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# REAL-TIME IMPLEMENTATION OF AN INTERNET OF THINGS-BASED ROSE ECO-ENZYME FERMENTATION MONITORING SYSTEM FOR WOMEN FARMERS GROUP

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***Abstract.*** The surplus of rose flower harvest in Ngliman Village causes some rose petals to be underutilized and potentially become organic waste. One effort to utilize this is through eco-enzyme fermentation using rose petals. However, the fermentation process carried out by the Women Farmers Group (KWT) is still monitored manually, making fermentation conditions difficult to control and at risk of failure. This study aims to implement an Internet of Things (IoT)-based eco-enzyme fermentation monitoring system to monitor fermentation conditions in real time. The research methods used include the design, development, and implementation of a monitoring system using an ESP32 microcontroller, a DHT22 sensor to measure temperature, and an MPX Pressure sensor to measure gas pressure during the fermentation process. The obtained data is sent via the internet and displayed on a web-based dashboard. The results show that the system is able to read, send, and display temperature and gas pressure data in real time effectively throughout the fermentation process. The developed system helps users monitor fermentation conditions more effectively, improves the accuracy of process monitoring, and reduces the risk of fermentation failure. Thus, this IoT-based monitoring system has the potential to support the optimization of rose petal waste processing into useful eco-enzyme products.

**Keywords:** Eco Enzyme, Internet of Things, Real-Time Monitoring, Fermentation, ESP32

***Abstrak.*** Surplus hasil panen bunga mawar di Desa Ngliman menyebabkan sebagian kelopak mawar tidak termanfaatkan secara optimal dan berpotensi menjadi limbah organik. Salah satu upaya pemanfaatannya adalah melalui fermentasi eco enzyme berbahan dasar kelopak mawar. Namun, proses fermentasi yang dilakukan oleh Kelompok Wanita Tani (KWT) masih dipantau secara manual sehingga kondisi fermentasi sulit dikendalikan dan berisiko mengalami kegagalan. Penelitian ini bertujuan mengimplementasikan sistem monitoring fermentasi eco enzyme berbasis Internet of Things (IoT) untuk memantau kondisi fermentasi secara real-time. Metode penelitian yang digunakan meliputi perancangan, pengembangan, dan implementasi sistem monitoring menggunakan mikrokontroler ESP32, sensor DHT22 untuk mengukur suhu, serta sensor MPX Pressure untuk mengukur tekanan gas selama proses fermentasi. Data yang diperoleh dikirim melalui jaringan internet dan ditampilkan pada dashboard berbasis web. Hasil penelitian menunjukkan bahwa sistem mampu membaca, mengirim, dan menampilkan data suhu serta tekanan gas secara real-time dengan baik selama proses fermentasi berlangsung. Sistem yang dikembangkan membantu pengguna memantau kondisi fermentasi secara lebih efektif, meningkatkan ketepatan pengawasan proses, serta mengurangi risiko kegagalan fermentasi. Dengan demikian, sistem monitoring berbasis IoT ini berpotensi mendukung optimalisasi pengolahan limbah kelopak mawar menjadi produk eco enzyme yang bernilai guna.

**Kata Kunci:** Eco Enzyme, Internet of Things, Monitoring Real-Time, Fermentasi, ESP32

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## INTRODUCTION

Agricultural waste management has become an important issue in supporting environmental sustainability and increasing the economic value of agricultural commodities. Organic waste that is not properly managed can lead to environmental problems while reducing opportunities for value-added product development. One potential source of organic waste is rose cultivation, particularly in areas with high production volumes. Ngliman Village is one of the largest rose-producing villages in the Kediri Residency area. Approximately 64.6% of the village's agricultural commodities consist of rose plants, making roses the dominant commodity cultivated by local farmers (Kiswardani et al., 2023; Suyanto et al., 2023).

