Design and Construction Pond Temperature Control System and Automatic Nile Tilapia Fish Feeder for Aquaponics

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Abstract— **Expansion of land for the development of human civilization reduces natural ecosystems. Especially land for agriculture and fisheries in densely populated areas. The more the population, the more food needs. One way to deal with this problem is aquaponic cultivation. Aquaponics is a modern practical farming system that integrates plant cultivation systems with aquatic animal cultivation. In aquaponics cultivation there are factors that need to be considered. One of these success factors is the Temperature and Automatic Feeder in the pond. To get the temperature needed by the fish, temperature control is carried out using the DS18B20 sensor. When the fish pond temperature drops below 28°C, the heater will automatically turn on to raise the pond temperature, and when the pond temperature rises above 32°C, the peltier will turn on and start lowering the pond temperature. Feeding is one of the success factors for aquaponics. If the feed given does not match the weight and age of the fish, the growth of the fish can be disrupted, causing the fish to die. Automatic feeding uses the RTC module as the set time and the servo motor as the opening valve for the fish feed container. Fish were fed at 08.00, 12.00, and 17.00. The average error obtained after validating the DS18B20 sensor is 0.61. The accuracy obtained is 98.05%. The ratio of fish RGR before and after the control system was installed was 7.14% and 11.2 The fish FCR values before and after the control system was installed were 12.50% and 21.07%. The plant growth rates before and after the control system was installed were 22.9% and 33.71%.**

Keywords—**Alphabetically sorted, Aquaponic, DS18B20 Sensor, Servo motor, RTC**

I. Introduction

The current use of land to build large buildings and expand human civilization. Land use is increasing, while the availability of land is limited which results in land conversion from agricultural to non-agricultural land. Agricultural land is becoming very scarce in urban areas. Meanwhile, the demand for food needs is increasing with the rapid increase in population. One alternative way to address this need is to use a landless farming system called Aquaponics.

Aquaponics is a modern practical agricultural system that combines an integrated plant cultivation system with the cultivation of aquatic animals (fish) [1]. Aquaponics is one way to reduce water pollution due to fish farming and as an alternative to reducing the amount of water used for aquaculture. Aquaponic technology is an alternative that can be applied to overcome water limitations [2]. Water as a medium for fish cultivation is the main factor in fish breeding [3]. Therefore, it is important to analyse and know the various factors that can affect water quality and natural characteristics to provide a natural source of life for aquaculture. To produce superior fish commodities, a system is needed to monitor and measure pond water quality and control feed in the aquaponics system. Pond temperature is one of the things that need to be considered so that fish can grow well. An increase and decrease in pond water temperature that is erratic and does not match the condition of the fish will cause the fish to have difficulty carrying out the energy mobilization process and result in death in a short time [4]. A good livestock management system is the main factor in obtaining good quality fish [5]. One of them is feeding which must be monitored to match the frequency of feed needed by fish, excess feeding will cause nile tilapia fish to get sick, even die [6].

Based on the problems described in the previous paragraph, this research will design a more innovative aquaponics system. The system identifies feed control and pond water temperature. Automatic feed control is set at the specified time using RTC. Feeding was given at 10.00, 14.00, and 22.00. When the temperature of the fish pond drops to about 28°C and below, the heater will automatically turn on to raise the temperature of the pond, and when the temperature of the pond rises, the peltier will turn on and start lowering the temperature of the fish pond. The importance of continuous monitoring of water quality and temperature on the success of Aquaponics, it is necessary to design an automatic water temperature control and monitoring system device. The parameters controlled in this study consisted of feed control and water temperature. Research is expected to provide better changes to the aquaponics system.

A. Aquaponic System Definition

Aquaponics is a combination of aquaculture and hydroponic cultivation systems that can be a solution to overcome land limitations, limited water resources and increase food security [7]. In normal aquaculture, excretions from reared aquatic animals will accumulate in the water and increase the toxicity of the water if the water is not removed. In aquaponics, animal excretions (ammonia) are given to plants to be broken down into nitrates and nitrites through natural processes, and utilized by plants as nutrients. The pond water then

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circulates back into the aquaculture system. Because hydroponic and aquaculture systems are very diverse in shape, aquaponic systems also become very diverse in terms of size, complexity, types of living things, and so on. Plants are grown in a hydroponic system with their roots submerged in a nutrient-packed solution. This makes the plant able to absorb nitrogen which can be toxic to fish, so the roots function as a natural filter. After the water is finished through the hydroponic system, it is cleaned through the plant roots and aerated before returning to the aquaculture system. Then the cycle continues repeatedly.

