CEPAT Journal of Computer Engineering: Progress, Application and Technology
Vol. 2, No. 2, September 2023, pp. 17-23
ISSN: 2963-6728, DOI: https://doi.org/10.25124/cepat.v2i03.6287 ❒ 17

Hardware design of IoT-based water quality control system for Vannamei post-larvae shrimp

Anas Satria[1], Arief Ilham Novandi[1], Purba Daru Kusuma[1], Reza Rendian Septiawan[1]
[1]Department of Computer Engineering, School of Electrical Engineering, Telkom University, Indonesia

Article Info

Article history:

Received July 6, 2023
Revised August 17, 2023
Accepted August 17, 2023

Keywords:

IoT
Shrimp
Vannamei
Microcontroller
Aquaculture
Post-larvae

ABSTRACT

The Vannamei shrimp is a type of shrimp whose natural habitat is in the Pacific Coast and Mexico. This shrimp was introduced to Indonesia in 1996 when Tiger shrimp experienced a decline in production due to disease caused by the White Spot virus. Demand for Vannamei shrimp immediately increased rapidly, requiring innovation to keep shrimp yields in line with market demand. The main problem in Vannamei shrimp cultivation is water quality, especially water temperature conditions where the shrimp live. Vannamei shrimp prefer water conditions that have temperatures range of 26-29°C. A water quality control system was developed to maintain water conditions under the best conditions for Vannamei shrimp to increase yields due to reduced mortality rates. The test result of the water quality system shows that this system can help decrease the mortality of the shrimp on average for 6 days at 52.74%.

Corresponding Author:

Anas Satria
Department of Computer Engineering
School of Electrical Engineering, Telkom University
Bandung, Indonesia
Email: anas.satria.as@gmail.com

1. INTRODUCTION

The shrimp industry in Indonesia has faced an unpredictable situation caused by White Spot Syndrome Virus (WSSV), which hit the black tiger shrimp (*Penaeus monodon*) industry in 1994. In 1996, many private sectors in Indonesia started to introduce white leg shrimp (*Penaeus vannamei*) to secure shrimp market demand. White leg shrimp offer specific advantages over black tiger shrimp, including faster growth rate, higher tolerance in low salinity, and certain disease resistance [1].

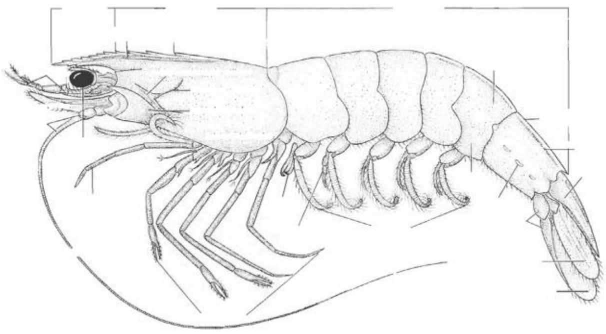

Figure 1. *P. vannamei* illustration by D. L. Lovett dan D. L Felder [2]

Figure 1 shows *P. vannamei* consists of several body segments. Legs are located at the first segment on the head of the shrimp or carapace, while the last segment is called the abdomen contains tail fans and 2 pairs of uropods and telsons to help to jump quickly [3].

Shrimp, as one of the fisheries and aquaculture commodities in international trade, has a significant role in the world market. Based on FAO (Food and Agriculture Organization) fisheries and aquaculture annual statistics report in 2019, shrimp trade in quantity and value always increases every year. In 2019, shrimp trade's total quantity and value reached 5.446.216 tons and thousand USD 32.190.978 respectively [3], [4].

The rapid growth of *P. vannamei* shrimp cultivation and the change from *P. monodon* pond to *P. vannamei* pond led to the new issue that *P. vannamei* also can be affected by WSSV, particularly the illegally imported shrimp was not specifically pathogen-free (SPF)[1]. However, the shrimp farmer in Indonesia prefers *P. vannamei* cultivation because of its advantages and as in 2020, shrimp is the leading export of the fisheries commodity with 39,68% of contribution with the export value reaching USD 2.064.612.816,04 [5]–[7].