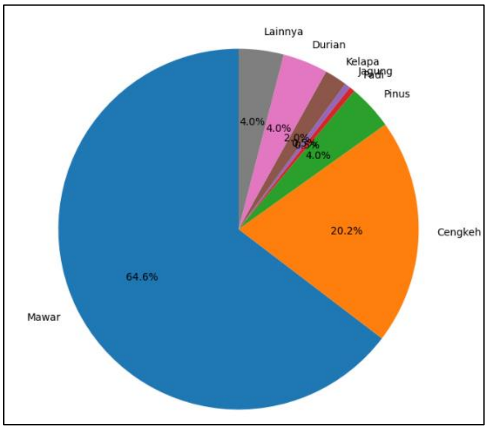


**Figure 1.** Distribution data of plant varieties in Ngliman village

Although Ngliman Village is recognized as the largest rose-producing village in the Kediri Residency area, the harvest output has not been optimally distributed (Kiswardani et al., 2023). This condition was caused by an oversupply of rose harvests in 2024. The harvest surplus resulted in a large quantity of rose petals being discarded without further processing or commercialization, which subsequently contributed to the low per capita income of the local community (Sephia & Ika Chandriyanti, 2024). Due to the short shelf life of rose petals, farmers have not been able to maximize sales in the form of raw materials, leading to economic losses (Sulfiani & Sukmawati, 2020).

The accumulation of untreated rose waste may cause economic losses as well as decomposition in agricultural areas. Uncontrolled decomposition has the potential to contribute to environmental pollution; therefore, proper and optimal waste management is required (Sulfiani & Sukmawati, 2020). To date, there has been no significant optimization in the processing of rose harvest products in Ngliman Village. As a result, the potential economic value that could be generated from rose cultivation has not been fully realized due to the lack of post-harvest processing optimization. One form of optimizing organic waste generated from rose petal harvests is by processing it into eco enzyme products. Eco enzyme was selected as a derivative product of rose cultivation due to its relatively simple production process, which utilizes organic waste while also offering significant potential for further product development. Eco enzyme made from rose petals is produced through a fermentation process. This fermentation process not only provides environmental benefits through organic waste utilization but also creates economic value by transforming raw materials into marketable derivative products.

Recent studies have shown that Internet of Things (IoT) technology can support real-time monitoring and control of production processes by providing continuous access to environmental and operational data (Ferdian Hutabarat et al., 2023; Rajagukguk & Widiantono, 2025). In the context of eco enzyme fermentation, parameters such as temperature and gas pressure are important indicators for maintaining fermentation stability and product quality. However, the application of IoT-based monitoring systems for eco enzyme fermentation at the community level, particularly for rose petal fermentation managed by Women Farmers Groups, remains limited. The novelty of this study lies in the implementation of a real-time IoT-based monitoring system that integrates temperature and gas pressure monitoring during rose petal eco enzyme fermentation at the community scale. Therefore, this study aims to implement and evaluate an IoT-based monitoring system using ESP32, DHT22, and pressure sensors to support real-time monitoring of the eco enzyme fermentation process and improve fermentation management within the Women Farmers Group in Ngliman Village.

## METHOD

### Research Method

This study employed an experimental method with an implementation-based approach. Experimental research is a scientific activity that emphasizes scientific credibility, repeatability, precision, and causality as the primary outcomes of the research process (Denscombe, 2014). Experimental research is also defined as a scientific method used to analyze cause-and-effect relationships (causality) between dependent and independent variables (Akbar et al., 2023). The main characteristics that distinguish experimental research from other research methods include manipulation, control, and randomization. These three characteristics play an important role in generating valid, objective, and reliable research data (Yulianti et al., 2024).

The study involved dependent variables, independent variables, and control variables. The dependent variables in this study were fermentation temperature and gas pressure. Meanwhile, the independent variable was the fermentation duration. The control variables included the composition of eco enzyme materials, environmental conditions, and the volume of fermentation materials. The study was conducted at the Women Farmers Group (Kelompok Wanita Tani/KWT) in Ngliman Village, Sawahan District, Nganjuk Regency, Indonesia. The research was carried out from November 2025 to May 2026. The KWT members are rose farmers who process rose petals into value-added products, including eco enzyme. The research conducted in this study consisted of seven stages, beginning with the requirements analysis stage and concluding with the analysis and conclusion stage. The stages of the research process carried out in this study are presented in Figure 2.


