



Design and Development of a Hydroponic Growing Media Monitoring System for The Growth of Melon Plants from Flowering to Harvest Based on The Internet of Things (IoT) (Case Study: Lara's Melon Hydroponic, Pasir Kulon, Karanglewes District, Banyumas)

Danang Dasa Ajunmas Rapita¹, Aulia Desy Nur Utomo²

^{1,2}Department of Informatics Engineering, Universitas Telkom Purwokerto, Indonesia, 53147

 danangdasa46@gmail.com

 <https://doi.org/10.37339/e-komtek.v10i1.3174>

Published by Politeknik Piksi Ganesha Indonesia

Abstract

Artikel Info

Submitted:

12-05-2026

Revised:

29-05-2026

Accepted:

09-06-2026

Online first :

09-06-2026

*Hydroponic melon (*Cucumis melo L.*) cultivation requires precise environmental parameter monitoring to achieve optimal results. This study aims to design an Internet of Things (IoT)-based monitoring system to monitor temperature, humidity, pH, and TDS in real-time via a website. The system was developed using the Prototype method with Arduino Uno and NodeMCU ESP8266 as the main controllers. The testing phase included system functionality testing, sensor calibration, and User Acceptance Testing (UAT). Technical testing results showed that the average accuracy of the DHT11 temperature sensor reached 96.61%, the pH sensor 99.67%, and the TDS sensor 64.67%. Meanwhile, the UAT results indicated a system feasibility level of 89.33%, categorized as "Very Feasible." System implementation over 8 weeks demonstrated an improvement in harvest quality, where monitored plants had an average fruit weight of 1.398 kg and a sweetness level of 13.25 °Brix, outperforming unmonitored plants which recorded an average of 1.379 kg and 12.75 °Brix. In conclusion, this system effectively provides measurable data, is feasible for user implementation, and contributes to improving harvest quality.*

Keywords: *Hydroponics, Melon Monitoring, Internet of Things (IoT), Prototype, Calibration.*

Abstrak

Budidaya melon (*Cucumis melo L.*) secara hidroponik memerlukan pemantauan parameter lingkungan yang presisi untuk mencapai hasil optimal. Penelitian ini bertujuan merancang sistem monitoring berbasis *Internet of Things* (IoT) untuk memantau suhu, kelembaban, pH, dan TDS secara *real-time* melalui *website*. Sistem dikembangkan menggunakan metode *Prototype* dengan pengendali utama Arduino Uno dan NodeMCU ESP8266. Tahap pengujian meliputi uji fungsionalitas sistem, kalibrasi sensor, dan pengujian pengguna. Hasil pengujian teknis menunjukkan akurasi rata-rata sensor suhu DHT11 mencapai 96,61%, sensor pH 99,67%, dan sensor TDS 64,67%. Sementara itu, hasil *User Acceptance Testing* (UAT) menunjukkan tingkat kelayakan sistem sebesar 89,33% dengan kategori Sangat Layak. Implementasi sistem selama 8 minggu memperlihatkan adanya peningkatan kualitas panen, di mana tanaman yang dimonitoring memiliki rata-rata berat buah 1,398 kg dan tingkat kemanisan 13,25 °Brix, lebih unggul dibandingkan tanaman tanpa monitoring yang mencatatkan rata-rata 1,379 kg dan 12,75 °Brix. Kesimpulannya, sistem ini efektif menyediakan data terukur, layak digunakan oleh pengguna, serta berkontribusi dalam meningkatkan kualitas hasil panen.

Kata-kata kunci: *Hidroponik, Pemantauan Melon, Internet of Things (IoT), Prototype, Kalibrasi.*



This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/).

1. Introduction

Hydroponic agriculture has become a promising solution in addressing modern agricultural challenges, particularly in areas with limited land availability. Hydroponic systems enable plant cultivation without the use of soil, making them flexible for implementation in narrow spaces such as home yards, residential areas, and rooftops [1]. One of the most widely used hydroponic methods is the Deep Flow Technique (DFT), which utilizes a continuously circulated nutrient solution with a certain depth to provide plants with stable supplies of water, nutrients, and oxygen. Although the DFT system is relatively simple and efficient, it requires continuous monitoring of nutrient solution parameters such as pH, nutrient concentration (TDS), and temperature to maintain optimal conditions for plant growth [2] [3].

Melon (*Cucumis melo* L.) is a high-economic-value horticultural commodity that is highly demanded in the market due to its taste and nutritional content. Scientifically, melon is known to contain bioactive compounds, vitamin C, and vitamin A that function as natural antioxidants [4], [5], [6]. The application of hydroponic techniques in melon cultivation has been proven to improve production quality, particularly in terms of fruit uniformity and overall quality [7]. In modern markets and premium retail sectors, hydroponic melon is categorized as a high-value crop with strict quality standards, including sweetness levels (Total Soluble Solids) of at least 12–14 °Brix [8].

Studies have shown that sweetness level is a primary indicator of consumer preference, where a decrease in °Brix value caused by improper nutrient management may reduce the selling price by up to 40–50% because the product is classified as off-grade quality [9]. In addition, the capital-intensive nature of hydroponic cultivation requires farmers to maximize the percentage of Grade A harvests to maintain profitability [10]. Therefore, environmental stability becomes a crucial factor in maintaining the quality and economic value of melon fruits.

