Jurnal Informatika Ekonomi Bisnis

http://www.infeb.org

2024 Vol. 6 Iss. 2 Hal: 394-398 e-ISSN: 2714-8491

Integration Hydroponic Aquaculture Systems for Optimizing Catfish Growth Management with Arduino

Lawrence Adi Supriyono[1✉], Andhika[2], Amalia Shifa Aldila[3], Prasetyo Hartanto[4]

[1,2,3,4]Universitas Jakarta Internasional

lawrence.supriyono@uniji.ac.id

Abstract

Modern agriculture faces significant challenges such as limited land and declining soil fertility. The integration of hydroponic systems with aquaculture, particularly catfish farming, offers an innovative solution to enhance agricultural efficiency and productivity. This study explores the integration of hydroponic systems with aquaculture for the simultaneous cultivation of plants and catfish in a controlled environment. The research utilizes Arduino technology for monitoring temperature, pH, and water turbidity, which are essential for the health of fish and plants. The research method used is Research and Development (R&D), involving the following steps: (1) Identifying potential problems, (2) Data collection, (3) Product design, (4) Design validation, (5) Design revision, and (6) Product testing. The results indicate that integrating hydroponic systems with Arduino technology improves the efficiency of monitoring and managing the cultivation environment, positively impacting plant and catfish growth. The implementation of this system shows an increase in plant nutrient content and better fish health. And then, this research significantly contributes to the development of sustainable agriculture and global food security through the adoption of innovative technology.

Keywords: Hydroponics, Plant Fertility, Aquaculture, Sustainable Agriculture, Arduino.

1. Introduction

Conventional agriculture faces significant challenges in meeting global food demands due to limited land and declining soil fertility. This situation drives the search for new methods that are more efficient and sustainable. One promising approach is the integration of hydroponic systems with aquaculture, where plants and fish are cultivated together in a controlled environment that benefits both [1], [2].

Hydroponic systems allow for soil-less cultivation of plants, with plant roots directly absorbing nutrients from mineral-rich water. Common types of hydroponic systems include floating raft systems, drip irrigation systems, and the Nutrient Film Technique (NFT). The NFT system, for example, is known for its efficiency in water and nutrient use but requires more intensive monitoring [3], [4].

On the other hand, aquaculture, particularly catfish farming, provides a significant protein source and has high economic potential. Research shows that optimal water quality is crucial for the growth and health of fish. For instance, the ideal water temperature for catfish ranges between 25-29 degrees Celsius [5]. The use of technologies such as Arduino allows for accurate monitoring of temperature, pH, and water turbidity, all of which are essential for the health of both fish and plants [6], [7], [8], [9]. Several studies have shown significant benefits of hydroponic systems. Researchers found that lettuce grown hydroponically has higher nutrient content compared to conventionally grown plants [10], [11], [12], [13]. Additionally, another researcher reported a 30% increase in the growth rate of tomato plants when using hydroponic methods compared to soil methods [14].

The integration of hydroponics and aquaculture, often referred to as aquaponics, shows potential for increasing overall agricultural productivity. Both also improving water quality as plants absorb nutrients produced by fish [15]. However, specific research on the integration of hydroponics with catfish farming is still limited.

This research aims to fill that gap by exploring ways to optimize plant and catfish growth through the latest technological approaches in hydroponic and aquaculture systems. The implementation of Arduino technology in this system is expected to improve the efficiency and effectiveness of monitoring and managing the cultivation environment, ultimately contributing significantly to the development of sustainable agriculture and global food security [16], [17].

2. Research Method

In this study, the research method used is based on Research and Development (R&D). The R&D research steps consist of 10 steps, but only 6 steps are used in product development, which include: (1) Identifying potential problems, (2) Data collection, (3) Product design, (4) Design validation, (5) Design revision, and (6) Product testing. The schematic steps are shown in the diagram on Figure 1.