**Figure 2.** Research Stages Flowchart

The research consisted of five main stages: (1) needs analysis, (2) system design, (3) system development, (4) implementation, and (5) evaluation. During the needs analysis stage, observations and interviews were conducted to identify problems in the existing fermentation process. The findings indicated that fermentation monitoring was still performed manually, making it difficult to detect changes in fermentation conditions. Based on these findings, an IoT-based monitoring system was designed using an ESP32 microcontroller, a DHT22 sensor for temperature monitoring, and an MPX Pressure Sensor for gas pressure monitoring. The developed system was installed on eco enzyme fermentation containers and connected to a web-based monitoring dashboard through an internet network.

The monitoring process was conducted continuously throughout the fermentation period. Temperature and gas pressure data were measured automatically by the sensors at predetermined intervals and transmitted by the ESP32 to the web server. The collected data were then displayed in real time on the monitoring dashboard, allowing users to observe fermentation conditions remotely. The monitoring focused on two key parameters: fermentation temperature and gas pressure, which are important indicators of fermentation stability and potential fermentation failure.

The monitoring parameters used in this study were fermentation temperature and gas pressure generated inside the fermentation containers during the fermentation process in real-time. The monitoring parameters applied in this study are presented in Table 1.

**Tabel 1.** Monitoring Parameters

| Monitoring Parameters | Sensor | Function |
|---|---|---|
| Fermentation Temperature | DHT22 | To monitor temperature fluctuations during the fermentation process. |
| Gas Pressure | MPX Pressure Sensor | To monitor gas pressure generated during the fermentation process. |

The collected monitoring data were analyzed descriptively to evaluate the performance of the IoT system in reading, transmitting, and displaying real-time temperature and gas pressure data. System performance was assessed based on the stability of sensor readings, data transmission capability, and real-time visualization on the web-based dashboard.

## RESULT

The IoT-based eco enzyme fermentation monitoring system was designed to monitor fermentation conditions in real-time. The system operates by collecting input data from several sensors installed in the fermentation containers. The acquired data are processed using the ESP32 microcontroller and subsequently transmitted through an internet network to the monitoring dashboard. The dashboard functions as a display interface that presents real-time fermentation conditions, including temperature and gas pressure, enabling users to monitor the fermentation process without opening the fermentation containers directly. This study, which employed an experimental method within the Women Farmers Group MSME, successfully developed an IoT-based eco enzyme fermentation monitoring system. The system implements a simple technology approach by utilizing sensors to monitor fermentation temperature and gas pressure. Both hardware and software components were designed to support an automated real-time monitoring system during the fermentation process.

### System Architecture

The eco enzyme fermentation monitoring system developed in this study utilized two main sensors, namely the DHT22 temperature sensor and the MPX Pressure Sensor for monitoring gas pressure during the fermentation process. The following figure illustrates the system architecture design implemented in the rose-based eco enzyme fermentation monitoring system.

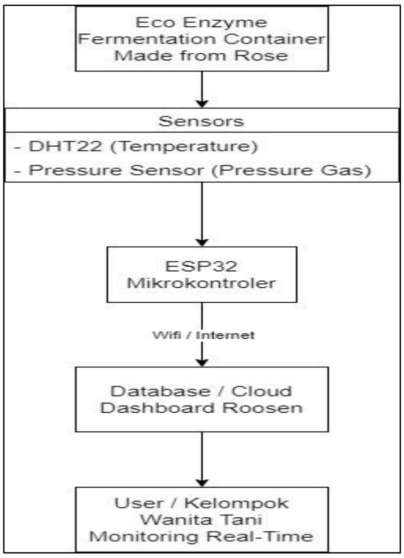


**Figure 3.** System architecture IoT monitoring

## Hardware Design

Hardware functions as the physical component utilized in the implementation of the rose-based eco enzyme fermentation automation system. The hardware components used in this study consisted of various sensors and supporting devices, as presented in Table 2.