Hydroponic melon cultivation is highly sensitive to microclimate fluctuations. Previous studies indicate that the optimal air temperature for melon growth ranges from 25–30°C, while temperatures below 18°C may significantly inhibit vegetative growth [11]. The ideal air humidity ranges between 60–80%, whereas the chemical parameters of the nutrient solution require high stability with an optimal pH range of 5.5–6.5. pH deviations outside this range may inhibit nutrient absorption and potentially cause stunted growth and decreased fruit quality [12]. Therefore, periodic monitoring of pH, TDS, and temperature parameters is essential in hydroponic melon cultivation [13].

However, in practice, monitoring of hydroponic environmental conditions is still commonly performed manually, which tends to be inefficient and increases the risk of delays in detecting critical environmental changes [14]. Delayed correction of pH reduction or TDS spikes may cause plant stress, disrupt metabolic processes, and reduce sugar accumulation in fruits [15]. Similar conditions were also observed in hydroponic melon cultivation at Lara's Melon Hydroponic, Banyumas, where inconsistent

fruit quality remains a challenge due to limitations in environmental monitoring systems. The urgency of implementing monitoring technology is further strengthened by academic research and mentoring programs related to Internet of Things (IoT)-based hydroponic melon cultivation in the Banyumas region [15].

Along with the advancement of digital technology, the Internet of Things (IoT) offers a solution through real-time monitoring systems capable of providing continuous and accurate environmental data. The availability of real-time data enables farmers to perform corrective actions more quickly and accurately, thereby maintaining environmental stability for plant growth. Therefore, this study focuses on the design and implementation of an IoT-based hydroponic monitoring system to support the growth and quality of melon plants during the flowering-to-harvest phase.

Although IoT-based hydroponic monitoring systems have been widely developed, most previous studies have primarily focused on monitoring basic environmental parameters in general hydroponic crops and evaluating sensor performance. Furthermore, previous studies generally have not specifically implemented monitoring systems for hydroponic melon cultivation during the generative phase until harvest accompanied by direct analysis of harvest quality. This study offers contributions in the form of implementing a real-time IoT-based monitoring system for hydroponic melon cultivation by monitoring five important parameters, namely air temperature, air humidity, water temperature, pH, and TDS. The system was directly implemented during one complete cultivation cycle from flowering to harvest to evaluate monitoring stability under real conditions. In addition, this study also analysed harvest quality based on fruit weight and sweetness level (°Brix), thus focusing not only on sensor monitoring but also on the resulting cultivation outcomes.

Therefore, this study contributes not only to the development of IoT-based hydroponic monitoring systems but also to the practical implementation of environmental monitoring to support the quality of hydroponic melon cultivation.

2. Method

This study applied an experimental method using a Prototype system development approach to develop a precision environmental monitoring system for hydroponic melon cultivation. This approach was chosen to enable iterative system development through several stages: (1) communication of requirements with farming partners, (2) rapid planning, (3) design modeling, (4) prototype construction, and (5) system delivery and user feedback. The research was conducted at the Lara's Melon Hydroponic greenhouse, Pasir Kulon, Banyumas, during one full cultivation cycle from the flowering phase until harvest.

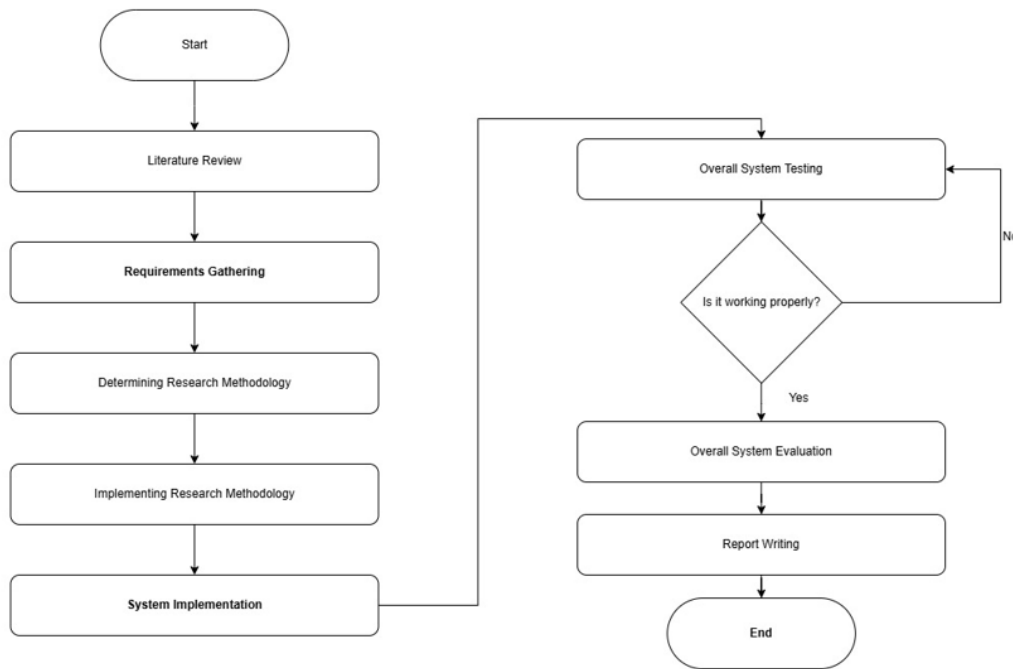


Figure 1. Research Workflow

Based on [Figure 1](#), the research workflow began with literature review and requirements gathering to obtain the theoretical foundation and appropriate system specifications. Based on the collected data, the research method was determined and followed by the implementation of the selected method into the system design. The next stage involved system implementation, in which both hardware and software components were developed. After the system was completed, comprehensive testing was conducted. If the system did not perform properly during testing, the process returned to the testing and improvement stage. However, if the system operated successfully, the research proceeded to the overall system evaluation stage and concluded with report writing.