However, viruses and diseases are still a problem for *P. vannamei* shrimp cultivation. The post-larvae (PL) known as the pre-juveniles stage, also has high sensitivity in lower temperatures which could lead to disease and toxicity [8]. Warm water temperature at 28-33°C helps to mitigate the high mortality of shrimp infected by WSSV [9], [10] and Decapod Iridescent Virus 1 (DIV1) [11]. Water temperature at 26-29°C can also give better shrimp production results. Therefore, temperature has a major role in the shrimp growth performance [12]–[15].

Developing an IoT-based system that controls and monitor water condition can help shrimp farmers keep the best water condition for the shrimp, especially PL *P. vannamei* shrimp, as it will increase the production rate. Based on previous research, this work is aimed to design the hardware of the IoT-based water quality control system. The water quality control system is designed especially for Vannamei shrimp farming, specifically in the post-larvae phase.

2. METHOD

The target system can operate for 24 hours, sending temperature data to the farmer's smartphone, and the system can maintain a water temperature range of 26-29°C as it shows to increase the production rate of the *P. vannamei* [15], [16]. Based on previous research, water temperature >30°C for the *P. vannamei* has the least efficient growth and described water temperature at 28°C is the best for the shrimp production and 27.5°C for the weight gain [12]. While warmer temperature above 30°C can help shrimp survive in case infected by WSSV [9], [10], shrimp at water temperature above 32°C has a higher chance infected by DIV1. The objective of the development of an IoT-based system for controlling the water quality for *P. vannamei* pond is controlling water temperature at 26-29°C to improve the *P. vannamei* shrimp quality life at post-larvae[8], [9], [11]–[13]. While the water turbidity also affects the shrimp in the pond, with turbidity above 30 NTU will give stress and affect the growth of the shrimp [17]. As for the materials specification based on an interview with MMAFI Research and Human Resource Agency, which uses largely available materials, at least available an online marketplace, not expensive, easy to maintain, and the system can run for 24 hours. The method of developing this system starts with searching information for necessary materials that are largely available online. The main materials for the system are sensors, a water heater, a water pump, and a Wi-Fi-based microcontroller.

After the materials are gathered, the next development stage is designing the electricity wiring. As a microcontroller uses direct current (DC) to operate, unlike water heaters and water pump that use alternating current (AC) to operate, a relay module circuit is required to prevent damage to the microcontroller and fire hazards from short circuits.

2.1 Software

The software that is used to write the necessary code for a microcontroller is Arduino Integrated Development Environment (IDE). Arduino IDE is open-source software with sketches written in language modeled after Processing language, that run on a computer to compile and upload program code in C language into the microcontroller board that supports Arduino [18].

The monitoring software that can also be used to control microcontroller is a platform called Blynk. With its high availability ensure the IoT system can work and be monitored by smartphone. Blynk is an application service for controlling microcontroller over networks. Blynk is very easy to use as the apps themselves can be assembled as desired and can be customized based on user preferences.

2.2 Hardware

Hardware in this development is divided into 3 sections based on hardware types: microcontroller, sensor, and actuator.

Figure 2 shows the system while operating with the aquarium.

In Figure 2, it shows how the system is installed and running for controlling the water condition of the aquarium. Temperature DS18B20 sensor in the red box. While the yellow box indicates the DFRobot Turbidity sensor. The use of 2 temperature sensors is to increase the monitoring range of the water temperature then the average value of the temperature sensor is calculated as a reference of the water temperature.

