The Indonesian Journal of Computer Science
www.ijcs.net
Volume 14, Issue 1, February 2025
https://doi.org/10.33022/ijcs.v14i1.4624

Monitoring the Behavior of Chemical Reactions in Eco Enzymes

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Article Information

Received : 7 Jan 2025
Revised : 7 Feb 2025
Accepted : 24 Feb 2025

Keywords

Eco Enzymes, Internet of Things, Fermentation, Chemical Reaction Monitoring, Organic Waste Processing.

Abstract

Organic waste has become a serious environmental issue, with production reaching 20.23 million tons per year in Indonesia. This research offers an innovative solution through the eco enzyme method and Internet of Things (IoT) technology to monitor chemical reactions during the fermentation process in real-time using sensors and a website. The research compares two samples: a mixture of orange peels, papaya, pineapple, and Javanese sugar; and pineapple peels, water, and molasses (sugarcane syrup). Each used 2.1 kg of organic waste, 700 g of sugar, and 7,000 ml of water. During the 60-day fermentation period, the first sample produced gases such as Methane (CH4), Hydrogen Sulfide (H2S), Ammonia (NH3), Carbon (CO), and Hydrogen (H2), while the second sample produced Methane (CH4), Hydrogen Sulfide (H2S), Ammonia (NH3), and Nitrogen Oxide (NO2). there are also parameters measured such as pH and temperature. research shows that raw materials affect the gas produced, as well as utilizing IoT technology for more efficient and sustainable waste management.

A. Introduction

Waste is one of the issues that often becomes a serious problem for the government and society in Indonesia. The increase in waste production in each region can be estimated on the basis of data, which show that the amount of urban waste generated in Indonesia reaches about 20.23 x 106 tonnes per year [1]. This situation requires a wise waste treatment and recycling, since waste has the potential to have serious adverse effects on the environment and living beings. The effects of uncontrolled waste disposal can cause serious heavy metal pollution in water, soil, air and plants [2], while open waste combustion can produce CO, CO2, SO, NO, PM10 and other pollutants affecting the atmosphere [3]. One way to deal with this waste problem is to use a fermentation method called eco enzyme. Eco enzyme is a process that transforms organic waste into a useful enzyme solution, where eco enzyme has cleaning properties and can be used as a multi-purpose cleaner [4],[5]. Eco enzyme is also a solution composed of complex organic substances produced by the fermentation process of organic waste, sugar and water. This liquid of eco-enzymes has a dark color and emits a strong sour or fresh aroma [6],[7]. The eco enzyme was discovered by Dr. Rosukon Poompanvong, an environmental researcher and researcher from Thailand. This innovation has had a very positive impact on the environment, as it enables the reuse of organic waste from household waste into more environmentally friendly products.

Eco enzymes can be applied in various fields, such as agriculture, household cleaning liquids, and there is even research that mentions that eco enzymes can be used as handwashing, disinfectant, and detergent. In addition to offering a variety of benefits, eco-enzymes are also very popular as one of the environmentally friendly methods of waste management and low-cost fermentation [8]. This research aims to integrate technological innovations into the method of fermentation of eco-enzyme. This research aims to integrate technological innovations into the fermentation process of eco-enzymes. One approach to enhancing the efficiency and effectiveness of fermentation is the implementation of the Internet of Things (IoT) to monitor chemical reactions in real time. IoT is gaining popularity due to its diverse applications, which typically involve various sensors that monitor the physical environment and transmit data to a gateway device [9].

This IoT-based tool allows you to collect real-time data that can be used to analyze fermentation dynamics and support better decision-making regarding the quality and potential benefits of the eco-enzyme solution produced. By combining traditional methods and modern technologies, this research is expected to contribute to the development of the eco-enzyme industry and to the more efficient and effective use of eco-enzyme solutions for communities involved in fermentation activities.

B. Research Method

1. System design

The system consists of several important components The system consists of several important components described in Figure 1. The sub-hardware components, such as sensors measure temperature, gas, and pH. The variables monitored in this study include pH, temperature, CO, CH4, H2, C2H5OH, NH3, NO2, and H2S, the Arduino Mega Microcontroller device part is in charge of processing measurement data from these sensors, except for the temperature sensor which is connected to ESP32. After data processing, the ESP32 device will send data using the MQTT communication protocol. The data is transferred to the internet via the MQTT protocol. Next, in the sub-software, there is a website that will display the data sent via the Internet.