a) Study Literature

The first stage of this research was the literature review. At this stage, references and information were collected from various existing written sources, such as journals, books, theses, internet sources, and summaries of previous studies. The literature review aimed to identify theories relevant to the research problem while also establishing an analytical framework to support the research being conducted.

b) Requirements Gathering

The requirement's gathering stage was conducted to identify and define the system specifications to be developed. At this stage, supporting data were collected through

observations and discussions with farmers. The observation process involved direct monitoring of hydroponic melon cultivation activities in the field to understand the actual conditions and challenges encountered during cultivation. Meanwhile, interviews and discussions with farmers were carried out to obtain information regarding the problems faced and their needs related to environmental monitoring systems for melon cultivation. After the data collection process was completed, the researcher determined the hardware and software components required for system development.

c) Determining the Research Method

This stage aimed at determining the method used in the system design process. In this research, the Prototype method was applied because it allows gradual system development through iterative processes. The method was designed based on system requirements, then tested and refined according to the evaluation results, enabling the system to meet user needs more effectively and optimally.

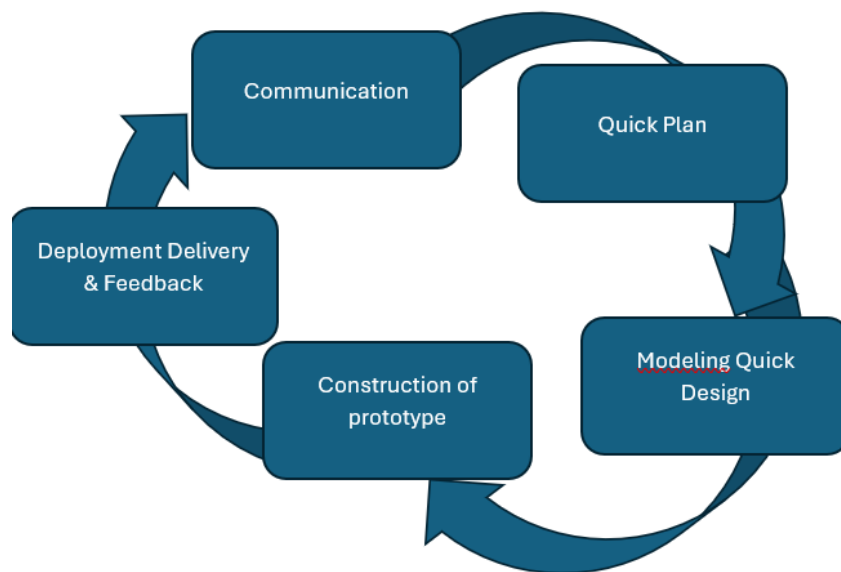


Figure 2. Prototype Method

As shown in **Figure 2**, the Prototype method consists of several stages, namely communication, quick plan, modeling quick design, construction of prototype, and deployment delivery & feedback.

d) Implementation of the Research Method

The next stage was the implementation of the selected research method, namely the Prototype method. The implementation process of the Prototype method consisted of several stages as follows:

1) Communication

At this stage, the researcher conducted intensive communication with users to understand the needs and problems encountered in monitoring hydroponic melon cultivation. The information collected included important parameters that needed to be monitored, such as temperature, humidity, pH, and nutrient concentration, as well as system expectations and technical constraints found in the field.

2) Quick Plan

At this stage, the researcher carried out data collection and obtained accurate information. Based on the collected information, a requirements analysis and rapid planning process were conducted, including hardware specifications, software specifications, and the system development steps to be implemented.

3) Modelling Quick Design

At this stage, the implementation planning of the system model or design was conducted. The design process consisted of two main aspects, namely software design and hardware design.

4) System Implementation

At this stage, the overall system was implemented, where the hydroponic monitoring device and website were designed and applied to the research object at Lara's Melon Hydroponic. Both the hardware and software components that had been designed were implemented and integrated to operate as a complete monitoring system.

a. Software (Website)

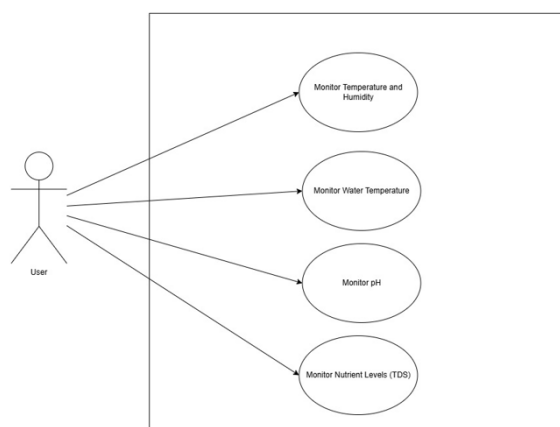


Figure 3. Use Case Diagram

A Use Case describes the interactions that users can perform within the system. As shown in **Figure 3**, the use case diagram illustrates the functionality of the website to be developed, where users can access real-time sensor data through the website interface.