B. DFT (Deep Flow Technique) Aquaponic System

DFT Aquaponics is an aquaponic system which working system is to drain water from the bottom pool to the vegetable plant pipe at the top. Next, the water will return to the lower pool. Pumps are used to drain water.

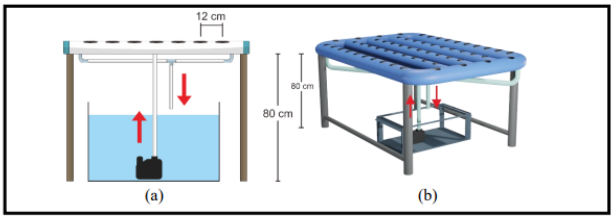

Figure 1. DFT Aquaponics

C. Factors Affecting Aquaponic Cultivation

To start aquaponics activities, exact knowledge is needed so that aquaponics can be successful. However, there will be problems that must be resolved so that it does not affect aquaponics. The problem consists of several factors that can affect the success of aquaponics cultivation. One of the factors that affect the success of aquaponics is the temperature and feeding time. Water temperature is one of the important factors that affect the fish's living media because the right temperature can provide fish comfort. Feeding fish on time can meet the basic needs of fish so that fish growth is stable.

D. Static Characteristics Measurement System of the Sensor

In the tool that will be made in this study, learning media is needed to determine the use and need for sensors in the datasheet to be used, so it is necessary to analyze the static characteristics. The static characteristics that are often used in instrumentation are:

1. Error
   Error is the difference between sensor and validator readings on an object. The smaller the error value, the more accurate the sensor is.
   Measurement error, E:
   $$E = measured\ value - true\ value = system\ output - system\ input \quad (1)$$
   The mean value of the system error is the difference between the mean value of the system output and the mean value of the system input or:
   $$E = O - I \quad (2)$$
   If the probability density of the output of the measurement system elements is normal, then the probability density function of the system output and system error is also normal [6].
2. Accuracy
   Accuracy is the ability of a measuring instrument to provide an approximate indication of the object being measured in actual value. Accuracy is defined as the difference or closeness between the read value of the measuring instrument and the actual value. The accuracy formula is:
   $$Accuracy = 100 - eror \quad (3)$$

E. Parameters Measured in Aquaponics

Parameters measured in the aquaponics system to be worked on are water spinach and nile tilapia fish. These parameters are related to the survival rate and growth rate of water spinach and nile tilapia fish.

1) Parameters Measured from Water Spinach
   Plant growth parameters were measured every three days including plant height, leaf width, leaf length, number of leaves, and plant weight after harvest. The data obtained from the observations were tabulated and processed in tabular form and analyzed descriptively. Water spinach can be harvested simultaneously on the 30th day after planting.
   Plant growth was measured on the absolute length variable with the formula used in the studies, in the journal.
   $$L = L_t - L_0 \quad (4)$$
   L = Absolute length (cm)
   L_t = Plant length at the end of the study (cm)
   L_0 = Plant length at the beginning of the study (cm)
   The results of an analysis from a journal [9] on aquaponics using catfish and water spinach showed that the growth rate of water spinach in the aquaponics system included plant height, leaf length, and leaf width, respectively, 2.51 cm/three days, 0.75 cm/three days, and 0.24 cm/three days, without a control system.
2) Parameters Measured from Nile Tilapia Fish
   In addition to having a positive effect on the growth of water spinach, the aquaponics system also has a positive effect on the survival of the catfish. The fish used are baby catfish with a length of 5cm-8cm and a weight of approximately 0.6 grams. The fish are acclimatized and fasted for 2 days in order to adapt to their environment. Feeding in the morning and evening with a dose of 5% of the fish body weight. The growth of catfish measured was the length and weight of the fish.
   The calculation of fish weight or relative growth rate (RGR) in this study was calculated for 14 days. Fish weight will be measured every week after the prototype has been installed. Fish weight is calculated based on the formula described:
   $$RGR = \frac{W_t - W_0}{W_0 \times t} \times 100\% \quad (5)$$
   RGR = Relative Grow Rate (%/day)
   W_t = Average fish weight at the end (g)
   W_0 = Average fish weight at the beginning (g)
   t = length of treatment (day)
   Feed was given ad satiation for each treatment and replication [11]. Ad satiation is feeding until the fish are full. Feeding is given every 3 times a day. Feeding uses the formula below according to :

