some outliers that might indicate reading errors or incorrect data transmission.

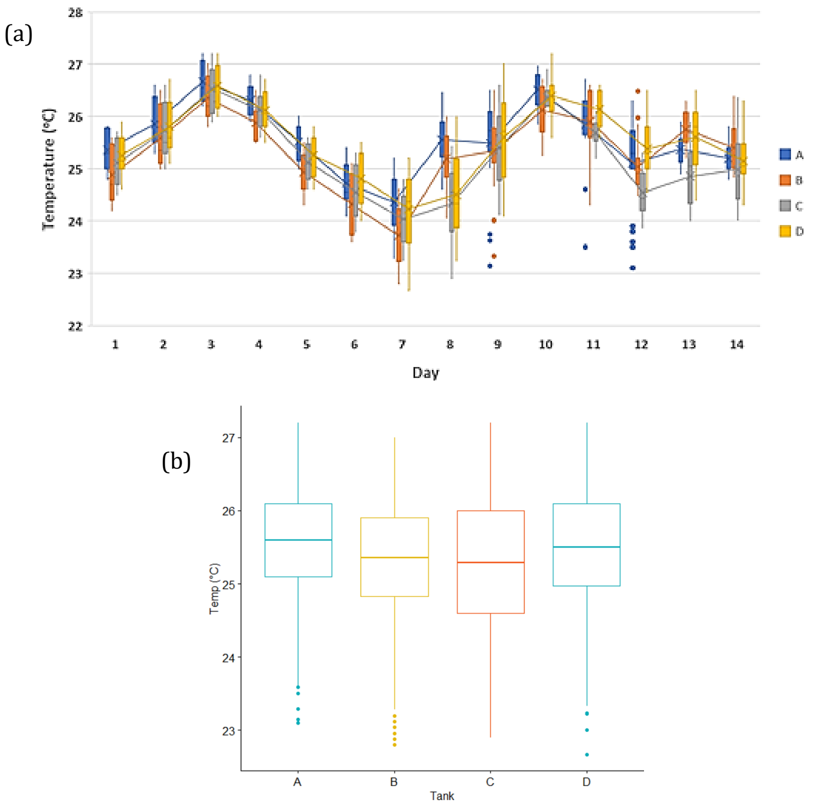


Figure 4. Boxplot graph of temperature (°C) for 14 days in the 4 tanks (A, B, C and D)

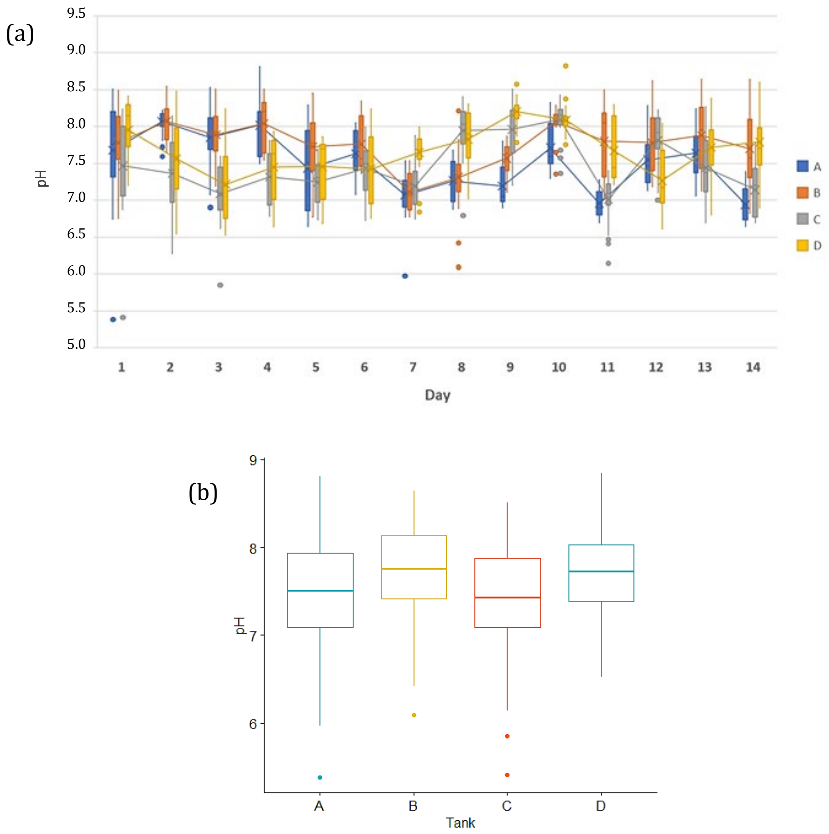
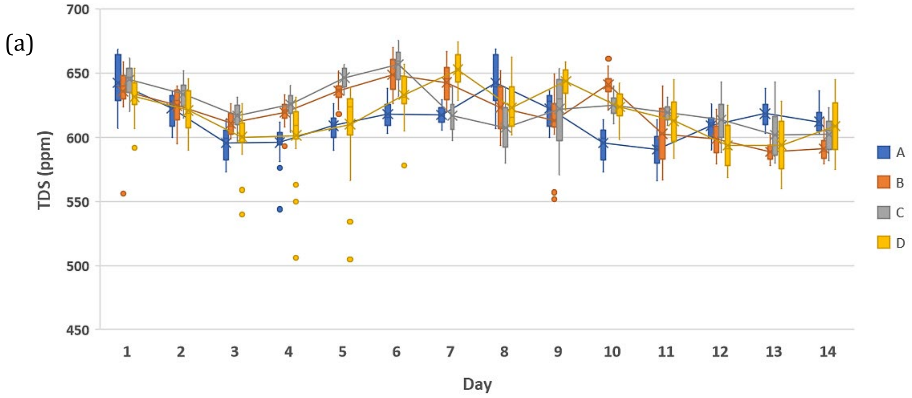


