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Automation of Microcontroller-Based Control System for Ph, Temperature, and Turbidity of Aquarium Water

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Abstract

This research is an experimental study to know the effectiveness of the control system for pH, temperature, and turbidity of aquarium water in ornamental fish cultivation. The method used is by assembling an automation tool for controlling the pH, temperature, and turbidity of the aquarium water based on a microcontroller, which is then compared with an aquarium without a control system. This tool is designed using the Arduino Uno as a system controller, the pH sensor E-201-C as a measuring tool for pH levels with a solenoid valve to drain pH up and pH down as a stabilizer for water pH levels, the DS18B20 sensor as a temperature measurement tool by utilizing a heater and DC fan as a water temperature stabilizer, and the turbidity sensor as a turbidity measurement tool with a clean water replacement system as a water turbidity stabilizer. Based on the experiments carried out, it was found that there were significant differences between aquariums using a control system automation tool compared to aquariums without a control system tool. This means that the system that is made is effective and proven to be able to maintain the environmental conditions of ornamental fish with measurement results of pH ranging from 7–7.5, the temperature of 24°–27°C, and water turbidity of 10 NTU.

Keywords: Control System Automation, pH, Temperature, Turbidity, Microcontroller

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INTRODUCTION

Indonesia is a major exporter of world fishery products, which is ranked 8th in 2020 (Perikanan 2021). The fishery products produced come from seawater and freshwater, one of which is freshwater ornamental fish. Freshwater ornamental fish are not only cultivated and exported; they are also in great demand to be kept as entertainment, stress relief or to beautify indoor and outdoor decorations. The thing that needs to be considered in the care of freshwater ornamental fish is the environment of the fish. A healthy fish environment is in the form of water quality that must meet the needs of fish according to their type (H. and K. 2005). Standard water parameters such as pH, temperature, oxygen, ammonia, and carbonic acid are things that need to be considered and maintained so that they are always in optimal conditions, not fluctuating (up and down) (Lesmana and Daelami 2019). The instability of these factors can cause delays in the development of ornamental fish and disruption of fish metabolism, especially osmoregulation, and the worst impact is the death of fish.

The density of community activities, including ornamental fish owners, means fish owners often do not have enough time to pay attention to the health of their pets. Busyness makes the owner sometimes leave the aquarium in a dirty condition, which can cause abnormal water quality that interferes with the growth and development of ornamental fish (Sulaksono and Suryo 2021).

Based on previous research conducted by Rendy Nur Antono in 2022. The result was the tool is capable of monitoring the pH and temperature conditions of the aquarium with a buffer alarm as a sign when aquarium water conditions are not suitable and endanger the condition of the fish (Antono 2022). This study has a drawback in that the pH and temperature control are not designed automatically so that the fish owners wait for free time to stabilize the pH and temperature conditions of the aquarium.

Then further research was carried out by Wike Arianti in 2021. This research resulted in an automation system for controlling pH, temperature, and turbidity (Arianti 2020), but this monitoring system was not equipped with the capability of draining aquarium water. So, if the turbidity of the aquarium water passes the limit point, the aquarium water will remain cloudy until the fish owner drains it manually.

Based on these problems, the authors developed the previous research by raising the topic of Automation of Microcontroller-based Control System for pH, Temperature, and Turbidity of Aquarium Water. This system is expected to make it easier for aquarium owners to control the stability of their aquarium water conditions. In addition to providing information on the values of temperature, pH, and water turbidity, this system provides problem-solving when the three indicators do not match properly. This research aims to determine the effectiveness of the automatic control system for pH, temperature, and air turbidity in ornamental fish cultivation, which is designed automatically so that the air condition is stable following the ornamental fish environment.

METHOD

The method used is experimental research, which is analyzed descriptively through graphs. The object used in this research is the Louhan fish (Flowerhorn) aquarium water with a pH of 7.0–7.5, a temperature of 24–27 °C (Lesmana and Daelami 2019), and water turbidity of 10 NTU (Anonim 2008).

System Design

Hardware Design

The overall hardware system design can be seen in Figure 1.