Accepted: 10-06-2024 | Revision: 18-06-2024 | Publication: 30-06-2024 | doi: 10.37034/infeb.v6i2.912

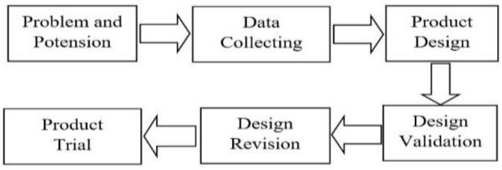

Figure 1. R&D Research Procedures

a. Problem and Potension: The research begins by identifying problems in catfish farming and hydroponic cultivation, such as the need for more efficient water quality monitoring and better environmental management.

b. Data Collection: Data is collected through literature reviews on hydroponic technology, Arduino sensors, and previous studies on aquaculture and hydroponic integration. Information about the ideal environmental conditions for catfish and plants is also gathered.

c. Product Design: The initial design includes the use of temperature, pH, and turbidity sensors connected to an Arduino for real-time environmental monitoring. Data from the sensors will be displayed on an LCD screen to provide farmers with information on water conditions.

d. Design Validation: The design is validated through simulations and initial laboratory tests. These trials ensure that the sensors accurately measure parameters and that the Arduino processes data correctly.

e. Design Revision: Based on the validation results, the design is revised to improve sensor accuracy and the user interface. Sensor calibration is performed to ensure accurate data, and the LCD display is improved for easier information reading.

f. Product Trial: Full-scale testing is conducted in a catfish farming and hydroponic environment. The system is tested to evaluate its impact on plant and fish growth. The results show that this system effectively improves the efficiency of monitoring and managing the farming environment.

The Arduino is connected to various sensors, including a temperature sensor, pH sensor, turbidity sensor, and LCD. The operation of this device begins when it is powered on; the temperature sensor measures the water temperature in the fish pond, the pH sensor measures the pH level of the pond water, and the turbidity sensor collects data on the water's turbidity. All of this data is then displayed on the LCD as information for the farmers. The circuit design can be seen on Figure 2.

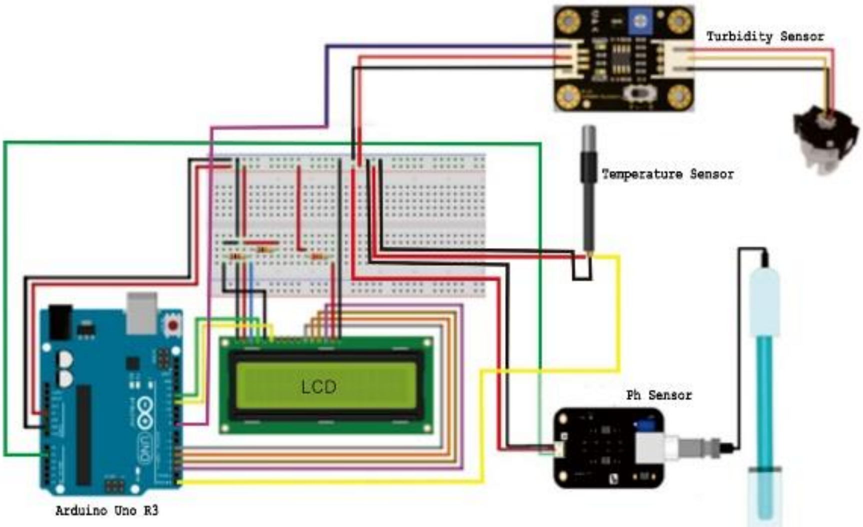

Figure 2. Circuit Design

2.2 Prototype Design

The efficient hydroponic prototype is designed to ensure optimal nutrient provision for plants while creating an aquatic environment that supports the growth and health of catfish. Maintaining catfish in this system involves constant monitoring of water quality, pH regulation, and appropriate nutrient management, with the aim of enhancing overall cultivation yields. Thus, the prototype design can be seen on Figure 3.