2.2.1 Microcontroller

Microcontroller is a device that can read and write a value based on voltage from IO pins to communicate with the sensor and control actuator [18], [19]. Wemos D1 Mini is a microcontroller module based on ESP-8266EX with a WiFi feature built-in, removing the need for an additional WiFi board. Wemos D1 Mini specification with 11 digital I/O pins is enough to connect with the sensor and actuator [20].

2.2.2 Relay

Relay is hardware that controls another electronic device that uses a higher current which needs to be separated from the microcontroller. Songle Relay SRD-05VDC is a type of relay that switches at 5V with DC. The relay itself is a mechanical switch that is controlled electromagnetically by giving 5V to the pin coil.

As shown in Figure 3, the Songle Relay can operate electronic devices with up to 10A 250VAC and 10A 20VDC. The pin coil is connected to 5V and ground from the microcontroller. While the common pin is used for the input of AC. NC is short of Normally Closed and NO is short of Normally Open. One of the NC and one NO pin is connected to the AC device. This type of relay is compatible with Wemos D1 Mini since the Wemos D1 Mini is capable to give 5V output at its pin to activate the relay. To safely control the relay, an optocoupler device is required to isolate from surge voltage, low-level between the AC for the actuator and DC for the microcontroller and sensors [18].

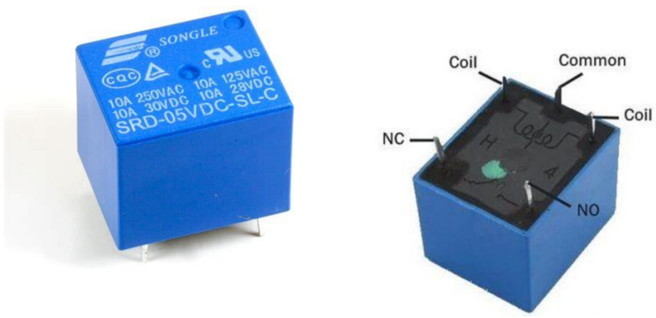

Figure 3 5V DC Songle relay

2.2.3 Sensors

The sensor will communicate with the microcontroller by sending voltage to the microcontroller based on environmental changes. The sensor used in this system is turbidity sensor and temperature sensors. The turbidity sensor is the DFRobot Turbidity sensor, which is capable to send digital signal to the microcontroller. The Wemos D1 Mini is not capable to read a 5V analog signal, therefore digital signal from the turbidity sensor is used. For the water temperature sensor, DS18B20 water-resistant type temperature sensors are used by submerging it in the water. Based on Wemos D1 Mini hardware specification, D1 Mini is only equipped with 1 pin for analog reading with 5V, hence DS18B20 is selected as it supports data transfer in digital mode. Based on the datasheet, DS18B20 has accuracy at ±0.5°C There are 2 temperature sensors installed to increase the monitoring area inside the aquarium. From the temperature sensor, the average value from both sensors is calculated by the microcontroller. This average value is used to decide whether the temperature is the best for the shrimp's survival.

Table 1. DS18B20 sensor readings compared to 6802 II Thermometer T1/T2

Test Number	DS18B20 Sensor value(°C)	6802 Thermometer control value (°C)	Difference (°C)	Errors (%)
1	15.6	15.5	0.1	0.64
2	16.8	16.5	0.3	1.81
3	17.3	17.1	0.2	1.16
4	20.5	20.8	0.3	1.44
5	25.7	25.8	0.1	0.38
6	26.8	26.6	0.2	0.75
7	26.3	26.7	0.4	1.49
8	27.4	27.7	0.3	1.08
9	28.9	29.1	0.2	0.68
10	29.7	29.9	0.2	0.66
	average		0.23	1.009

DS18B20 sensor needs to be compared with another water temperature sensor to make sure the sensor reading is correct and accurate. The 6802 II Thermometer is used as a control to compare the difference in the temperature readings. Based on the specification, this thermometer has accuracy at ±0.4°C. As shown in Table 1, the average difference between the DS18B20 and 68021 II Thermometer is 0.23°C with a 1% error. Based on the difference in the sensors, the DS18B20 is per the IEC 60751-22 *Class* B [21]