$$FCR = \frac{F}{((W_t + t) - W_0)} \quad (6)$$

FCR = Feed Convertation Ratio
F = Amount of fish feed during rearing (g)
W_t = Fish biomass at the end of the study (g)
W_0 = Fish biomass at the beginning of the study (g)
D = Total dead fish weight (g)
Mass deaths occur when it rains with high intensity. The decrease in water temperature due to high intensity rain causes the seeds to weaken. The water temperature in the aquaponic system not only affects the type of fish, but also affects plant growth and the performance of nitrifying bacteria .
The survival rate of nile tilapia fish can be calculated using the formula according to :

$$SR = \frac{N_t}{N_0} \times 100\% \quad (7)$$

SR = Survival Rate (%)
N_t = Number of live fish at the end of rearing
N_0 = Number of live fish at the beginning of rearing
According to journal for 30 days of fish rearing, there was an increase in weight of 11.25 grams/fish with a survival rate of 93% [14].

F. *Components Used in Research*

Aquaponics usually does not include sophisticated automated systems. The aquaponics system that will be made uses two kinds of sensors. The sensor used is the DS18B20 temperature sensor and the component used as a timer for feeding is RTC which is programmed using the ATmega328 microcontroller. The following are the components that will be used in this research.

1. DS18B20 Temperature Sensor
   The DS18B20 is the latest series digital temperature sensor from Maxim IC which is capable of reading temperatures with an accuracy of 9 to 12-bit, a range of -55°C to 125°C, with an accuracy of ±0.5°C [15]. The temperature sensor resolution is user configurable up to 9, 10, 11, or 12 bits, according to temperature increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively and the resolution the default in power-up is 12-bit . The DS18B20 sensor uses a pull-up resistor of 4.7kΩ which is connected to VCC and a signal so that the temperature value can be read properly. This sensor uses 1-Wire communication which means it only requires one pin [16]. The DS18B20's unique 64-bit sensor allows the DS18B20 to be connected to several of the same functions via the same cable.
2. Motor Servo
   A servo motor is a motor with a closed feedback system in which the position of the motor will be informed back to the control circuit in the servo motor. This motor consists of a DC motor, a series of gears, a potentiometer and a control circuit. Potentiometer to determine the angular limit of the servo rotation . While the angle of the servo motor axis is regulated based on the pulse width sent through the signal leg from the motor cable .

Figure 2. Motor Servo

3. DS3231 RTC Module
   The DS3231 RTC (Real Time Clock) module is an IC chip that functions to calculate time starting from seconds, minutes, hours, days, dates, months, to years accurately. To maintain or store time data that has been turned ON, the module has its own power supply source in the form of a button battery, and the accuracy of the time data displayed is used by an external crystal oscillator.

Figure 3. DS3231 RTC Module

4. ATmega328
   This microcontroller has complete features, consisting of large program and data memory capacity, interrupts, timer/counter, PWM, USART, TWI, analog comparator, internal EEPROM, and internal ADC. The ATMega328 microcontroller pin configuration is shown in Figure 4.

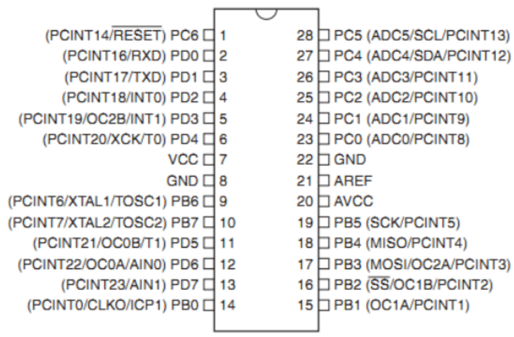

Figure 4. ATmega328

5. Peltier
   A Peltier cooler is a cooling machine consisting of a Peltier element (TEC chip). When a DC voltage is applied to the TEC chip, the positive and negative charge carriers in the plate array absorb heat energy from one surface of the medium and release it to the substrate on the opposite side. The surface where heat energy is absorbed becomes cold, and the opposite surface where heat energy is released becomes hot.

Figure 5. Peltier

6. LCD 16×2
   LCD (Liquid Crystal Display) 16×2 is one of the tools used as a display. M1632 is a dot-matrix liquid crystal display module with a 2x16 row display with low power consumption.

Figure 6. Heater

G. Nile Tilapia Fish Feeding

Feed is important as a nutrient that is needed by fish (Amalia & Agriculture of the State of Pangkajene Islands, 2018). Fish feed management is one of the success factors for fish farming [20]. Feeding is adjusted based on the age and weight of the fish. If the feed given is too large, the feed will expand in the stomach and make it difficult for the fish to move. If the feed given is too small, the fish will often starve to death. Nile tilapia fish feeding is carried out 3 times a day. Feeding 3 times is also written in the Standard Operational Procedure for Tilapia (Oreochromis niloticus) enlargement made by the Ministry of Marine Affairs and Fisheries of the Directorate General of Aquaculture in 2020.