Figure 5. Boxplot graph of pH for 14 days in the 4 tanks (A, B, C and D)



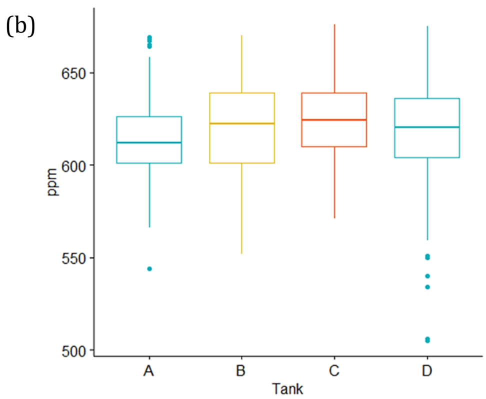


Figure 6. Boxplot graph of TDS for 14 days in the 4 tanks (A, B, C and D)

As observed from Levene's test (LT), the *p*-value was smaller than 0.05 in all cases except for temperature. This indicates that it is reasonable to assume that each group's treatment was different in terms of variance distribution. In addition, Kruskal Wallis test (KWT) was performed to determine whether the current data are statistically different. The findings demonstrate that all categories of data have *p*-values lower than 0.05, indicating that each tank in the group measurements were different. An ANOVA test was run using the findings of the analyses, and the results are presented in Table 1.

Table 1. *p*-value of tanks pairs

Tank	***p*-value**		
	Temperature	**pH**	**TDS**
A–B	0.0011	0.0000	0.0032
A–C	0.0000	0.8071	0.0000
A–D	0.6669	0.0001	0.0861
B–C	0.6535	0.0000	0.1099
B–D	0.0447	0.1101	0.6926
C–D	0.0010	0.0000	0.0046
LT	0.0704	0.0008	9.791e-07
KWT	1.392e-06	2.689e-15	5.007e-09

The temperature readings revealed a substantial difference between tanks A–B, A–C, B–D and C–D, with *p*-values of less than 0.05. Tanks A–C and B–D, where the *p*-value was greater than 0.05, did not exhibit any discernible differences in pH. However, the pH in the other tanks showed noticeable variations. The TDS results demonstrate a substantial difference in A–B, A–C and C–D, where the p-value is less than 0.05. The *p*-value was greater than 0.05 in tanks A–D, B–C and B–D. Overall, feeding mealworms had no detrimental effect on water quality.

4. CONCLUSION

The quality of experimental feeding tanks for vannamei shrimp has been studied using temperature, pH, and TDS sensors, as well as IoT technology. The results demonstrate that the output, which can be seen from all sensors using a smartphone, was excellent. The measurements of temperature, pH, and TDS in the four tanks showed that there were statistical differences between them. However, there were no significant water quality differences compared to the control. By examining the data stored in the cloud, the water quality in the tank could be tracked and compared. It is expected that other applications will also be able to use this method to monitor the water quality.

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