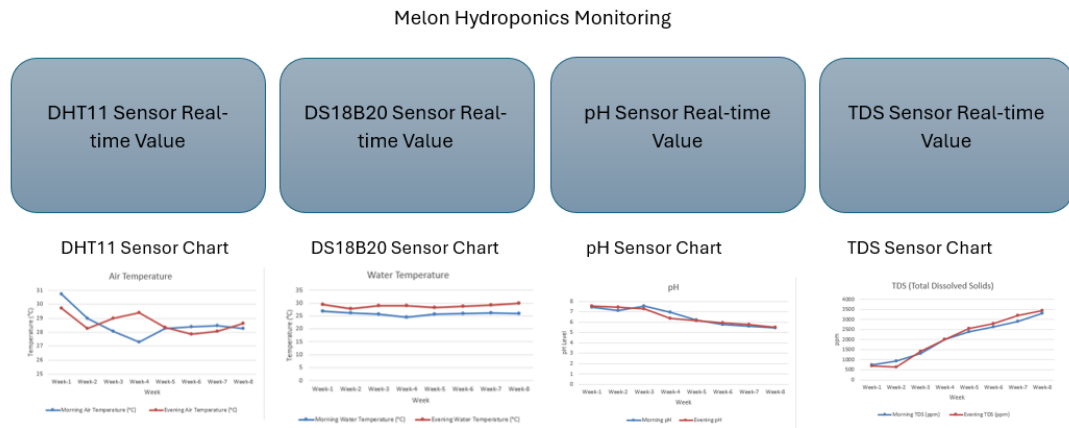


Figure 4. Layout of The Website Interface

The website design shown in Figure 4 represents a preliminary layout of the website interface. The website page is designed to display real-time data obtained from the DHT11 sensor, pH sensor, and TDS sensor. In addition, the website will also provide graphical visualizations of the data generated by each sensor to facilitate monitoring and analysis of environmental conditions.

b. Hardware

Figure 5 illustrates the overall architecture of the proposed Internet of Things (IoT)-based monitoring system, showing the interaction between sensing devices, the microcontroller, the communication module, and the cloud platform. The system is designed to collect environmental data in real time and transmit the information to users

through an internet-connected web interface.

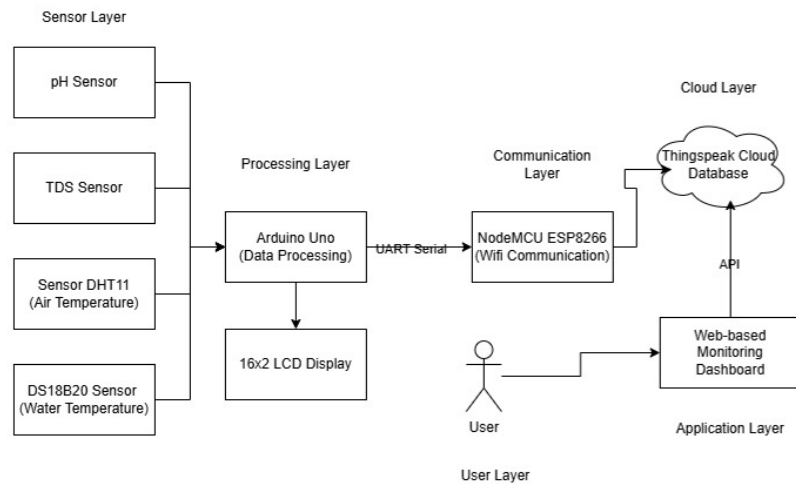


Figure 5. Architecture of Proposed IoT

Based on Figure 5, the data obtained from the four sensors are processed by the Arduino Uno microcontroller. The processed data are then transmitted serially from the Arduino Uno to the NodeMCU ESP8266. Furthermore, NodeMCU ESP8266 sends the data to the cloud database platform, namely Thing Speak, provided that the NodeMCU ESP8266 is connected to the internet. The website platform subsequently retrieves the data from the cloud database through the Thing Speak service and displays information on a web interface that can be accessed by users through smartphones or laptops connected to the internet.