H. Control System Performance

This research makes automatic monitoring and control of aquaponics temperature using DS18B20 as a temperature sensor and servo motor as an actuator for opening fish feed containers. According to SNI 06-6989.23-2005, a good water temperature range for fish is 27 ± 28 °C. Meanwhile, according to the journal the right temperature for tilapia is 28°C-32°C. If the temperature drops below 28°C, the heater will automatically turn on to raise the temperature of the aquaponics pool. While the peltier will lower the temperature when the pool water increases in temperature. Feed is given when the servo motor opens the lid of the feed container at a predetermined angle and time. Feeding time has been programmed using RTC, where fish are fed 3 times a day at 08.00, 12.00, and 17.00.

II. METHOD

A. Aquaponic Design

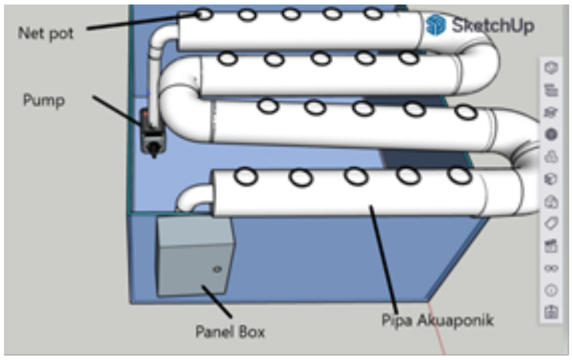

Figure 7. Aquaponic design

Figure 7 shows the design of a Temperature Control and Automatic Feeding Device. In the picture there is an S-shaped pipe that functions as a netpot for water spinach. To drain the water in the pipe, a water pump is installed which functions as a source of plant growth. In addition, there are temperature and ammonia sensors as the main variables in this study. there is a water filter and an oxygen source so that the water conditions are good enough for fish.

The block diagram for controlling the temperature control system and automatic feed in aquaponics using the on-off method is shown in Figure 8.

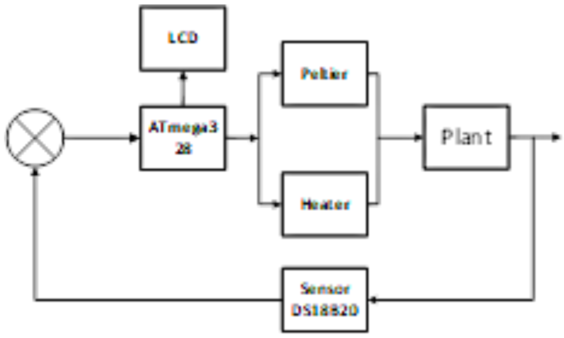

Figure 8. Temperature Control System Block Diagram

The input of this temperature control system is the temperature of the pool water which has been sensed by the DS18B20 temperature sensor. Sensing results will be inputted to activate the heater or peltier. If the temperature is less than 28°C the heater will turn on, if the temperature is more than 32°C the peltier will be turn on to normalize the pool temperature.

Feed will be fed using a feed control system using a servo motor as a valve for opening and closing the feed container. Feeding is scheduled at 08.00, 12.00, and 17.00 using RTC as a real time module.

The hardware design scheme for the temperature and feed control system in aquaponics is made as shown in Figure 9.

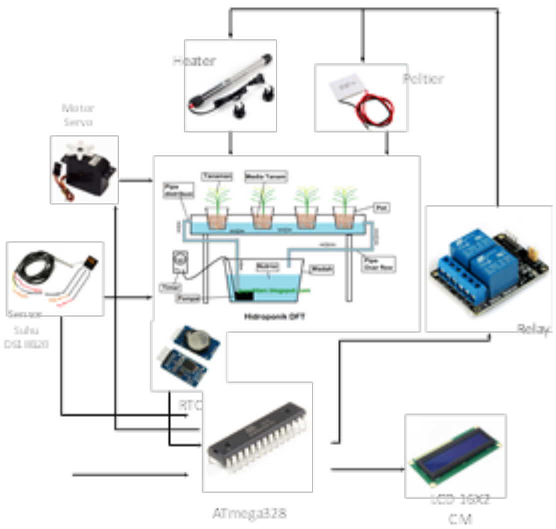

Figure 9. Design Schematic of Temperature Control System and Automatic Feeding Hardware in Aquaponics