**Table 2.** Components and functions of the control system

| Components | Function |
|---|---|
| ESP32 20P Type C | Main Microcontroller |
| DHT22 | Temperature and Humidity Sensor |
| MQ135 | Gas Quality Sensor |
| Pressure Sensor | Fermentation Gas Pressure Sensor |
| Ultrasonic Sensor | Liquid Level Sensor |
| Relay 4CH | Output Device Controller |
| Adaptor 12V | System Power Supply |
| Breadboard | Circuit Prototype Board |
| Panel Box | IoT System Protective Enclosure |
| Motorized Ball Valve | Liquid Flow Controller |
| Heater Fan | Temperature Stabilization System |
| Cooling Fan | Cooling System |

The hardware design of the IoT-based eco enzyme fermentation monitoring system utilized the ESP32 microcontroller as the main control center of the system. The DHT22 sensor was used to monitor fermentation temperature, while the MPX Pressure Sensor was utilized to measure gas pressure generated during the fermentation process. The system was also equipped with an I2C-based LCD to display real-time monitoring data from the fermentation container, as well as a relay module to control supporting devices integrated into the fermentation system.

The entire circuit was designed using 3.3V and 5V power supplies according to the operational requirements of each system component.

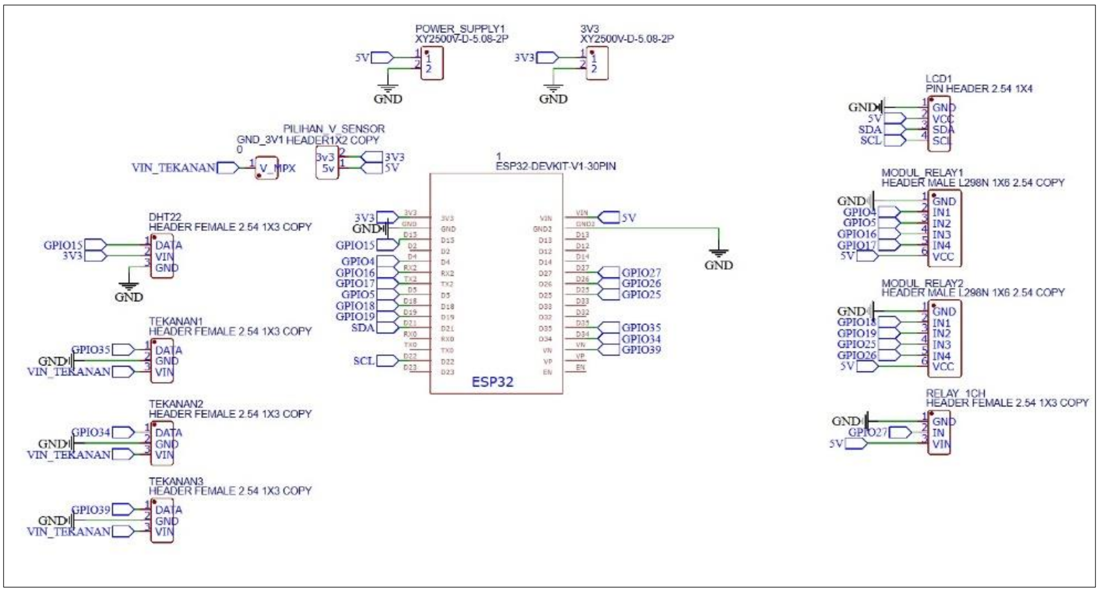

**Figure 3.** Control system schematic

Figure 3 illustrates the control system schematic utilized in the monitoring system developed in this study. All components were connected using 3.3V and 5V power supplies according to the operational requirements of each device component. The implementation of the schematic design shown in Figure 3 enables the eco enzyme fermentation monitoring process to operate in a more structured and real-time manner without requiring users to repeatedly open and close the fermentation containers during the fermentation process.