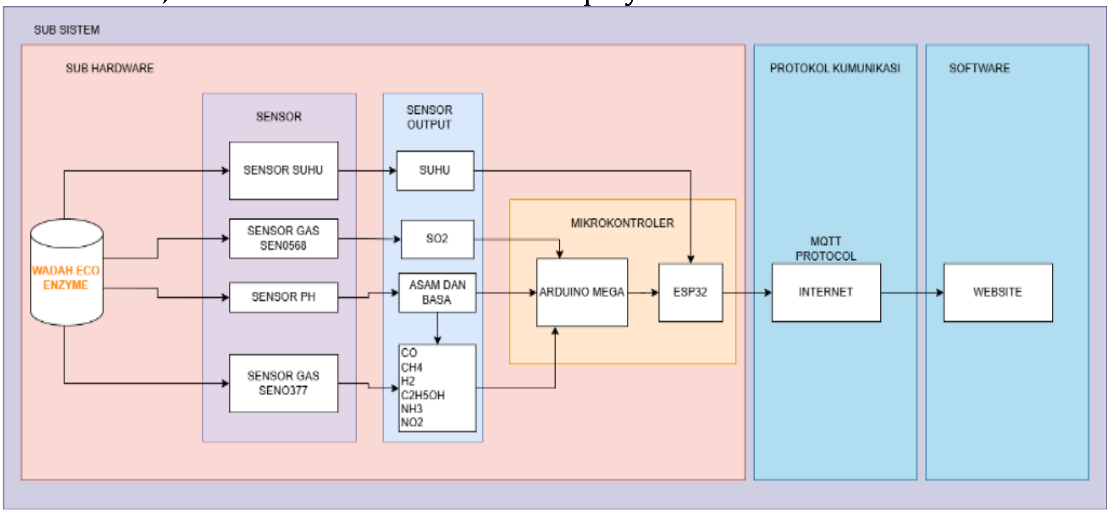


Figure 1. System design

The objective of this research methodology is to apply modern technology to the eco-enzyme fermentation process, a new development that converts organic waste into practical enzyme solutions. This research aims to monitor the behavior of chemical reactions occurring during the fermentation process in real-time by using Internet of Things (IoT) based technology, Because of this, the idea behind IoT is to make the Internet more intelligent and user-friendly. Apart from that, by enabling easy access[10]. This research will also take several steps, such as creating an eco-friendly enzyme fermentation formula and designing hardware and software that will make it easy to track chemical reactions during fermentation.

2. IoT system Architecture

In this context, the IoT architecture of the designed system is described in Figure 2. This design adopts the IEEE 1451.2 standard as a reference for accessing various sensors and transducers, as this standard specifies a series of specifications ranging from sensor interface definition to data acquisition [11], [12], [13]. This IoT-based monitoring system consists of three main layers. The first layer is the sensor layer, which includes a DSB1866 temperature sensor with an accuracy of ±0.5°C, a SEN0377 multi-gas sensor to detect CO, CH4, H2, C2H5OH, NH3, and NO2, a SEN0566 H2S gas sensor, and a pH sensor to monitor acidity. The second layer is the communication layer that uses an Arduino Mega microcontroller for main sensor data processing, ESP32 module for wireless communication, MQTT protocol implementation, and local network configuration. MQTT is used because it has advantages over the CoAP (Constrained Application Protocol) protocol in the context of M2M (Machine-to-Machine) communication. The MQTT (Message Queuing Telemetry Transport) protocol has the advantage of being used on devices with low power and limited memory[14], [15]. The third layer is the application layer, which provides a web-based monitoring interface, real-time data visualization, and historical data storage.

In its implementation, the system uses a multi-threaded approach for simultaneous sensor readings. The primary thread handles temperature and pH readings, the secondary thread processes gas sensor data every 5 minutes, and the communication thread manages MQTT publish/subscribe operations. Data processing is done separately after all the data is collected. In the interface section, the system is designed with a real-time dashboard feature that displays the latest sensor readings. In addition, the system is equipped with data management that allows data to be exported in CSV format.