The DS18B20 temperature sensor senses objects in aquaponics to obtain sensing data. ATmega328 which processes data sensing to be monitored and controlled automatically. Sensing data by the temperature sensor is sent to the ATmega328 which is then processed to give commands to the automatic control system. Sensing data that enters the ATmega328 will appear on the LCD screen as a monitoring device. The pool water temperature sensing data on the ATmega328 will give an order based on the program to the relay to turn on the heater, if the pool temperature decreases to less than 28°C, and if the temperature rises more than 32°C, the relay will turn on the peltier to cool the pool water. Automatic feed control in this system runs with time setup using RTC at 08.00, 12.00, and 17.00. The valve to open and close the feed container will be controlled using a servo motor with the help of RTC which is programmed using an ATmega328 microcontroller to set the servo motor valve opening time.

When the pool water temperature shows less than 28°C, the heater will turn on until the temperature is stable which will then re-initialize. And when the initialized temperature shows more than 32°C, then the peltier will turn on to normalize the pool temperature. When the temperature control system is correct in measuring the temperature of the pool water, it can be said that the system can control the temperature well. The servo motor opening valve will open when the RTC timing program shows the set time. For example, when the time shows 08.00, the servo valve will open with an amount of feed of approximately 9 grams for fish weighing an average of 6 grams.

B. Hardware Design

The electrical design schematic is shown in Figure 9 where the ATmega 328 acts as a microcontroller that controls the sensor output into commands that will control the heater, peltier, and servo motor according to a predetermined set point.

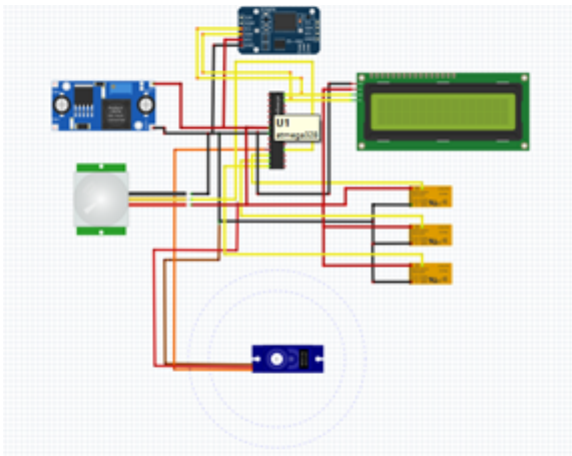

Figure 10. Wiring Machine Scheme

The specifications of the tools in Figure 10 are:

1. ATmega328
   The microcontroller used to control the system is ATmega328. This IC is designed with crystals to function the same as Arduino.

Figure 11. ATmega328

ATmega328 specifications are shown in Table 1.

TABLE 1.
ATMEGA328 SPECIFICATION

Program Memory Type	Flash
Program Memory Size (KB)	32
CPU Speed (MIPS/DMIPS)	20
SRAM (B)	2,048
Data EEPROM/HEF (bytes)	1024
Digital Communication Peripherals	1-UART, 2-SPI, 1-I2C
Capture/Compare/PWM Peripherals	1 Input Capture, 1 CCP, 6PWM
Timers	2 x 8bit, 1 x 16bit
Number of Comparators	1
Temperature Range (°C)	-40 to 85
Operating Voltage Range (V)	1.8 to 5.5
Pin Count	32
Low Power	Yes

2. DS18B20 Temperature Sensor
   The temperature sensor used for this aquaponics control system is the DS18B20, which is often used to sense water temperature.

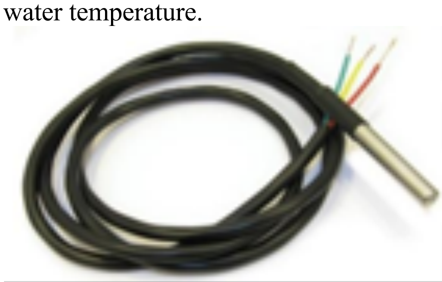

Figure 12. DS18B20 Sensor

DS18B20 specifications are shown in Table 2.

TABLE 2.
DS18B20 SPECIFICATION

Programmable Digital	Temperature Sensor
Communicates	1-Wire method
Operating voltage	3V to 5V
Temperature Range	-55°C to +125°C
Accuracy	±0.5°C
Output Resolution	9-bit to 12-bit (programmable)
Unique 64-bit address	enables multiplexing
Conversion time	750ms at 12-bit

3. RTC
The ammonia sensor used for this aquaponic control system is MQ137. This sensor needs an enclosed space in order to sense ammonia in aquaponics.