### Software Design

The software system for the monitoring platform was developed using Arduino IDE to program the ESP32 microcontroller. The program was designed to enable the ESP32 to read data obtained from the DHT22 sensor and the MPX Pressure Sensor during the fermentation process. Figure 4 presents the software system workflow utilized in the monitoring system.

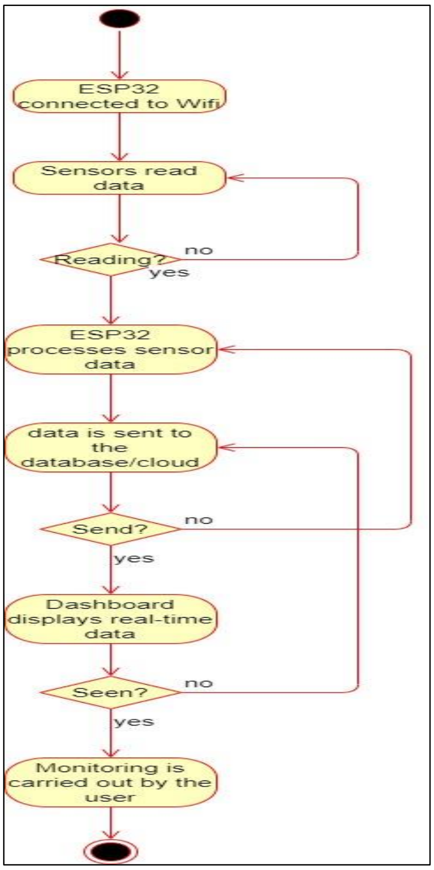


**Figure 4.** Software System Workflow of the Monitoring System

The IoT-based eco enzyme fermentation monitoring system begins with the ESP32 microcontroller connecting to a network using WiFi as the communication medium for input data transmission. Once the connection is successfully established, the sensors begin reading fermentation parameters, including temperature and gas pressure, periodically based on sensor input. The sensor data obtained are continuously checked, and successfully acquired data are processed by the ESP32 before being transmitted to a database or cloud server through an internet connection. The system then performs a verification process to ensure that the data have been successfully transmitted. The transmitted data are subsequently displayed on the monitoring dashboard in real-time, as shown in Figure 5.

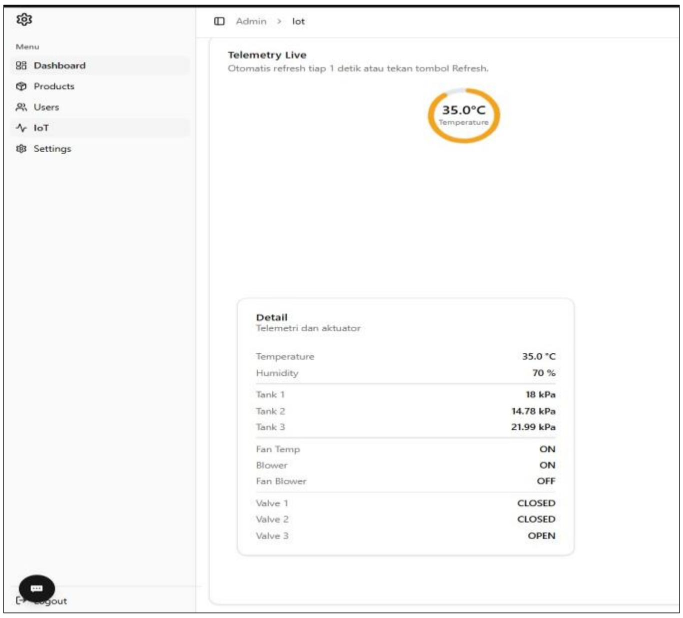


**Figure 5.** Monitoring Dashboard Interface

The monitoring dashboard is capable of displaying input data collected from the sensors integrated into the system. The displayed data serve as monitoring information for the Women Farmers Group MSME during the eco enzyme fermentation process. Through the dashboard interface, users are able to monitor fermentation conditions in real-time, particularly temperature and gas pressure parameters, without directly opening the fermentation containers.