2.2.4 Actuator

The actuator is the hardware that can directly manipulate the water quality in this IoT-based system development. A water pump for a small aquarium that connects to the microcontroller through the relay will give aeration to the pond and increase the dissolved oxygen in the pond. For the heater, a water dispenser heater can be used as it will not have direct contact with the shrimp in the water. The heater also connects to the microcontroller through an optocoupler relay to separate the DC for the microcontroller and sensors from AC for the water pump and heater.

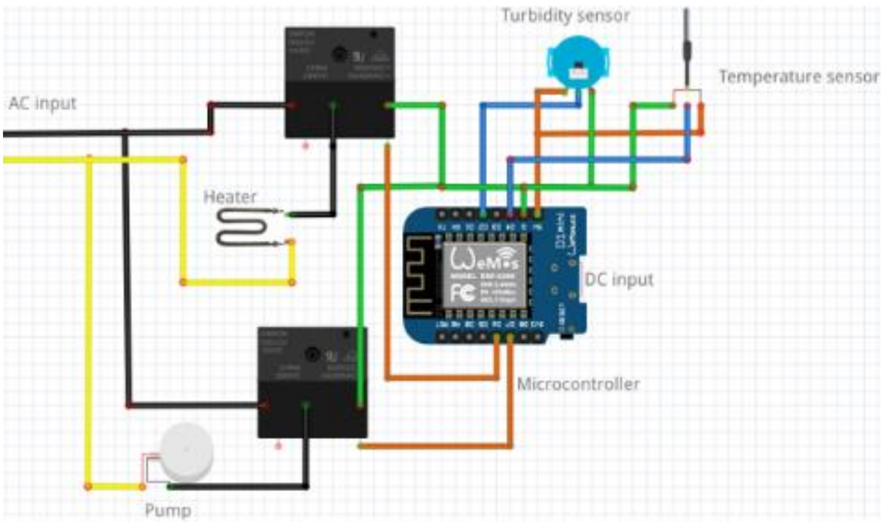

Figure 4. Simple schematic sketch of the system

Figure 4 shows the wiring connection of the microcontroller with the other components. With 4 digital I/O pins used to communicate with sensors and actuators. The actuator in this system is 2 optocoupler relays, as it can control the water pump and water heater with isolation provided by an optocoupler to isolate high voltage from the water pump and heater to the microcontroller and other low-voltage components.

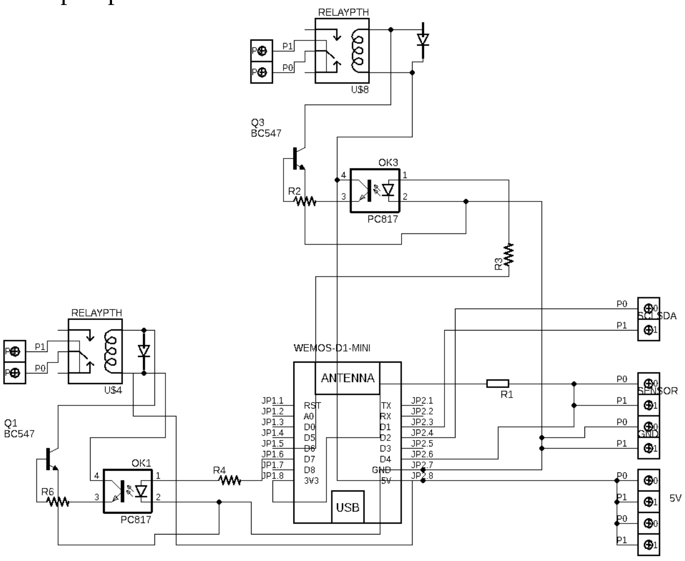

Figure 5. Schematic design of the system

Figure 5 shows the schematic design with several components connected to the microcontroller module Wemos D1 Mini. The socket header is mostly on the right side and can be used to connect sensors and pass on power to the sensors from the microcontroller. For controlling the actuators, it must have isolation because of the high voltage the actuator requires. Hence relay is used for controlling the actuator. A relay alone is not enough to protect the microcontroller from high voltage; therefore, a diode and optocoupler are a must to provide isolation. This type of isolation is to provide double-galvanic isolation between high-voltage devices in AC and low-voltage devices in DC.