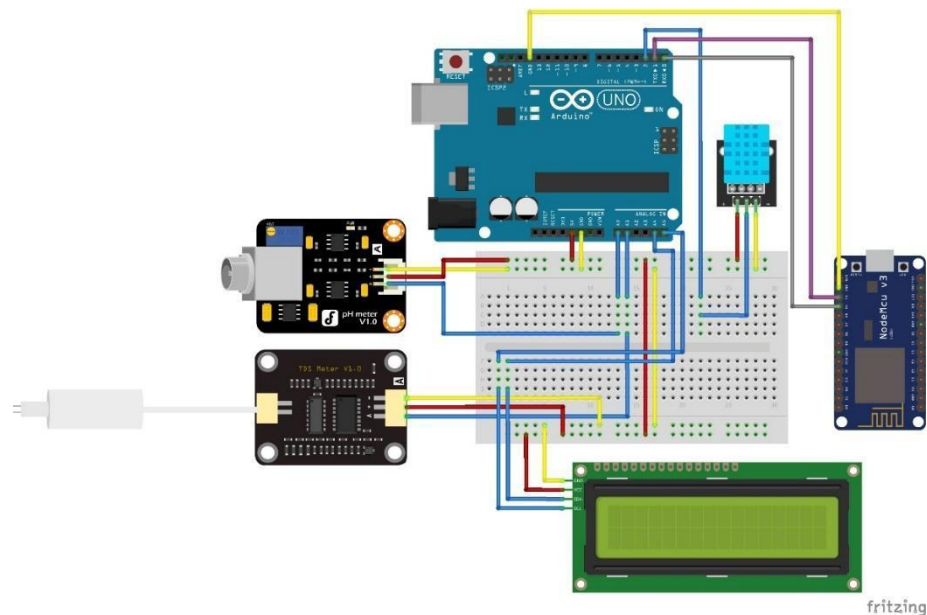


Figure 6. Schematic Design

Figure 6 illustrates the schematic design of the proposed monitoring system. This schematic illustration is used to identify the connection pathways between each component within the system. As shown in the figure, each sensor is connected to the Arduino Uno microcontroller, while the NodeMCU ESP8266 is connected to the Arduino Uno for data communication and internet connectivity.

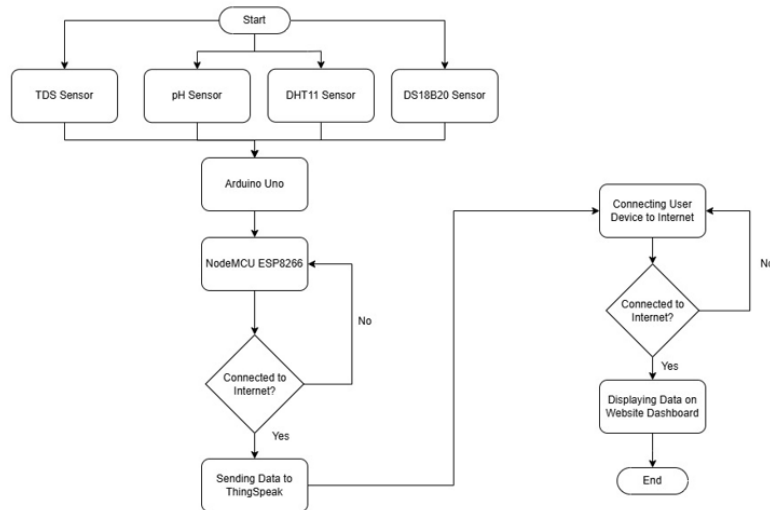


Figure 7. Illustrates The Initial Process of System Workflow

Figure 7 illustrates the initial process of the system workflow, which begins with sensors detecting environmental parameters based on the program embedded in the microcontroller. The collected data are then processed by the Arduino Uno before being transmitted serially to the NodeMCU ESP8266 microcontroller. Once the ESP8266 is connected to the internet, the data is sent to the ThingSpeak database platform. Subsequently, users can monitor the data through the designed website interface using devices such as smartphones or laptops connected to the internet.

5) Overall System Testing

At this stage, comprehensive testing was conducted on the entire system that had been designed and programmed to ensure that all components functioned properly. The system testing process included functionality testing, calibration testing, and User Acceptance Testing (UAT).

6) Overall System Evaluation

At this stage, the evaluation of the testing results was carried out to assess the effectiveness and efficiency of the system in monitoring environmental parameters. The evaluation included analyzing the suitability of the system with the initial requirements,

identifying weaknesses or anomalies, and providing recommendations for system improvement. In addition, the evaluation compared the performance of the automated system with the conventional manual methods commonly used by farmers.

7) Report

The final stage was report, which documented the entire research process, starting from the literature review to the system evaluation stage. The report presents the analysis results, conclusions, and recommendations for further system development. The report also serves as documented evidence that the research has been conducted.

3. Results and Discussion

3.1. System Implementation

The system realization process was divided into two implementation stages, namely hardware development and software development, including program coding and system interface design, as described [Figure 8](#).

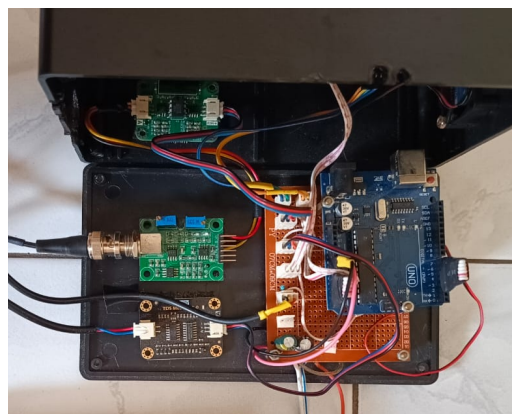


Figure 8. Physical Form

[Figure 8](#) presents the physical form of the components along with their supporting modules. The system was designed using two microcontroller units for data processing and communication purposes and was supported by four sensors to monitor plant conditions in real time.



Figure 9. Monitoring System Hardware

Figure 9 shows the placement position of the monitoring system hardware, which was installed beneath the PVC pipe structure. This placement was intended to keep the device close to the power source while also facilitating the connection between the hardware components and the sensors installed within the hydroponic system.