### System Workflow

To support the real-time monitoring process of rose-based eco enzyme fermentation, a structured system workflow is required to ensure that the processes of data acquisition, data processing, and data transmission can operate effectively. The workflow was designed to illustrate the communication process among components within the developed monitoring system, starting from the sensors as input devices, the microcontroller as the data processing center, and the monitoring dashboard as the user monitoring interface. Figure 6 illustrates the workflow of the developed monitoring system.

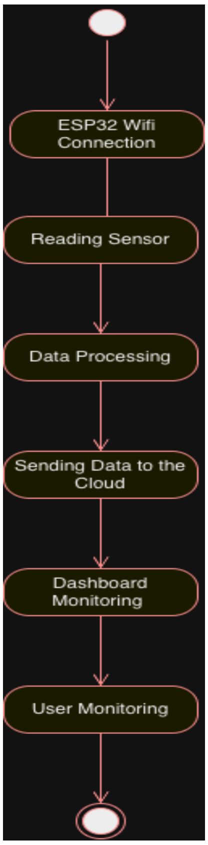


**Figure 6.** Workflow of the Eco Enzyme Fermentation Monitoring System

The workflow of the eco enzyme fermentation monitoring system begins with the ESP32 microcontroller connecting to a WiFi network, which functions as the communication medium for data transmission within the system. Once the connection is successfully established, input data generated by the sensors are read continuously by the DHT22 sensor and the MPX Pressure Sensor during the fermentation process. The acquired sensor data are then processed by the ESP32 before being transmitted through an internet connection to the database or cloud monitoring platform.

After the data are successfully transmitted to the database or cloud monitoring platform, the incoming data are displayed on the monitoring dashboard in real-time. This enables users to monitor fermentation conditions more easily and efficiently without directly opening the fermentation containers. The system is also equipped with a relay module that functions as a controller for supporting devices such as cooling fans and heaters used to maintain fermentation stability. The entire monitoring process operates automatically, allowing the system to provide continuous and real-time monitoring reports throughout the fermentation process.

## Monitoring Parameters

Monitoring parameters were utilized to observe the real-time conditions of the rose-based eco enzyme fermentation process. In this study, the developed monitoring system focused on two main parameters, namely temperature and gas pressure within the fermentation containers. Both parameters play an important role in maintaining the stability and quality of the fermentation process.

*Temperature Monitoring*

Temperature monitoring was conducted using the DHT22 sensor, which was directly connected to the main control center, namely the ESP32 microcontroller. The temperature parameter was used to monitor the fermentation chamber conditions in order to maintain the activity of microorganisms involved in the fermentation process. Temperature data obtained from the sensor were transmitted to the monitoring dashboard in real-time, enabling users to directly observe fermentation conditions and activities without performing manual inspections of the fermentation area.

*Gas Pressure Monitoring*

Gas pressure monitoring was conducted using the MPX Pressure Sensor installed in each fermentation container. The gas pressure parameter was utilized to monitor gas activity generated during the fermentation process. In addition, gas pressure monitoring aimed to reduce the risk of excessive gas accumulation during fermentation. Excessive gas pressure may potentially cause fermentation container explosions. The gas pressure data displayed in real-time on the monitoring dashboard were used to facilitate and improve the fermentation supervision process.

*System Testing*

Based on the prototype design that had been developed, system testing was conducted through several stages, including sensor testing, data transmission testing, real-time monitoring testing, and overall system testing. The purpose of these tests was to evaluate whether all processes within the system operated according to the designed system architecture and workflow. Through the testing process, potential errors and system limitations within the monitoring process could also be identified and evaluated.

*Sensor Testing*

Sensor testing was conducted to evaluate whether the DHT22 sensor could properly function in reading fermentation parameters during the fermentation process. In addition to testing the DHT22 sensor, testing was also performed on the MPX Pressure Sensor. The testing process was carried out directly on the fermentation containers by connecting the sensors to the ESP32 microcontroller. The test results were then observed through the data displayed on both the LCD interface and the monitoring dashboard.