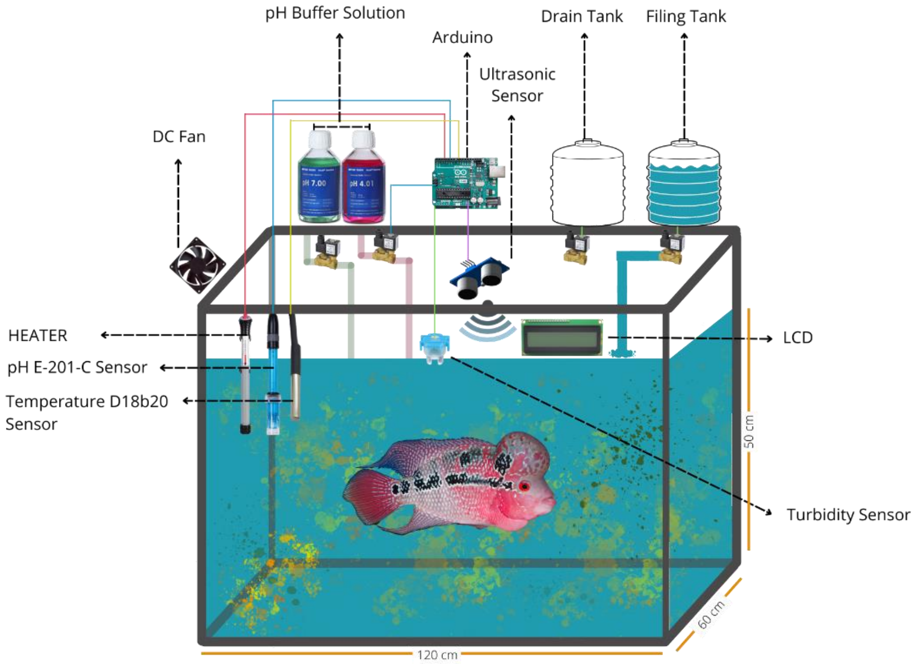

Figure 1. Overall hardware system design.

Based on Figure 1, there are components of the system that will be made with each different use, including:

1. The DS18B20 temperature sensor is used as a component for detecting the aquarium water temperature value.
2. The E-201-C pH sensor is used as a component to detect the pH value of aquarium water.
3. The heater is used to raise the temperature of the aquarium water.
4. A DC fan is used to lower the aquarium water temperature.
5. The pH buffer solution is used as pH up and pH down.
6. The Arduino Uno is used as a system controller and processes data from sensors.
7. An ultrasonic sensor is used as a component for detecting the water level of the aquarium.
8. The tank is used as a water change container.
9. An LCD is used as a component for displaying sensor measurement data.
10. A turbidity sensor is used as a component for detecting the turbidity of aquarium water.

Software Design

Software design Automated Control System for pH, Temperature, and Turbidity of Aquarium Water based on a microcontroller follows the flowchart below.