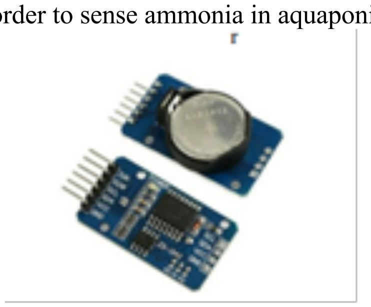

Figure 13. RTC

RTC Specifications are shown in Table 3.

TABLE 3.
RTC SPECIFICATION

Specification
DS3231 Module Operating Voltage: 2.3V – 5.5V
Can operate at low voltage
Consumes about 500nA while on battery
Maximum voltage on SDA, SCL: VCC + 0.3V
Operating Temperature: -45ºC to +80ºC

4. LCD 16 x 2
The LCD used to display the temperature and ammonia sensing results is a 16 × 2 LCD with I2C. This LCD can be controlled using only 2 pins, SDA and SCL.

Figure 14. LCD 16 x 2

LCD 16 x 2 Specifications are shown in Table 4.

TABLE 4.
LCD 16 X 2 SPECIFICATION

Specifications	
The operating voltage of this display	ranges from 4.7V to 5.3V
The display bezel	72 x 25mm
The operating current	1mA without a backlight
PCB size of the module	80L x 36W x 10H mm
HD47780	controller
LED color for backlight	green or blue
Number of columns	16
Number of rows	2
Number of LCD pins	16
Characters	32
works	in 4-bit and 8-bit modes
Pixel box of each character	5×8 pixel
Font size of character is	0.125Width x 0.2height

5. Motor Servo
The servo motor is used to open and close the valve of the fish feed container according to a predetermined set time.

Figure 15. Motor Servo

Motor Servo Specifications are shown in Table 5.

TABLE 5.
MOTOR SERVO SPECIFICATION

Specifications	
Size	38 x 11.5 x 24mm (Include tabs) 28 x 12.7 x 27mm (Not include tabs)
Weight	17g (Not include a cable and a connector) 18g (Include a cable and a connector)
Speed	0.14sec/60degrees (4.8V) 0.12sec/60degrees (6.0V)
Torque	2.5kgf-cm (4.8V) 3.0kgf-cm (6.0V)
Voltage	4.8V-6.0V
Connector Type	JR type '(Yellow: Signal, Red: VCC, Brown:GND)'

6. Peltier
The coolant used in the aquaponics temperature control system is Peltier. There is a heatsink on the peltier which is attached with a small and clear hose for water to flow. The water turns cold which is then flowed into the pool so that the temperature returns to normal.

Figure 16. Peltier

Peltier Specifications are shown in Table 6.

TABLE 6.
PELTIER SPECIFICATION

Specifications	
Power supply	0 - 15.2V (max)
Input current	0 - 6A (max)
Power	60W
Operating Temperature	-55 - 83°C
Dimensions	40 x 40 x 4mm
One side produces heat and the other side produces cold	
This module must be used together with a heatsink	

C. System Testing

Testing or validation of sensors to determine the accuracy of sensor readings, so that when the system is running it can support the success of system control. Data retrieval is carried out after the sensor readings are appropriate. The data taken will be compared with the readings on the measuring instrument used. If the sensor reading is far from the results read by the measuring instrument, it will be re-validated. Control testing is also carried out by testing whether the heater and peltier can respond according to the set point that has been determined. Likewise with the automatic feed system, whether the servo motor can function properly according to the set point that has been determined or not.

D. Data Analysis

Data analysis to determine the measurement and control performance of the temperature control system and automatic feeding in aquaponic fish ponds. The measurement results are used to process and run the system. Measurement data from sensors and measuring instruments will be used as comparison data. Quantitative data analysis techniques are used in this study because numerical data can be calculated accurately and analyzed in the form of tables and graphs.

III. RESULTS AND DISCUSSION

A. DS18B20 SENSOR VALIDATION

Validation using a mercury thermometer validator and temperature sensor DS18B20 was carried out on June 6, 2022. The data taken has a span of 5 minutes for each data collection in an aquaponic pond. The temperature sensor validation table data is shown in Table 7.

TABLE 7.
DS18B20 SENSOR VALIDATION

Time	DS18B20 (°C)	Validator (°C)	Error	Accuracy
09:05	26.12	27	0.88	96.74
09:10	26.3	27	0.7	97.41
09:15	26.44	27	0.56	97.93
09:20	26.5	27	0.5	98.15
09:25	26.5	27	0.5	98.15
09:30	26.56	27	0.44	98.37
14:05	27.94	28.5	0.56	98.04
14:10	27.94	28.5	0.56	98.04
14:15	27.87	28.5	0.63	97.79
14:20	27.94	28.5	0.56	98.04
14:25	28	28.5	0.5	98.25
14:30	28	28.5	0.5	98.25
21:05	27.5	28	0.5	98.21
21:10	27.56	28	0.44	98.43
21:15	27.56	28	0.44	98.43
21:20	27.5	28	0.5	98.21
21:25	27.62	28	0.38	98.64
21:30	27.62	28	0.38	98.64

The graph can be seen in Figure 17.