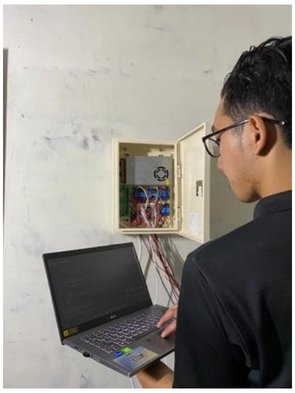

**Figure 7.** Sensor Testing

The testing results demonstrated that both main sensors operated properly, as indicated by their ability to detect gas pressure and temperature fluctuations during the fermentation process. The sensor data were successfully transmitted to the monitoring dashboard in real-time. Therefore, the sensors utilized in the monitoring system were considered capable of supporting continuous and real-time monitoring of the eco enzyme fermentation process.

**Data Transmission Testing**

Data transmission testing was conducted to ensure that sensor data could be successfully transmitted from the ESP32 microcontroller to the monitoring dashboard through an internet connection. The testing process was carried out by connecting the ESP32 to a WiFi network and observing the periodic transmission of temperature and gas pressure data generated during the fermentation process. Successfully transmitted data were displayed on the web-based monitoring dashboard in real-time.

Based on the testing results, the system successfully transmitted monitoring data from the sensors to the dashboard without significant data transmission failures. Temperature and gas pressure data were displayed in real-time, enabling users to monitor eco enzyme fermentation conditions without performing direct manual inspections. These results indicate that the data communication system implemented in the IoT device operated effectively and was capable of supporting continuous fermentation monitoring.

**Real-Time Monitoring Testing**

Real-time monitoring testing was conducted to evaluate the system's capability to continuously and directly display fermentation data throughout the fermentation process. The testing process involved observing changes in temperature and gas pressure data acquired by the sensors and subsequently displayed on the web-based monitoring dashboard in real-time. In addition, monitoring was also performed through the LCD integrated into the control system to ensure that the monitoring data could be displayed locally.

The testing results showed that the system was capable of displaying monitoring data in real-time effectively. Sensor data could be updated periodically on the dashboard, allowing users to monitor eco enzyme fermentation conditions without directly opening the fermentation containers. The implementation of this real-time monitoring system improved the effectiveness and efficiency of the fermentation supervision process while minimizing the risk of contamination during fermentation.

**Overall System Testing**

Overall system testing was conducted to ensure that all components within the Internet of Things (IoT)-based eco enzyme fermentation monitoring system operated in an integrated manner. The testing process included sensor data acquisition, data processing by the ESP32 microcontroller, data transmission through the internet network, and data visualization on both the monitoring dashboard and LCD interface. The testing was carried out throughout the fermentation process to evaluate the stability of the system in performing continuous monitoring.

Based on the testing results, all system components were able to function properly according to their respective roles. The sensors successfully detected fermentation parameters, the ESP32 effectively processed and transmitted data through the internet network, and the monitoring dashboard displayed the monitoring data in real-time. In addition, the relay module and other supporting devices also operated effectively during the monitoring process. Therefore, the IoT-based eco enzyme fermentation monitoring system was considered capable of operating automatically and in real-time while supporting a more effective and structured fermentation monitoring process.

## DISCUSSION

The implementation of the Internet of Things (IoT)-based rose eco enzyme fermentation monitoring system demonstrates that digital monitoring technology can effectively support community-scale fermentation activities. The system enables continuous monitoring of fermentation conditions through real-time temperature and gas pressure measurements without requiring users to open the fermentation containers. This finding supports the concept of IoT proposed by Rajagukguk and Widiantono (2025), which states that IoT technology facilitates remote monitoring and improves operational efficiency through real-time data acquisition and transmission.