a. Temperature Sensor Programming

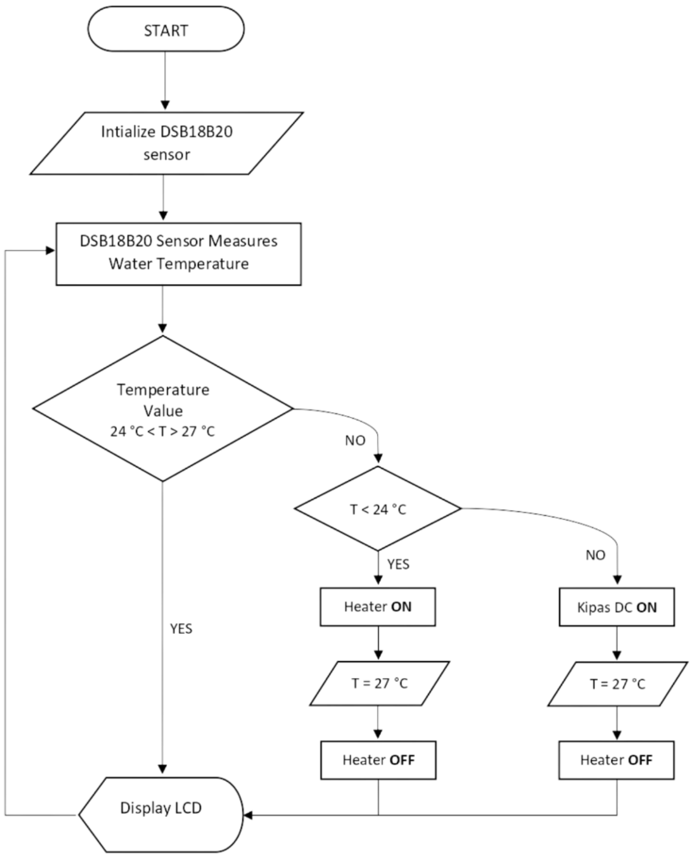

Figure 2. Temperature sensor software design.

Monitoring the water temperature using the DS18B20 temperature sensor is recommended because the DS18B20 sensor has a high accuracy rate of 0.5 °C in a temperature range of 0.5 °C to +85 °C and does not require an ADC to communicate with the microcontroller (Pratiwi 2009). This sensor will read the condition of the aquarium water temperature with its probe. The water temperature is said to be normal if it is 24–27 °C. If the water condition is below 24 °C, it will trigger the heater to turn on, and if it is above 27 °C, it will trigger the DC fan to turn on. The DC fan and heater will turn off automatically when the water temperature reaches normal conditions.

b. Turbidity Sensor Programming

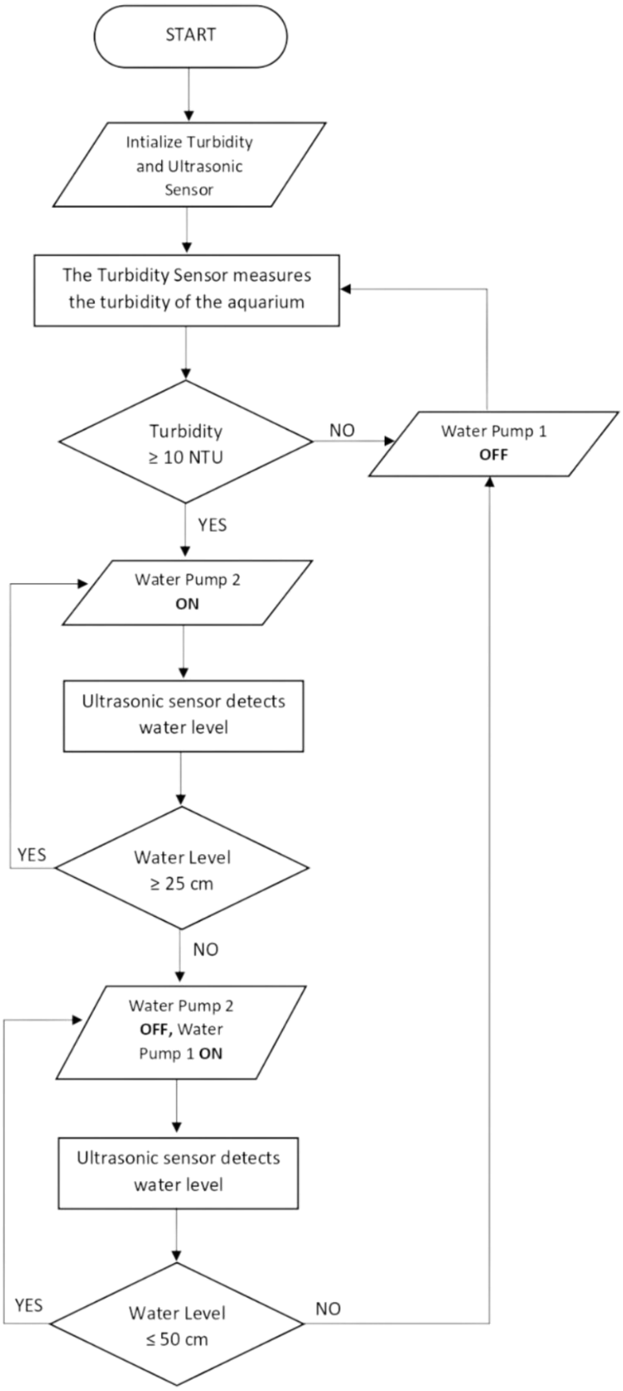

Figure 3. Turbidity sensor software design.