3. RESULTS AND DISCUSSION

3.1 System Performance

The system has been tested to run for 6 days without stopping. From Table 2, the system can increase the water temperature from 26 to 29°C within 16 minutes. This gradually increases temperature also to not give the shrimp a shock from a sudden increase in water temperature. The result also shows that the system can maintain the water temperature at a range that is better for shrimp production.

Table 2. Time for the water temperature to increase.

Time	Heater	Temperature (C°)
06/22/23 11:16:00 PM	off	29.0
06/22/23 11:15:00 PM	on	28.8
06/22/23 11:14:00 PM	on	28.7
06/22/23 11:13:00 PM	on	28.5
06/22/23 11:12:00 PM	on	28.3
06/22/23 11:11:00 PM	on	27.9
06/22/23 11:10:00 PM	on	27.9
06/22/23 11:09:00 PM	on	27.6
06/22/23 11:08:00 PM	on	27.3
06/22/23 11:07:00 PM	on	27.0
06/22/23 11:06:00 PM	on	26.9
06/22/23 11:05:00 PM	on	26.7
06/22/23 11:04:00 PM	on	26.5
06/22/23 11:03:00 PM	on	26.4

06/22/23 11:02:00 PM	on	26.2
06/22/23 11:01:00 PM	on	25.9

The microcontroller is connected to WiFi with 802.11 n IEEE standard at 2.4GHz and the distance between the microcontroller access point (AP) at 3 meters. Based on Table 3, the average response time of the system from user input is 2.093s.

Table 3. Response time of the system

Test number	Response time (s)
1	1.56
2	1.44
3	2.02
4	2.49
5	2.26
6	2.62
7	2.73
8	2.97
9	1.46
10	1.38
average	2.093

3.2 Shrimp Mortality

There is a difference in shrimp performance when the shrimp aquarium is installed with the monitoring system and another aquarium without a monitoring system. Each tank has the same source of the water and same source of shrimp vendor. The shrimp is spread at the same time in both water tanks. On Day 4, the water turbidity warning notification is pushed to the Blynk, then the water from both tanks is changed with new water.