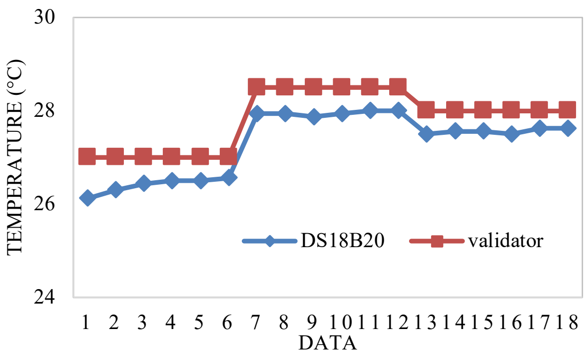

Figure 17. DS18B20 Sensor Validation Graph

B. CONTROL TESTING

The test carried out is the temperature control that has been applied. The test was carried out for 3 days in the morning, afternoon, and evening. Data is taken in the aquaponics system directly by placing the temperature sensor into the pond and monitoring the results of the sensing sensor on the screen. Monitoring the control system is done by seeing whether the heater and peltier match the set points that have been set. Based on table 8, when the temperature is below 28°C, the heater will turn on and when the temperature is above 32°C, the Peltier will turn on.

Temperature control testing was carried out using 3 samples in 3 different containers. The three containers have different rates of temperature change depending on the amount of water. The first container uses a gallon with a volume of 1.76625 L and an initial temperature of 28.37 °C. This gallon test takes 3 hours for the Peltier test and 30 minutes for the heater test. The graph of the temperature response in gallons can be seen in Figure 18.

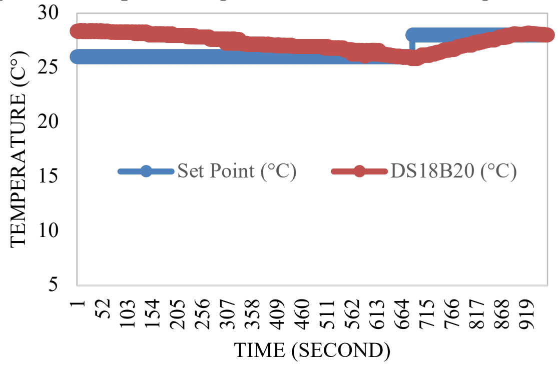

Figure 18. Graph of Temperature Control in Container 1

The second test was carried out on a lunch box with a size of 16 cm x 16 cm x 7 cm. The volume of water used is 0.6631 L and the initial temperature is 31.56 °C. The second test takes 1 hour 30 minutes for the Peltier test and 40 minutes for the heater test. The graph of the temperature control test in the second container can be seen in Figure 19.

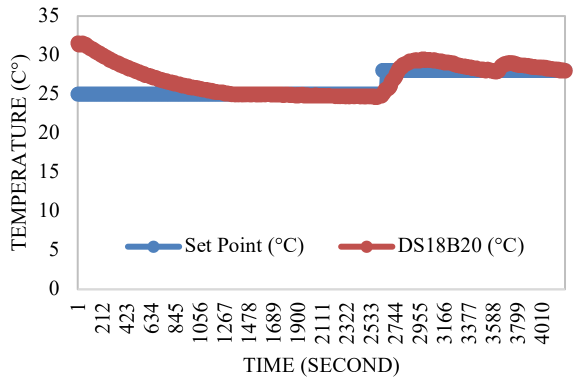

Figure 19. Graph of Temperature Control in Container 2

The third test was carried out on a 1.5 L drinking water bottle with a water volume of 0.3285 L and a temperature of 27.12 °C. Testing on the third container was carried out for 20 minutes for the peltier and 45 minutes for the heater. The graph of the temperature control response in the third container can be seen in Figure 20.