Monitoring water turbidity using a turbidity sensor. This sensor will read the condition of the turbidity value of the aquarium water, and the data will be sent to the Arduino Uno as the system control center. The measured turbidity value is displayed on the LCD. The water is said to be clear if the turbidity of the water is 10 NTU or greater. If > 10 NTU, the relay which was originally off will turn on and the water pump will automatically drain the dirty water. When the drain pump is open, the ultrasonic sensor works to determine the water level in the aquarium. If the ultrasonic sensor detects the water level reaching 25 cm, the device control will stop the drain pump relay and activate the filling pump relay until the water level reaches 50 cm.

c. pH sensor programming

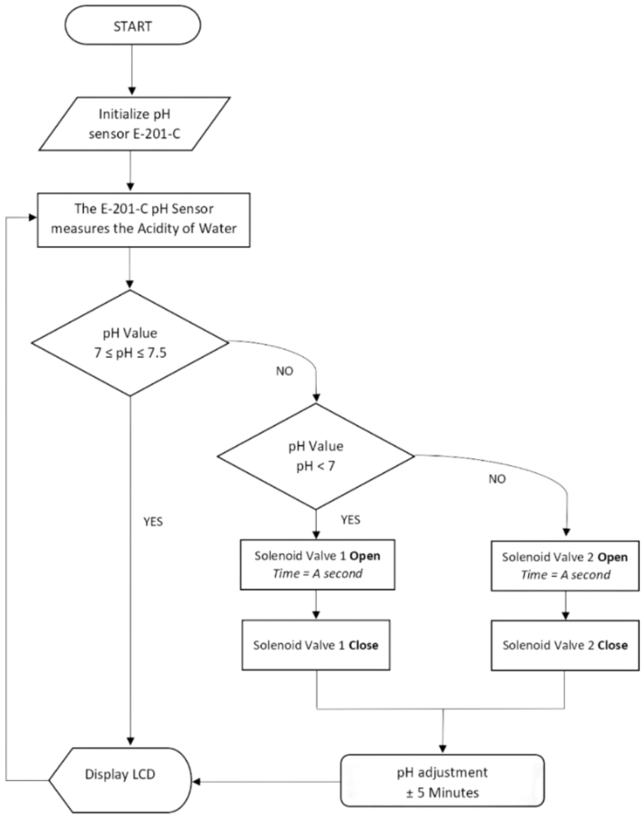

Figure 4. pH sensor software design.

Monitoring the acidity of aquarium water using a pH sensor E-201-C A pH sensor with an electrode can measure changes in pH in real-time, which allows researchers to use it in the industry (Kakooei, Ismail, and Ari-Wahjoedi 2013). Then this sensor will read the pH of the aquarium water. The pH of the aquarium water is said to be normal if it is between 7 and 7.5. If the pH condition is below 7, then solenoid valve 1 drains the pH buffer 7 solution as pH up, and if the pH condition is above 7.5, then solenoid valve 2 drains the pH buffer 4 solutions as pH down. It was given 5 minutes to adjust the pH level and then again measured the pH of the water using the E-201-C pH sensor. The E-201-C pH sensor is analog, so to use it requires an analog to digital conversion (ADC).

RESULTS AND DISCUSSION

This research has produced a prototype of an automation control system for pH, temperature, and water turbidity in ornamental fish aquariums. This tool aims to condition the pH, temperature, and turbidity of the water so that it remains stable according to the type of ornamental fish to be studied. A stable and non-fluctuating ornamental fish environment will result in healthy fish that experience good growth and breed optimally.