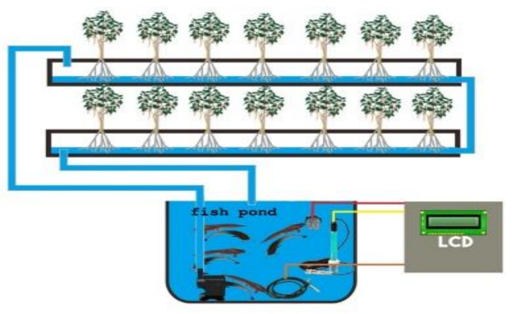

Figure 3. Prototype Design

The configuration of this intelligent system consists of input, process, and output. On the input side, there are the pH sensor, water turbidity sensor, and water temperature sensor, with the Arduino Uno R3 serving as the processor. The data output is displayed on an LCD, which functions to present information from the aquaponics system. The overall system can be seen at diagram on Figure 4.

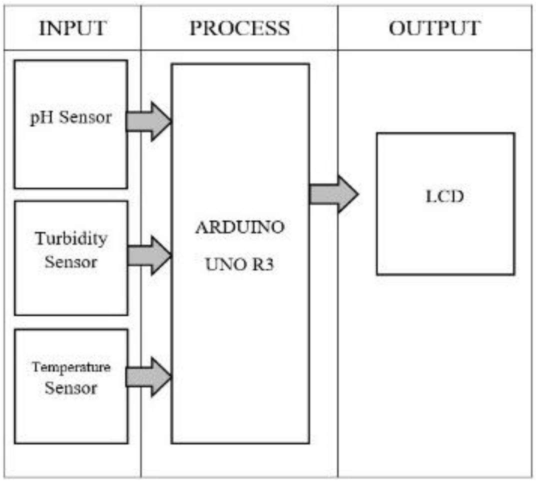

Figure 4. Work System Process

System flowchart depicts the steps taken to ensure that all sensors (pH, temperature, and turbidity) are working correctly before the collected data is processed and displayed. If any sensor is not functioning, the process will return to the start to address the issue. System flowchart that will be used can be seen on Figure 5.

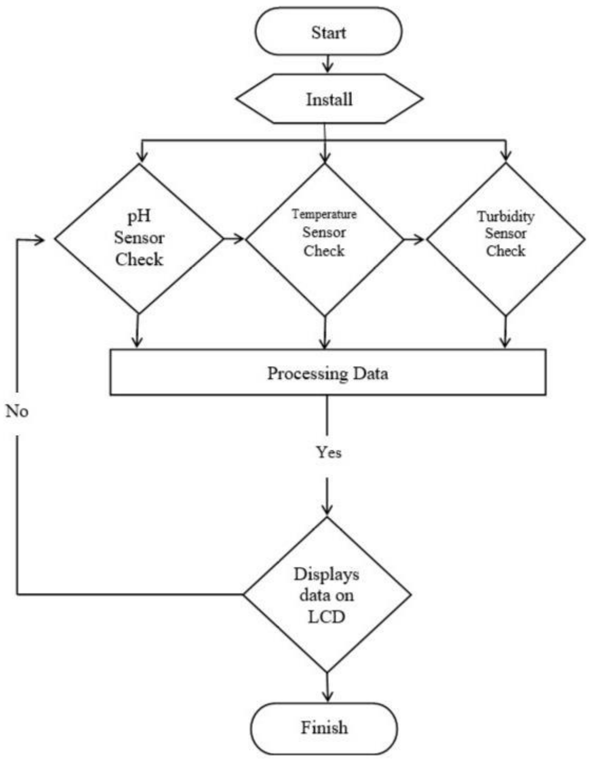

Figure 5. System Flowchart

3. Result and Discussion

The research results show that this integrated hydroponic system with Arduino technology can improve the efficiency of water quality monitoring and environmental management in catfish farming. Implementing this technology can significantly contribute to the development of sustainable agriculture and global food security. This system also makes it easier for farmers to manage the farming environment, which ultimately positively impacts the growth and health of catfish and hydroponic plants. This research successfully developed a prototype that can be used to increase efficiency and productivity in integrated farming systems, opening up opportunities for the application of advanced technology in the agriculture and aquaculture sectors in which can be seen on Figure 6.