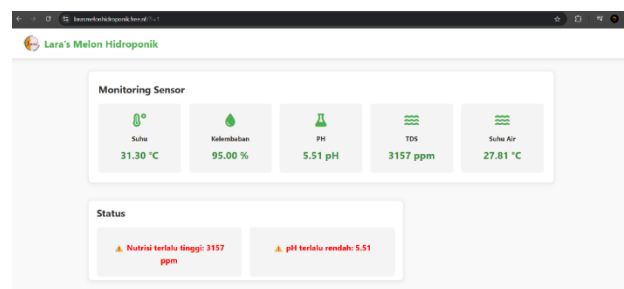


Figure 10. Interface of the Hydroponic

Figure 10 presents the interface of the hydroponic monitoring website, which displays data obtained from the ThingSpeak API. The displayed data include air temperature, humidity, water temperature, pH, and TDS values. In addition to displaying numerical data, the website also provides automatic status information. If the TDS value exceeds 1100 ppm, the status “nutrient level too high” is displayed; if it is below 900 ppm, the status “nutrient level too low” is shown; and if the value is between 900–1100 ppm, the status “sufficient nutrient level” is displayed. Meanwhile, for pH values, if the value is above 7.0, the status “pH too high” is displayed; if it is below 6.0, the status “pH too low” is shown; and if the value is between 6.0–7.0, the status “optimal pH” is displayed.

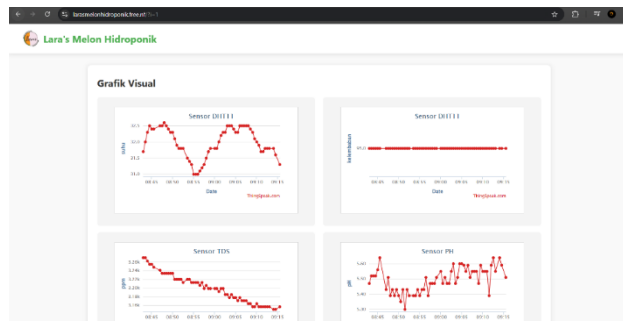


Figure 11. Visualization of Sensor Data Readings

The visualization of sensor data readings is displayed on the website in graphical form integrated with ThingSpeak, as shown in **Figure 11**. This page presents monitoring graphs for environmental parameters, including air temperature and humidity, as well as water quality parameters such as TDS and pH simultaneously to facilitate the analysis of plant conditions.

3.2. Discussion

Based on the results of the observations, the following data were obtained.

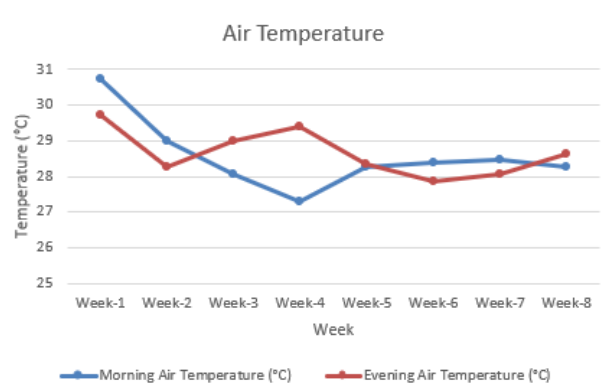


Figure 12. Air Temperature

The graph in **Figure 12** shows fluctuations between morning and afternoon temperatures. During the first week, morning temperatures tended to be higher than afternoon temperatures. However, in the third and fourth weeks, afternoon temperatures were recorded higher than morning temperatures.

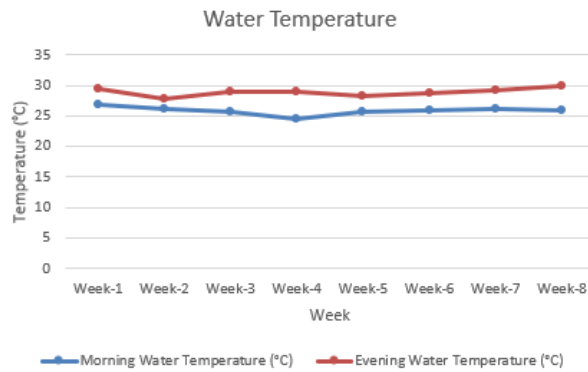


Figure 13. Water Temperature

The visualization in Figure 13 demonstrates a consistent trend in which the afternoon temperature graph (orange line) remains above the morning temperature graph (blue line), with an average difference of approximately 2°C to 4°C. Although the temperature increased in the afternoon, the water temperature remained below 30°C.

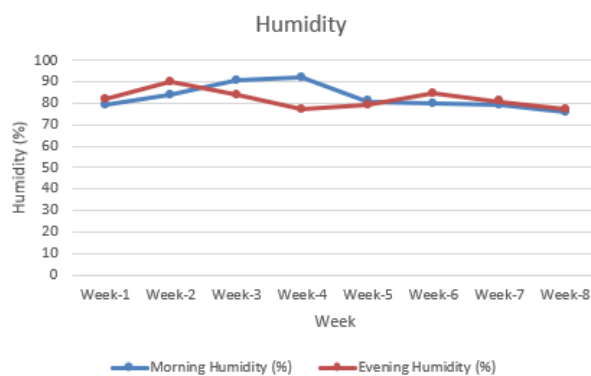


Figure 14. Humidity

The fluctuation pattern of humidity can be observed more clearly in Figure 14. During the early weeks (Weeks 1 to 4), air humidity tended to increase in both morning and afternoon sessions. Significant spikes occurred during the afternoon of Week 2 (90%) and the mornings of Weeks 3 (91%) and 4 (92%). However, entering the final growth phase (Weeks 5 to 8), the graph trend showed a stable decline, where humidity gradually decreased to around 76–77% in the final week.