In designing this tool, it is necessary to test each system to find out if the components used in each system are functioning properly. Then the entire system is tested in the aquarium and compared to an aquarium without a system tool for 10 days to find out the difference between an aquarium using a control system and an aquarium without a control system.

pH E-201-C Sensor Test

Testing the pH E-201-C sensor is done by dipping the probe of the pH E-201-C sensor into each sample of the pH buffer solution three times to get an analog value that is read on the LCD (output) and then the measurement results of the pH-E sensor 201-C will be compared to the pH meter as manual measurement. The data from the E-201-C pH sensor test results can be seen in table 1.

Table 1. pH E-201-C sensor test results

Trial to -	Sample	Measurement Results		*Error* (%)
		pH E-201 C Sensor	pH Meter	
1.	pH 4.01 Powder	4.28	4.20	1.9
2.		4.32	4.20	2.9
3.		4.43	4.30	3.0
4.	pH 6.86 Powder	6.98	6.80	2.6
5.		7.08	6.90	2.6
6.		7.15	7.00	2.1
		Average *error*		2.5

Based on the data from the E-201-C pH sensor test results that have been carried out, it is found that the values measured by the E-201-C pH sensor and pH meter are not the same. This is because the level of accuracy of the measuring instruments used is different. However, the measurement value obtained by the E-201-C pH sensor is not much different from the pH meter and has an average error value of 2.5%, which is still in the good category because the allowable error value is less than 5% (Anwar, Wisana, and Nugraha 2017). This means that pH measurements using the E-201-C pH sensor can read the pH of the aquarium water very well.

Temperature Sensor Test with DS18B20

Testing of the DS18B20 sensor is carried out by dipping the DS18B20 sensor probe into a drinking water sample for 5 trials to get the water temperature accuracy value that is read on the LCD (Output). Then the DS18B20 sensor measurement results are compared with the thermometer as a manual measurement (Pramana 2018). The data from the DS18B20 sensor test results can be seen in table 2.

Table 2. Temperature DS18B20 sensor test results

Trial to-	Measurement Results (°C)		*Error (%)*
	Sensor DS18B20	Thermometer	
1.	26.75	26.80	0.19
2.	27.76	27.80	0.14
3.	28.16	28.20	0.14
4.	30.22	30.30	0.26
5.	30.44	30.50	0.20
	Average *error*		0.18

Based on the data from the DS18B20 temperature sensor test results that have been carried out, it is obtained that the measured value of the DS18B20 sensor and thermometer are not the same. This is because the level of accuracy of the measuring instruments used is different. However, the measurement value obtained by the DS18B20 temperature sensor is not much different from the thermometer and has an average error value of 0.18%, which is still in the good category because the allowable error value is less than 5% (Anwar, Wisana, and Nugraha 2017). This means that temperature measurements using the DS18B20 sensor can read the aquarium water temperature very well.

Turbidity Sensor Test

The turbidity sensor testing is done by dipping the turbidity sensor probe into each water sample five times to get the value that is read on the LCD (output) on the turbidity sensor. The higher the turbidity level of the water, the more the sensor output voltage will change (Wadu, Ada, and Panggalo 2017). Then the results of the turbidity sensor measurements will be compared with a turbidity meter as a manual measurement with the same units to standardize the level of turbidity, which allows comparisons to be made (Azman et al. 2017). The data from the turbidity sensor test results can be seen in table 3.

Table 3. Turbidity sensor test results

Trial to-	Sample	Measurement Result (NTU)		*Error* (%)
		Turbidity Sensor	Turbidity Meter	
1.	PDAM Water	2.85	2.92	0.82
2.		3.30	3.28	0.60
3.		3.55	3.51	1.13
4.		3.45	3.48	0.86
5.		3.39	3.42	0.87
6.	Ground Water	60.98	60.78	0.32
7.		63.73	64.07	0.53
8.		66.96	66.85	0.16
9.		65.36	64.98	0.58
10.		64.88	64.21	1.04
Average *error*				0.69

Based on the turbidity test data that has been carried out, it is found that the values obtained by the turbidity sensor and the turbidity meter are not the same. This is because the penis in cleaning the sample area is not clean so it affects the reading of the measuring instrument in detecting turbidity. However, the measurement value obtained by the turbidity sensor is not much different from the turbidity meter and has an average error value of 0.69%, which is still in the good category because the permissible error value is less than 5% (Anwar, Wisana, and Nugraha 2017). This means that the turbidity measurement using the turbidity sensor has succeeded in reading the turbidity level of the water very well.