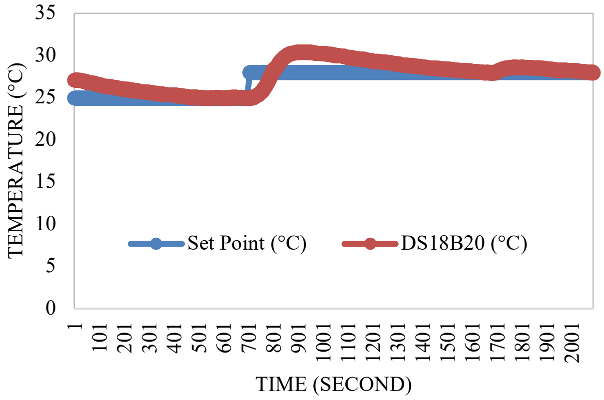

Figure 20. Graph of Temperature Control in Container 3

C. *Nile Tilapia Fish Feeding*

Feeding of nile tilapia fish is based on fish weight and feeding time. Fish feed was given 3 times a day with feeding time at 08.00, 12.00, and 17.00 WIB. Feeding using the satiation method by the National Standardization Agency, 1999.

TABLE 8.
FISH FEEDING ADJUSTMENT

Fish weight (g)	Servo Angle (°)	Delay (ms)	Feed Weight (g)
6	120	1400	9
7	122	1400	10.5
9	123	1300	13.5
11	124	1400	16.5

Fish weight affects feeding based on the servo motor angle that is set. The opening of the servo motor valve is set to a time setting in the form of a delay, to obtain the weight of the feed according to what the fish need. In one feeding, given 9 grams for fish with an average weight of 6 grams with an angle of 120° and an opening delay of 1400 ms.

D. *Water Spinach Comparison Before and After the Control System*

The growth data of plants and fish were compared before and after the control and automatic feed were installed. The data is compared to find out which plant and fish growth is better between before and after the automatic temperature and feed control system.

1. Plant Growth Rate
   To determine that water spinach grows well, it is necessary to measure and analyze the growth of plants and fish. Measurement and analysis of water spinach growth rate data before the installation of the control system can be seen in Table 9.

TABLE 9.
PLANT GROWTH BEFORE CONTROL SYSTEM

Week-	Plant Height (cm)	Absolute Length	Growth Rate (%)
1	2.40	3.2	22.9
2	5.60		

In Table 9 it is known that water spinach grows at a growth rate of 22.9% and an absolute length of 3.2 cm. The growth rate table after the control system is shown in Table 10.

TABLE 10.
PLANT GROWTH AFTER CONTROL SYSTEM

Week-	Plant Height (cm)	Absolute Length	Growth Rate (%)
1	2.52	4.7	33.71
2	7.24		

Table 10 shows the growth rate of water spinach was higher than before the control system, which was 33.71%. In addition, water spinach has an absolute length of 4.7 cm. If the two tables are compared, plant height, plant weight, absolute length, and plant growth rate show higher after the control system was installed.

2. Fish Growth Rate Comparison Data
   The growth of fish before the control system in Table 11 includes the growth rate of fish and the survival rate observed in 4 weeks. It is known that the growth rate of fish is not high enough while the survival rate can be said to be quite high, especially when the system is running well as in the 2nd week which shows a survival rate of 82%. The survival rate value from week 1 to week 2 is getting higher as evidenced by the highest average (RGR) Relative Grow Rate of fish in the 2nd week of 7.14% and the number of fish which is slowly not decreasing with a survival rate of 82%.

TABLE 11.
FISH GROWTH BEFORE CONTROL SYSTEM

Week	W0 (gr)	Wt (gr)	Initial fish amount	Final fish amount	RGR (%)	FCR (g)	SR/ week (%)
1	6	8.6	51	34	7.14	19.8	67
2	8.6	12	34	28			82

The growth rate table after the control system is shown in Table 12.

TABLE 12.
FISH GROWTH AFTER CONTROL SYSTEM

Week	W0 (gr)	Wt (gr)	Initial fish amount	Final fish amount	RGR (%)	FCR (g)	SR/week (%)
1	3	3.9	40	34	11.2	20.7	100
2	3.9	7.7	40	28			100

From Table 12 it can be seen that the growth of fish with the highest survival rate was produced after the control system, which was 100%.

IV. Conclusion

1. The accuracy of the DS18B20 temperature sensor reaches 98.09% with an average reading error of 1.91, indicating that the sensor is accurate enough to be used in the system.
2. The temperature control device has been able to function properly as evidenced by the stable sensing results, which makes the actuator work according to the specified set point.
3. The cooling device/peltier used is too small for a 0.5m x 0.5m x 0.5m pool so that the cold temperature produced by the peltier is not strong enough to cool the pool water if the temperature is

too high above the setpoint. Peltier is only able to cool faster in smaller containers.

4. The automatic feeder is functioning properly, as evidenced by the feed released in accordance with the angle setting and the time delay specified

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