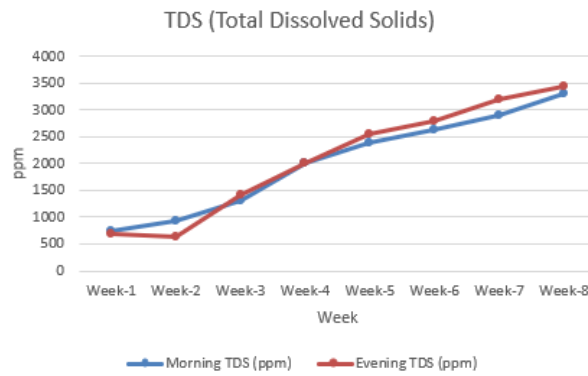


Figure 15. TDS

This increasing trend is clearly illustrated in **Figure 15**, where the graph shows a continuously rising linear pattern from the first week to the eighth week. A significant increase was observed starting from Week 3 (approximately 1,300–1,400 ppm) to Week 4 (approximately 2,000 ppm). In addition, the difference between morning and afternoon readings was relatively small, indicating that the nutrient solution concentration in the reservoir remained stable throughout the day.

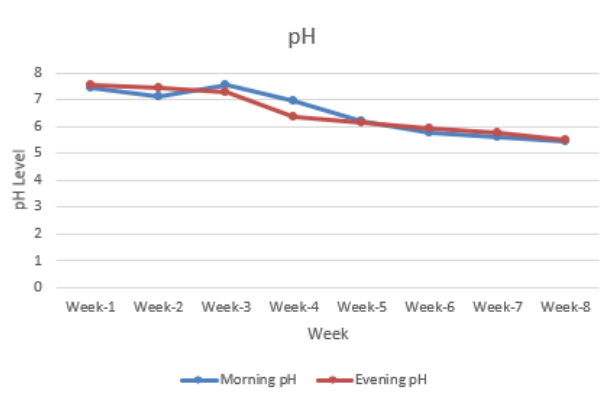


Figure 16. Graph with a Consistently Negative Slope

The visualization in **Figure 16** shows a graph with a consistently negative slope. The graph gradually decreased from 7.5 pH in the first week to 5.5 pH in the final week. No extreme fluctuations were observed between morning and afternoon sessions, indicating that pH changes occurred gradually due to the biological activity of the plants rather than sudden disturbances.

To evaluate the effectiveness of the IoT-based monitoring system implementation, a comparison of harvest results was conducted between plants monitored using the developed system (treatment) and plants cultivated conventionally without the assistance of a real-time monitoring system (control). The quality parameters measured included fruit weight and sweetness level (°Brix).

Table 1. The Weighing Results

No	Weight (g) – Monitored	Weight (g) – Unmonitored
1	1535	1420
2	1425	1470
3	1455	1350
4	1350	1415
5	1420	1330
6	1520	1435
7	1415	1335
8	1065	1275
Average (g)	1398	1379
Average (kg)	1.4	1.38

Based on **Table 1**, the weighing results showed that the monitored plants produced an average fruit weight of 1,398 grams (1.4 kg), which was slightly higher than the non-monitored group with an average weight of 1,379 grams (1.38 kg). Although the numerical difference appears relatively small, this trend indicates that environmental stability, particularly water temperature and humidity monitored through the IoT-based system, contributed positively to the fruit cell enlargement process. With the availability of real-time data, maintenance actions such as adding water when the reservoir temperature increased could be performed more quickly, thereby maintaining optimal plant metabolic activity.

Table 1. Group of Plants Monitored

No	°Brix – Monitored	°Brix – Unmonitored
1	13	14
2	14	12
3	14	11
4	12	14
Average	13.25	12.75

Based on **Table 2**, the group of plants monitored using the developed system achieved an average sweetness level of 13.25 °Brix, which was higher than the non-monitored group that only reached 12.75 °Brix. This improvement in taste quality strongly correlates with the stability of the chemical parameters discussed in the previous subsection, where the system's capability to monitor nutrient accumulation (TDS) until the final cultivation phase ensured that the plants received sufficient nutrient concentration for fruit sugar formation. In addition, the pH condition was maintained within the optimal range of 5.5–6.5 during the fruiting phase, which played a vital role in maximizing micronutrient absorption for sweet taste synthesis.

4. Conclusion

Based on environmental monitoring conducted over eight weeks, the microclimate and nutrient parameters generally remained within conditions that supported melon plant growth, although several deviations occurred as the plants matured. Air temperature remained relatively stable within the range of 27–30°C, while water temperature ranged between 24–30°C, which is still considered optimal for nutrient absorption. Air humidity temporarily increased to 90% during the third and fourth weeks; however, these fluctuations did not cause significant negative effects.

Regarding chemical parameters, the TDS value showed an increasing trend exceeding 3000 ppm due to nutrient accumulation without a flushing process, while the pH gradually decreased from 7.5 to 5.5. The gradual pH change allowed the plants to adapt without experiencing physiological stress. The environmental stability monitored through the system showed a positive correlation with harvest results, where the monitored plant group produced an average fruit weight of 1.40 kg, slightly higher than the non-monitored group with an average of 1.38 kg. In addition, the sweetness level of the monitored group reached 13.25 °Brix, outperforming the control group, which achieved 12.75 °Brix.