Ultrasonic Sensor Test

Ultrasonic sensor testing is done by placing the ultrasonic sensor above the aquarium and providing a water sample at a certain height that has been measured by the ruler. The experiment was carried out five times at different heights and three times in each experiment. The ultrasonic sensor measures the water level, which is read on the LCD (output). The ultrasonic sensor measurement results will be compared with a ruler as manual measurement. Ultrasonic test results data can be seen in table 4.

Table 4. Ultrasonic sensor test results

Trial to-	Measurement Result (cm)		*Error (%)*
	Ultrasonic Sensor	Mistar	
1.	5	5	0
2.	7	7	0
3.	9	9	0
4.	15	15	0
5.	20	20	0
Average *error*			0

Based on the ultrasonic test data that has been carried out, the ultrasonic sensor measurements with a ruler are worth it and have an average error value of 0%.

Overall System Test

Overall system testing was carried out by monitoring, for 10 consecutive days, the condition of the aquarium water. This process is carried out to observe changes in the aquarium water every day, which is useful to see if an aquarium with an automated control system provides better results than an aquarium without any treatment. The following is the data from the comparison of the aquarium using a control system tool with an aquarium without a control system tool.

Table 5. Observational data on the comparison of aquariums using a control system tool with aquariums without a system tool

Days to-	pH		Temperature (°C)		Turbidity (NTU)	
	With System	Without System	With System	Without System	With System	Without System
1.	7.48	7.50	28.35	28.30	4.24	4.21
2.	7.43	7.20	26.83	28.30	4.35	5.49
3.	7.42	6.90	26.38	28.30	4.63	7.80
4.	7.37	6.40	26.54	28.40	5.34	10.80
5.	7.35	5.80	26.22	28.30	5.75	10.90
6.	7.29	5.60	26.07	28.30	6.32	11.20
7.	7.36	5.20	25.76	28.20	6.58	11.57
8.	7.27	5.20	25.98	28.30	6.87	12.56
9.	7.22	4.80	26.11	28.30	7.27	13.70
10.	7.19	4.50	25.43	28.20	7.64	15.24

Based on the results of observations that have been made, a comparison of the results of measuring pH, temperature, and turbidity of aquarium water using a control system tool and an ordinary aquarium without any treatment is obtained, which is presented in the form of table 5.

In the observation data of pH measurements, it can be seen that the aquarium using the system can condition the pH of the aquarium water stably in the range of 7–7.5, where the range is following the growth and development of flower horn fish as the object under study. While the aquarium without being treated with a control system shows a change in the degree of acidity of the aquarium water, the aquarium water is getting more acidic day by day. This is because the feeding of ornamental fish, which is carried out 3 times a day, namely in the morning, afternoon, and evening (Hartoyo et al. n.d.), causes a lot of leftover dirt and food to be left to settle and not cleaned so that the remnants of dirt and food are left behind. It will release ammonia, which causes the pH of the water to tend to be acidic. Ammonia can increase due to feed residues, sediment that settles, and dead fish carcasses in fish-rearing media (Minggawati and Saptono 2012)

From the data, the results of the difference in pH measurements for aquariums with a control system and aquariums without a control system can be presented in a graph. Here is a graph of the difference in pH measurements for the aquarium.