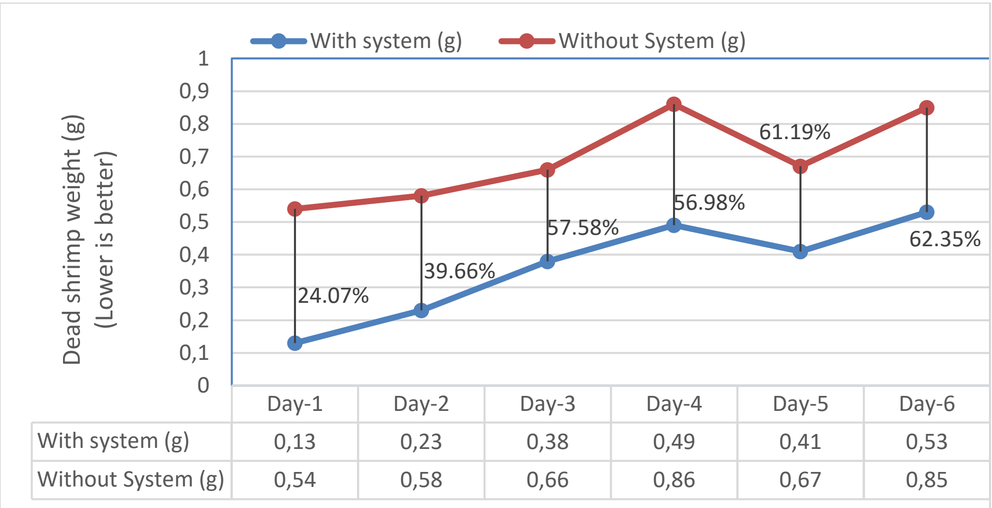

Figure 6. Shrimp mortality rate

Figure 6 is a chart that shows the mortality rate of the shrimp in 2 different tanks. The red line is the mortality of the shrimp in a tank without a monitoring system. While the blue line is the tank with a monitoring system installed. Water temperature control can affect the mortality of the shrimp. A tank installed with a monitoring system has lower mortality than a tank without a monitoring system. The total decrease in mortality of the shrimp at 52.74%. On Day 5, the mortality from the 2 tanks is decreased because of the water change that conducted on Day 4. Thus, water turbidity can also affect the mortality of shrimp.

4. CONCLUSION

From the test results, it can be concluded a system to maintain the water quality pond of the *P. vannamei* shrimp is needed. As it can help to improve the health and performance of the shrimp, it can also give a higher yield on harvest day. The mortality rate of the shrimp decreased to 52.74% on average for 6 days. With an IoT-based system, it can help shrimp farmers control the water quality of the pond without direct contact with the pond thus saving time to check the water quality and increasing the safety of the farmer. The system can also maintain the best water condition for the shrimp at 26-29°C and send a notification to change water if the water turbidity is above 30NTU. Shrimp farmers are also able to change the variable of condition based on their preference so it can be used for another type of shrimp.

REFERENCES

[1] M. Briggs, S. Funge-Smith, R. Subasinghe, and M. Phillips, "Food and agriculture organization of the United Nations regional office for Asia and the Pacific: Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific," Bangkok, 2004.

[2] D. L. Lovett and D. L. Felder, "Ontogeny of kinematics in the gut of the white shrimp penaeus setiferus (Decapoda: Penaeidae)," 1990. [Online]. Available: http://www.jstor.orgURL:http://www.jstor.org/stable/1548669

[3] H. Dugassa and D. G. Gaetan, "Biology of white leg shrimp, Penaeus vannamei: Review," *World Journal of Fish and Marine Sciences*, vol. 10, no. 2, pp. 5–17, 2018, doi: 10.5829/idosi.wjfms.2018.05.17.

[4] Food and Agriculture Organization of the United Nations, *FAO Yearbook. Fishery and Aquaculture Statistics 2019/FAO annuaire. Statistiques des pêches et de l'aquaculture 2019/FAO anuario. Estadísticas de pesca y acuicultura 2019*. FAO, 2021. doi: 10.4060/cb7874t.

[5] F. Amelia, A. Yustiati, and Y. Andriani, "Review of shrimp (Litopenaeus vannamei (Boone, 1931)) Farming in Indonesia: Management Operating and Development", [Online]. Available: www.worldscientificnews.com

[6] L. A. Wati, "Analyzing the development of Indonesia shrimp industry," *IOP Conf Ser Earth Environ Sci*, vol. 137, p. 012101, Apr. 2018, doi: 10.1088/1755-1315/137/1/012101.

[7] [MMAFI] Ministry of Marine Affairs and Fisheries of Indonesia, "MMFI Annual Report 2020," 2020.

[8] A. P. Pawar, S. V. Sanaye, S. Shyama, R. A. Sreepada, and A. S. Dake, "Effects of salinity and temperature on the acute toxicity of the pesticides, dimethoate and chlorpyrifos in post-larvae and juveniles of the whiteleg shrimp," *Aquac Rep*, vol. 16, p. 100240, Mar. 2020, doi: 10.1016/j.aqrep.2019.100240.