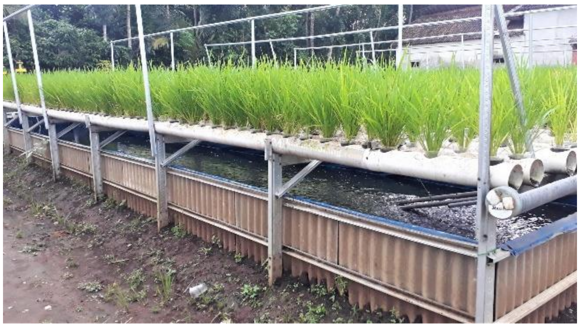

Figure 6. Hydroponics and Catfish Ponds

a. Testing All Sensors in a Safe Condition

Testing the normal condition of the temperature sensor, pH sensor, and turbidity sensor on the LCD displays water temperature at 28 degrees Celsius and water acidity (pH) at 7, indicating normal pond water conditions with the green LED turn ON. The test result is shown at Figure 7.

Figure 7. Sensor status is safe

b. Abnormal Temperature Sensor Testing

Good water conditions for cultivating Catfish range from 25 to 29 degrees Celsius. In the event of abnormal temperature readings, such as water temperature at 8 degrees Celsius, the red LED turn ON, and the green LED turn OFF. As for the test result, it can be seen on Figure 8.

Figure 8. Abnormal Water Temperature

c. Abnormal pH Sensor Testing

In the case of abnormal pH readings, for instance, showing water acidity at pH 4, the red LED turn ON. The LCD display indicates that the water acidity is below the standard range of pH 5-6. Example of pH sensor with abnormal status can be seen on Figure 9.

Figure 9. pH Sensor Status Abnormal

d. Turbidity Sensor Testing for Turbid Water

The LCD displays the water in a cloudy condition because the sensor detects turbidity in the pond water so the pond water needs to be drained and refilled with clean water. The detected result can be seen on Figure 10.

Figure 10. The water is detected to be cloudy.

e. Research Data and Sensor Testing

For normal condition testing, the system maintained optimal water parameters for catfish and plant growth with temperature 28°C (LED: green), pH level 7 (LED: green), and water turbidity normal (LED: green). As for abnormal condition testing, the system identified deviations from optimal parameters, with temperature 8°C (LED: red), pH level: 4 (LED: red), water turbidity is high (LED: red). Detailed data testing can be seen on Table 1.

Table 1. Data Testing for All Sensor

Sensor Type	Condition	Result	LED Indicator	Description
Temperature Sensor	Normal	28°C	Green	Water temperature is within the optimal range (25-29°C) for growth.
	Abnormal	8°C	Red	Water temperature is far below the optimal range, inhibiting growth.
pH Sensor	Normal	7	Green	Water acidity is within the optimal range (pH 5-6) for growth.
	Abnormal	4	Red	Water acidity is below the optimal standard, inhibiting growth.
Turbidity Sensor	Normal	Normal	Green	Water turbidity is at a level that does not hinder growth.
	Abnormal	High	Red	Water turbidity is at a level that can hinder growth.

4. Conclusion

The system effectively monitors critical environmental parameters such as temperature, pH, and turbidity. During normal conditions, the system maintained optimal water parameters with a water temperature of 28°C, a pH level of 7, and normal water turbidity, all indicated by green LEDs. The system accurately identified deviations from optimal conditions, including a water temperature of 8°C, a pH level of 4, and high-water turbidity, which were indicated by red LEDs. These alerts facilitate timely interventions to maintain a healthy environment for catfish and hydroponic plants. The integrated system ensures the provision of optimal nutrient levels for hydroponic plants while maintaining water quality conducive to catfish growth, enhancing the overall efficiency and productivity of both aquaculture and hydroponic farming. This integration of Arduino technology represents a significant advancement in sustainable agriculture, as it provides farmers with real-time data on an LCD screen, enabling immediate and actionable information. This integrated hydroponic and aquaculture system with Arduino technology significantly contributes to the development of sustainable agriculture by enhancing the efficiency of environmental monitoring and management. The research demonstrates the potential for advanced technology to improve the productivity and sustainability of farming practices.