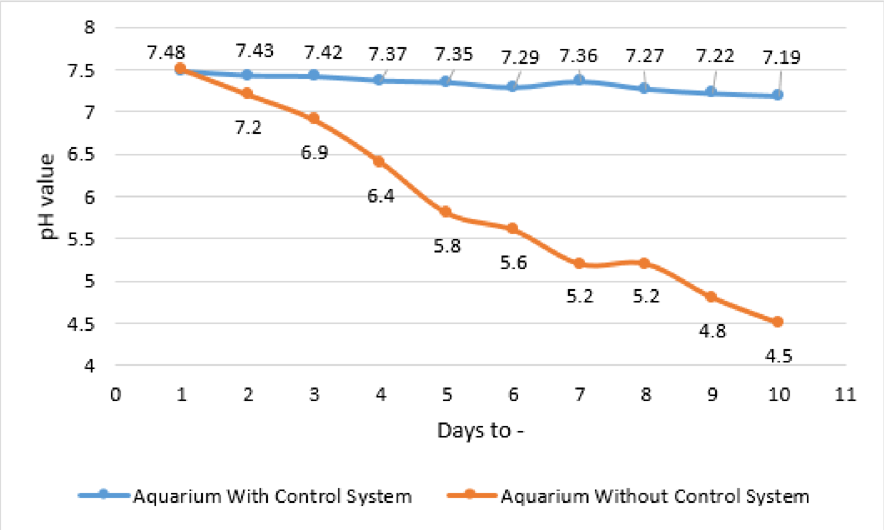

Figure 5. A comparison graph of measurement values for aquarium water pH over 10 days

The graph above shows that the control system that has been made can maintain the pH of the water in the range of 7–7.5 by the living environment of the Lohan fish. Compared to an aquarium without treatment, the longer the pH measured getting lower. Fish will die if the pH falls below 4 or rises above 11 (New 1983).

In the observation data of temperature measurements, it can be seen that the aquarium temperature using the system can condition the aquarium water temperature ranging from 24–27 °C, where the range is following the growth and development of flower horn fish as the object under study. Water temperature affects the growth and development of fish (Cahyono 2006). While the aquarium without being treated with a control system shows that the measured temperature tends to be constant at 28 °C, the temperature is not in the Lohan fish's living environment. The constant temperature at 28 °C is due to the aquarium being in a room that is not exposed to sunlight so the temperature in the aquarium water is relatively free from temperature fluctuations (Gusrina 2008).

From the data on the difference in the results of temperature measurements for an aquarium with a control system and an aquarium without this control system, it can be presented in a graph. The following is a graph of the difference in pH measurements for the aquarium.

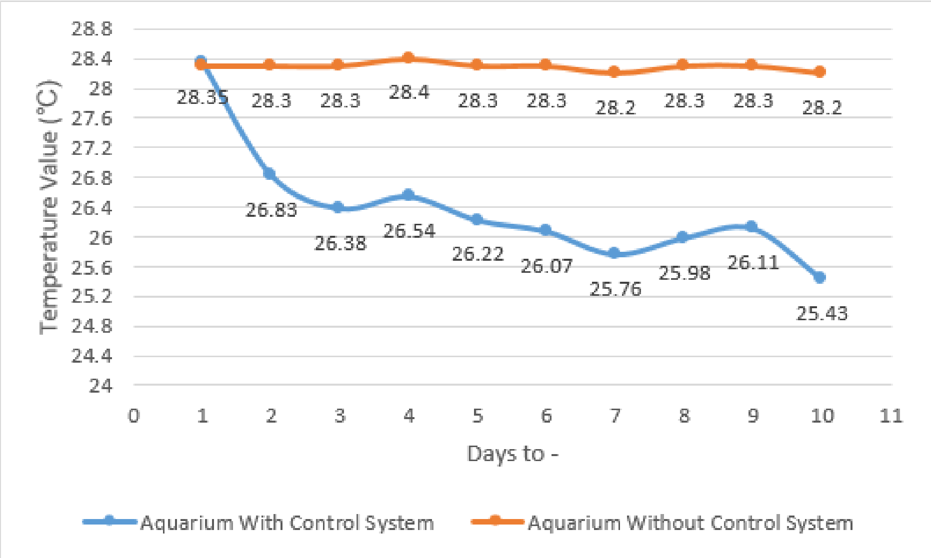

Figure 6. A comparison graph of measurement values for aquarium water temperature over 10 days

The graph above shows that the control system that has been made can control temperatures ranging from 24-27°C according to the Louhan fish's living environment compared to an aquarium without measured treatment (±28°C) which is less suitable for the Louhan fish's living environment.