[9] O. M. Vidal, C. B. Granja, F. Aranguren, J. A. Brock, and M. Salazar, "A Profound Effect of Hyperthermia on Survival of Litopenaeus vannamei Juveniles Infected with White Spot Syndrome Virus," *J World Aquac Soc*, vol. 32, no. 4, pp. 364–372, Dec. 2001, doi: 10.1111/j.1749-7345.2001.tb00462.x.

[10] M. M. Rahman *et al.*, "The effect of raising water temperature to 33 °C in Penaeus vannamei juveniles at different stages of infection with white spot syndrome virus (WSSV)," *Aquaculture*, vol. 272, no. 1–4, pp. 240–245, Nov. 2007, doi: 10.1016/j.aquaculture.2007.07.228.

[11] X. Liao *et al.*, "The effect of water temperature on the pathogenicity of decapod iridescent virus 1 (DIV1) in Litopenaeus vannamei," *Israeli Journal of Aquaculture - Bamidgeh*, vol. 74, 2022, doi: 10.46989/001C.33012.

[12] H. A. Abdelrahman, A. Abebe, and C. E. Boyd, "Influence of variation in water temperature on survival, growth and yield of Pacific white shrimp Litopenaeus vannamei in inland ponds for low-salinity culture," *Aquac Res*, vol. 50, no. 2, pp. 658–672, Feb. 2019, doi: 10.1111/are.13943.

[13] A. P. Pawar, S. V. Sanaye, S. Shyama, R. A. Sreepada, and A. S. Dake, "Effects of salinity and temperature on the acute toxicity of the pesticides, dimethoate and chlorpyrifos in post-larvae and juveniles of the whiteleg shrimp," *Aquac Rep*, vol. 16, Mar. 2020, doi: 10.1016/j.aqrep.2019.100240.

[14] V Venkateswarlu, PV Seshaiah, P Arun, and PC Behra, "A study on water quality parameters in shrimp L. vannamei semi-intensive grow out culture farms in coastal districts of Andhra Pradesh, India," *International Journal of Fisheries and Aquatic Studies* , vol. 7, no. 4, pp. 394–399, 2019, doi: dx.doi.org/10.22271/fish.

[15] Y. S. Kim *et al.*, "Effects of wheat flour and culture period on bacterial community composition in digestive tracts of Litopenaeus vannamei and rearing water in biofloc aquaculture system," *Aquaculture*, vol. 531, Jan. 2021, doi: 10.1016/j.aquaculture.2020.735908.

[16] M. Araneda, E. Gasca-Leyva, M. A. Vela, and R. Domínguez-May, "Effects of temperature and stocking density on intensive culture of Pacific white shrimp in freshwater," *J Therm Biol*, vol. 94, Dec. 2020, doi: 10.1016/j.jtherbio.2020.102756.

[17] S. A. Kathyayani, M. Muralidhar, T. S. Kumar, and S. V. Alavandi, "Stress Quantification in Penaeus vannamei Exposed to Varying Levels of Turbidity," *J Coast Res*, vol. 86, no. sp1, p. 177, Nov. 2019, doi: 10.2112/SI86-027.1.

[18] M. Banzi and M. Shiloh, *Getting started with Arduino*, Third Edition. Sebastopol: Maker Media, 2014.

[19] M. Carminati and G. Scandurra, "Impact and trends in embedding field programmable gate arrays and microcontrollers in scientific instrumentation," *Review of Scientific Instruments*, vol. 92, no. 9, p. 091501, Sep. 2021, doi: 10.1063/5.0050999.

[20] Wemos, "Wemos LOLIN D1 Mini," 2021. www.wemos.cc/en/latest/d1/d1_mini.html (accessed Jan. 01, 2023).

[21] IEC, "IEC 60751: Industrial platinum resistance thermometers and platinum temperature sensors Thermomètres à résistance de platine et capteurs hermométriques de platine industriels," 2022