These findings indicate that although the system operated without automatic control features, the availability of real-time data was able to support faster and more accurate manual corrective actions. As a result, the system contributed to maintaining environmental stability and improving harvest quality compared to conventional monitoring methods.

References

- [1] M. H. F. F. Siregar and A. Novita, "Sosialisasi Budaya Sistem Tanam Hidroponik dan Veltikultur," *Jurnal Pengabdian Masyarakat*, vol. 3, no. 1, pp. 113–117, Apr. 2021.
- [2] H. T. Al Ghifary, M. S. Ma'ruf, A. M. Royyan, and Gunawan, "Optimalisasi Budidaya Melon Hidroponik melalui Smart Farming Sistem NFT Berbasis IoT untuk Peningkatan Produktivitas dan Pemberdayaan Mitra di Osaka99 Agro Farm, Pati Utara, Jawa Tengah," *Jurnal Abdi Masyarakat Indonesia*, vol. 5, no. 5, pp. 2319–2332, Sep. 2025.
- [3] Nashir, I., Luqman, H., Olugbemi, P. W., & Oladosu, Y. Effect of electrical conductivity and Nutrient Concentrations of Soilless Media Monitored with the Internet of Things (IoT) Sensor Nodes on Growth of Rock Melon.
- [4] N. Yadav, P. Jangra, and K. Yadav, "A Comprehensive Review on Medicinal Importance of Cucumis melo," *Asian Journal of Pharmaceutical Research and Development*, vol. 13, no. 1, pp. 117–122, 2025.

- [5] Adekunle, S. M., Rus, R. C., Usaizan, N., Nashir, I. M., Luqman, H., Olugbemi, P. W., & Oladosu, Y. (2023). Effect of electrical conductivity and Nutrient Concentrations of Soilless Media Monitored with the Internet of Things (IoT) Sensor Nodes on Growth of Rock Melon. *AgroTech-Food Science, Technology and Environment*, 2(1), 21-28.
- [6] M. A. Silva, T. G. Albuquerque, D. M. Ferreira, R. C. Alves, M. B. P. P. Oliveira, and H. S. Costa, "Nutritional and Bioactive Profiling of Cucumis melo L. By-Products: Towards a Circular Food Economy," *Molecules*, vol. 30, no. 6, Mar. 2025.
- [7] B. Supriyanta, F. R. Kodong, I. Widowati, and F. A. Siswanto, *HIDROPONIK MELON PREMIUM*. Yogyakarta: Lembaga Penelitian dan Pengabdian Kepada Masyarakat UPN "Veteran" Yogyakarta, 2021.
- [8] S. Nora, M. Yahya, M. Mariana, Herawaty, and E. Ramadhani, "Teknik Budidaya Melon Hidroponik Dengan Sistem Irigasi Tetes (Drip Irrigation)," *Agrium*, vol. 23, no. 1, pp. 21–26, Oct. 2020.
- [9] A. L. Adiredjo, M. Roviq, N. R. Ardiarini, and A. B. Leorentina, "Performance of Melon (Cucumis Melo L.) Hybrids Across Diverse Environmental Conditions," *SABRAO J Breed Genet*, vol. 56, no. 1, pp. 211–223, 2024.
- [10] Cahyono, M. S. D., Ray, N., & Intan, R. P. (2025). IMPLEMENTATION OF IOT-BASED E-HYDROPONIC SYSTEM TO INCREASE MELON FARMING PRODUCTIVITY IN NGANJUK DISTRICT. *Journal of Training and Social Empowerment for Indonesian Society*, 1(1).
- [11] Z. W. Putra, A. Setiadi, and H. Setiyawan, "Analisis Kelayakan Usaha Finansial Budidaya Melon Hidroponik di PT Indigen Karya Unggul," *Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis*, vol. 11, no. 1, pp. 1569–1581, Jan. 2025.
- [12] K. Sharma, R. Yadav, Shubham, and S. Kaushal, "Optimizing Hydroponic Crop Production: A Multifaceted Approach to EC, pH and Nutrient Management," *J Sci Res Rep*, vol. 31, no. 4, pp. 716–726, Apr. 2025.
- [13] S. Mifta Ramadan, Asriyadi, and A. Bastian, "Rancang Bangun Sistem Pemantauan dan Kendali Kebun Hidroponik Nutrient Film Technique (NFT) Berbasis IoT," *Seminar Riset Mahasiswa – Computer & Electrical (SERIMA-CE)*, vol. 1, no. 1, pp. 149–158, 2023.
- [14] Prasetyo, S. T., & Khoiri, S. (2025). Implementation of an IoT-Based Drip Irrigation System for Cucumis melo Cultivation in Greenhouse Environments: Initial Evaluation. *Agricultural Revolution Journal*, 1(1), 13-21.
- [15] Singh, Y. N., Bhole, B. S., Jayanthi, J., & Arun Kumar, K. (2025). Effect of nutrient concentrations and vermiwash on bottle gourd productivity in automated IoT-based hydroponic systems. *International Journal of Vegetable Science*, 31(4), 529-554.