In the observation data of the water turbidity measurement, it can be seen that the aquarium using the system can condition the turbidity of the aquarium water below 10 NTU where the range is suitable for the living environment of ornamental fish. While the aquarium without being treated with a control system looks increasingly cloudy every day until the 4th day the turbidity of the aquarium water reaches more than 10NTU. This is supported by Raharjo who stated that water changes should be done every three days (Erdiansyah, Raharjo, and Sunarto 2014). Suppose the turbidity of the water becomes higher. In that case, it causes a low oxygen-holding capacity, reduced fish appetite, the appearance of plankton that no longer functions as food for fish, and ornamental fish that have difficulty breathing because their gills are covered with mud particles (Gusrina 2008) (Bhatnagar and Devi 2013).

From the data on the difference in measurement results for an aquarium with a control system and an aquarium without a control system, it can be presented in a graph. Here is a graph of the difference in pH measurements for the aquarium

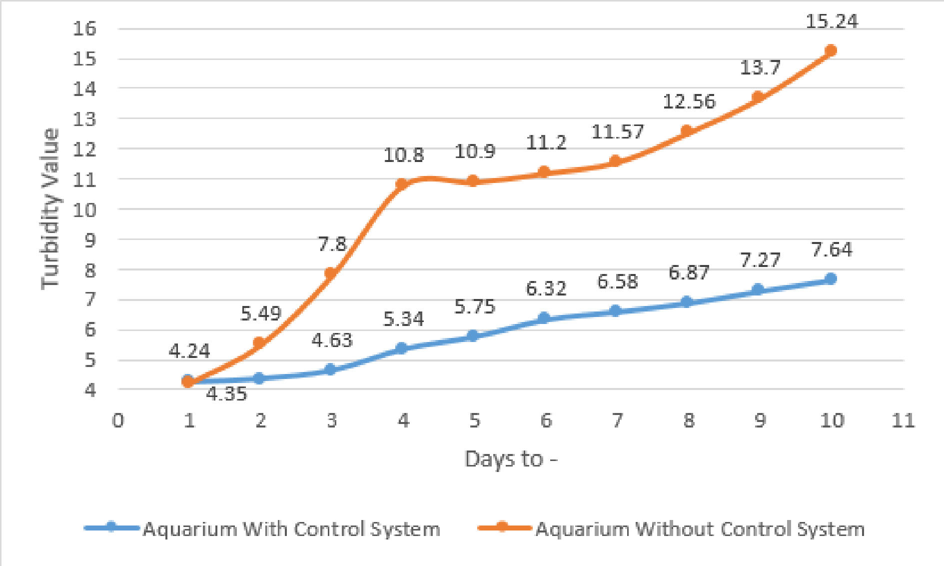

Figure 7. A comparison graph of measurement values for aquarium water turbidity over 10 days

The graph above shows that within 10 days of observation, the control system that has been installed can maintain the turbidity of the aquarium water below 10 NTU compared to the untreated aquarium, where the value is following water conditions suitable for ornamental living environments. This is supported by (Anonim 2008), where the clarity of the water used for fish rearing must meet the optimal needs of fish, which is less than 10 NTU.

CONCLUSION

Based on the research that has been done, it can be concluded that an aquarium without a control system causes unstable aquarium water conditions, while an aquarium with an automated control system for pH, temperature, and turbidity of aquarium water can function properly and can maintain aquarium water conditions following the flower horn fish's living environment, namely pH. The pH ranges from 7-7.5, the water temperature is 24–27 °C, and the turbidity of the aquarium water is below 10 NTU. This system can be said to be effectively used by fish owners in maintaining stable water quality conditions so that the growth and development of ornamental fish are better and the spawning/breeding process of ornamental fish is more optimal.

RECOMMENDATION

The author suggests further research to add other monitoring systems that can affect the quality of aquarium water, such as oxygen levels, etc., as well as research on the physical condition of fish and the length of the day in an aquarium without system control and an aquarium with system control to better understand the changes caused by uncontrolled aquarium water.

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