References

[1] Goddek, S., Joyce, A., Kotzen, B., & Dos-Santos, M. (2019). Aquaponics and Global Food Challenges. *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future*, 3-17. https://doi.org/10.1007/978-3-030-15943-6_1

[2] Somerville, C., Cohen, M., Pantanella, E., Stankus, A., & Lovatelli, A. (2014). Small-scale aquaponic food production: integrated fish and plant farming. *FAO Fisheries and aquaculture technical paper*, (589), I.

[3] Rakocy, J. E., Shultz, R. C., Bailey, D. S., & Thoman, E. S. (2004). Aquaponic production of tilapia and basil: Comparing a batch and staggered cropping system. *Acta Horticulturae*, 648, 63-69. https://doi.org/10.17660/ActaHortic.2004.648.8

[4] Dorais, M. (2003). The use of supplemental lighting for vegetable crop production: Light intensity, crop response, nutrition, crop management, cultural practices. *Canadian Greenhouse Conference*, 1-6.

[5] Rakocy, J. E. (2012). Aquaponics—integrating fish and plant culture. *Aquaculture production systems*, 344-386. https://doi.org/10.1002/9781118250105.ch14

[6] Graber, A., & Junge, R. (2009). Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination*, *246*(1-3), 147-156. https://doi.org/10.1016/j.desal.2008.03.048

[7] Resh, H. M. (2022). *Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower*. CRC press.

[8] Jones, J. B. (2005). *Hydroponics: A practical guide for the soilless grower (2nd ed.)*. CRC Press.

[9] Somerville, C., Cohen, M., Pantanella, E., Stankus, A., & Lovatelli, A. (2014). Small-scale aquaponic food production: integrated fish and plant farming. *FAO Fisheries and aquaculture technical paper*, (589), I.

[10] Treftz, C., & Omaye, S. T. (2015). Nutrient analysis of soil and soilless strawberries and raspberries grown in a greenhouse. *Food and Nutrition Sciences*, *6*(9), 805-815. http://dx.doi.org/10.4236/fns.2015.69084

[11] Rakocy, J. E., Bailey, D. S., Shultz, R. C., & Thoman, E. S. (2004). Update on tilapia and vegetable production in the UVI aquaponic system. *In South Pacific Soilless Culture Conference* (Vol. 648, pp. 63-69).

[12] Savidov, N., & Brooks, A. B. (2004). *Evaluation and development of aquaponics production and product market capabilities in Alberta*. Brooks, AB, Canada: Crop Diversification Centre South, Alberta Agriculture, Food and Rural Development.

[13] Kloas, W., Groß, R., Baganz, D., Graupner, J., Monsees, H., Schmidt, U., ... & Rennert, B. (2015). A new concept for aquaponic systems to improve sustainability, increase productivity, and reduce environmental impacts. *Aquaculture environment interactions*, *7*(2), 179-192. https://doi.org/10.3354/aei00146

[14] Komosa, A., Kowalska, I., & Kubik, M. (2017). Effect of different hydroponic systems on growth and nutrient status of tomato plants. *Scientia Horticulturae, 218*, 139-145.

[15] Lennard, W. A., & Leonard, B. V. (2004). A comparison of reciprocating flow versus constant flow in an integrated, gravel bed, aquaponic test system. *Aquaculture International*, *12*, 539-553. https://doi.org/10.1007/s10499-004-8528-2

[16] Love, D. C., Fry, J. P., Genello, L., Hill, E. S., Frederick, J. A., Li, X., & Semmens, K. (2014). An international survey of aquaponics practitioners. *PLOS ONE*, 9(7), e102662. https://doi.org/10.1371/journal.pone.0102662

[17] Endut, A., Jusoh, A., Ali, N., Nik, W. B. W., & Hassan, A. (2010). A study on the optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. *Bioresource Technology*, *101*(5), 1511-1517. https://doi.org/10.1016/j.biortech.2009.09.040