The successful integration of the DHT22 and MPX Pressure Sensor indicates that IoT devices can provide measurable and continuous information regarding fermentation dynamics. Temperature is a critical factor affecting microbial metabolism and fermentation performance, while gas pressure reflects biological activity occurring inside the fermentation container. The ability to monitor these parameters continuously provides a more objective approach than conventional manual observation. This finding is consistent with Hutabarat et al. (2023), who reported that IoT-based monitoring systems improve data accuracy and enable faster decision-making in production processes.

The web-based monitoring dashboard also contributed to more efficient supervision by allowing users to access fermentation data remotely. This result supports the findings of Tinmaz et al. (2022), who emphasized that the adoption of digital technologies in agricultural and livestock management can improve monitoring effectiveness, data accessibility, and operational control. Similarly, Hariyanto and Salsabiilah (2025) reported that digitalization contributes to greater efficiency and transparency in managing production activities at the community level.

A notable contribution of this study is the application of IoT technology within a Women Farmers Group (KWT) context for monitoring rose-based eco enzyme fermentation. Previous studies have largely focused on IoT implementation in agriculture, livestock management, and production monitoring systems, whereas studies involving eco enzyme fermentation at the community scale remain limited. Therefore, this research extends the application of IoT by demonstrating its feasibility in supporting small-scale fermentation activities and community-based agroindustry development.

From a practical perspective, the system contributes to the standardization of eco enzyme production by providing measurable fermentation indicators that can be monitored continuously. Such standardization is important because conventional fermentation practices often rely solely on fermentation duration without considering actual process conditions. Consequently, the developed system has the potential to reduce fermentation failure risks, improve production consistency, and support the utilization of rose petal waste as a value-added product. Despite these contributions, several limitations remain. The monitoring period did not cover the complete optimal fermentation cycle, and laboratory analyses of the final eco enzyme quality were not conducted. As a result, future studies should integrate additional parameters such as pH, humidity, and dissolved gas concentration, while also performing laboratory-based quality testing to examine the relationship between fermentation conditions and the quality of the resulting eco enzyme products.

## CONCLUSION

This study successfully implemented an Internet of Things (IoT)-based rose eco enzyme fermentation monitoring system within the Women Farmers Group (Kelompok Wanita Tani/KWT) as an effort to support a more effective and structured fermentation process. The developed system utilized a DHT22 sensor for temperature monitoring and an MPX Pressure Sensor for monitoring fermentation gas pressure, which were integrated with the ESP32 microcontroller and a web-based monitoring dashboard. Based on the testing results, the system was capable of reading, processing, and transmitting monitoring data in real-time through an internet connection effectively. The monitoring data could be displayed on both the dashboard and LCD interface, enabling users to monitor fermentation conditions without directly opening the fermentation containers. The implementation of this IoT-based monitoring system provided greater convenience in supervising the fermentation process while also minimizing the risk of contamination and excessive gas pressure during fermentation.

Therefore, the application of IoT technology in rose-based eco enzyme fermentation demonstrates strong potential as an appropriate technology for supporting community-based organic waste management. Furthermore, the developed real-time monitoring system can serve as an initial step toward supporting the digitalization of fermentation processes at the community level and promoting the development of eco enzyme products based on local resources.

## RECOMMENDATIONS

Based on the findings of this study, the Internet of Things (IoT)-based eco-enzyme fermentation monitoring system can be further developed to enhance the effectiveness and stability of the monitoring system. Future development may include the addition of other monitoring parameters, such as fermentation pH and gas quality, in order to achieve a more comprehensive and accurate fermentation monitoring process. Furthermore, system development can also be carried out by improving internet connection stability and optimizing the monitoring dashboard, so that the data transmission and display processes can operate more responsively. The use of more energy-efficient power sources and a more compact device design may also be considered in subsequent system development, thereby facilitating broader implementation at the community level.

Future research is also recommended to conduct laboratory-based quality testing of eco-enzyme products in order to determine the effect of fermentation monitoring on the quality of the resulting output. With these developments, the IoT-based fermentation monitoring system is expected to serve as a more optimally appropriate technology in supporting organic waste management and digitally-driven community empowerment.

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