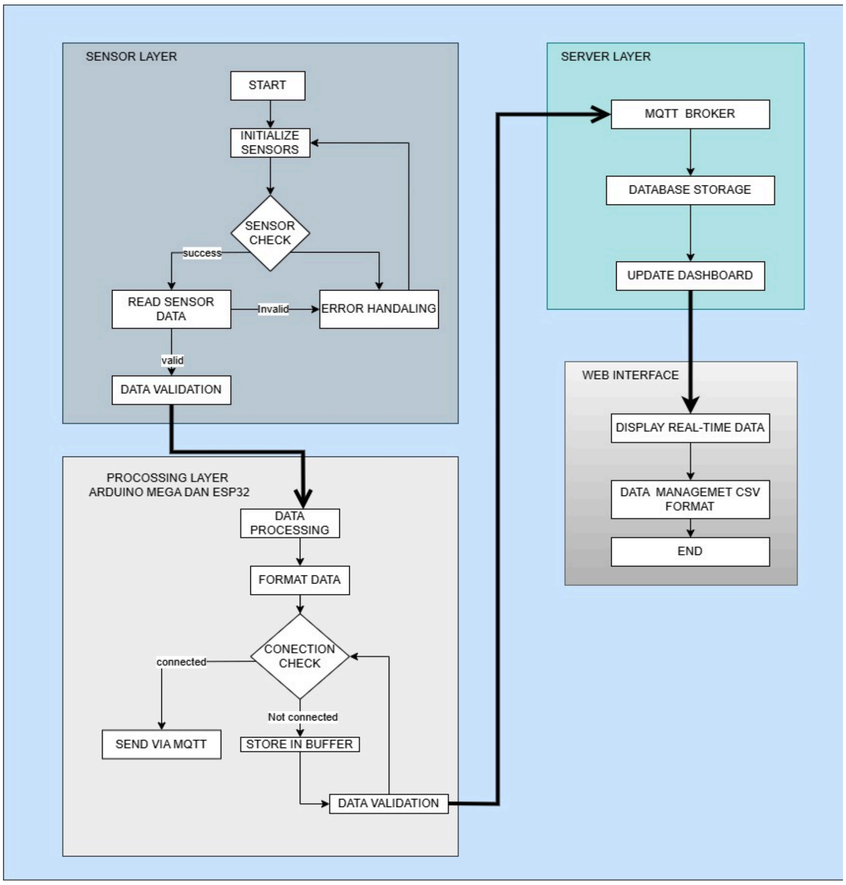


Figure 2. IoT System Architecture

3. Fermentation Formula

The eco enzyme has a special formula that needs to be considered in its production process. Figure 3 below shows the recommended pattern or stages for creating an optimal eco-enzyme fermentation model. The stages include: first, preparing 3 kilograms of fruit or vegetable peel waste as the main ingredient for fermentation; second, providing 10 liters of clean water to be used as the fermentation medium; and third, adding 1 kilogram of palm sugar or brown sugar as an energy source for the microorganisms involved in the process. By following these steps, the ideal ratio of materials in the production of eco enzymes is 3:10:1, which ensures a balanced composition to support the success of fermentation [16].

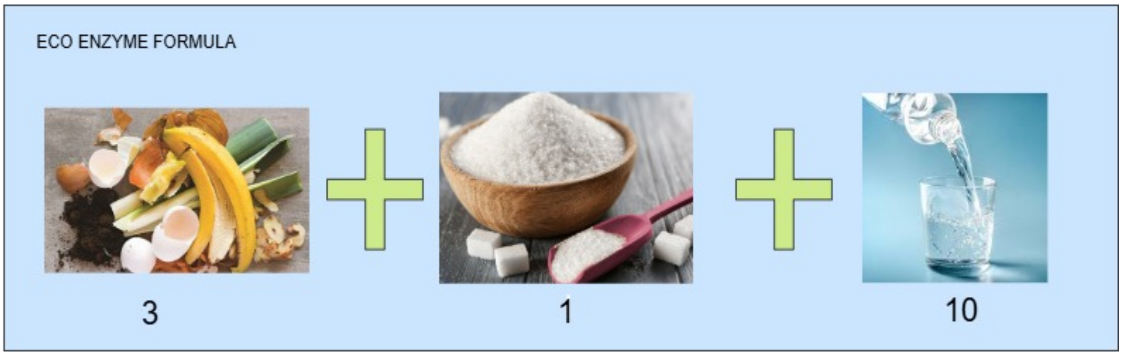


Figure 3. Eco enzyme manufacturing formula.

4. Software and Hardware Devices

To facilitate the monitoring and data collection process during this study, we used hardware in the form of sensors and software in the form of a monitoring website. Some of the sensors used in this research include DSB1866 sensors that measure temperature parameters, and SEN0377 sensors that can detect and measure gas concentrations such as CO (carbon monoxide), CH4 (methane), H2 (hydrogen), C2H5OH (ethanol), NH3 (ammonia) and NO2 (nitrogen dioxide). In addition, we also use the SEN0566 gas sensor to measure H2S (sulfur dioxide) and the pH sensor to determine the acidity of the eco enzyme solution, including the measurement of acidity and alkalinity.

C. Result and Discussion

1. Fermentation Ingredients

In this study, there are two different types of fermentation materials. The first consists of a mixture of orange peels, papaya peels, and pineapple peels. Meanwhile, the second fermentation ingredient only uses one variant, which is pineapple peel. The formula for the fermentation material can be seen in the table1.

Table 1. Types of fermentation materials

Category	*Types of Fermentation Materials*	*Voleme*
First fermentation sample	Orange peel	700 gr
	Pineapple skin	700 gr
	Pawpaw peel	700 gr
	Red sugar (palm sugar)	1200 gr
	water	7000 ml
Second fermentation sample	Pineapple skin	1200 gr
	water	7000 ml
	Molasses (sugarcane syrup)	700 gr

The creation of these two types of fermentation is carried out to understand the phenomenon of chemical reactions that occur during the fermentation process of both materials. This process aims to understand the differences in the patterns or trends of the chemical reactions that occur, as well as the final results of the fermentation of each material.

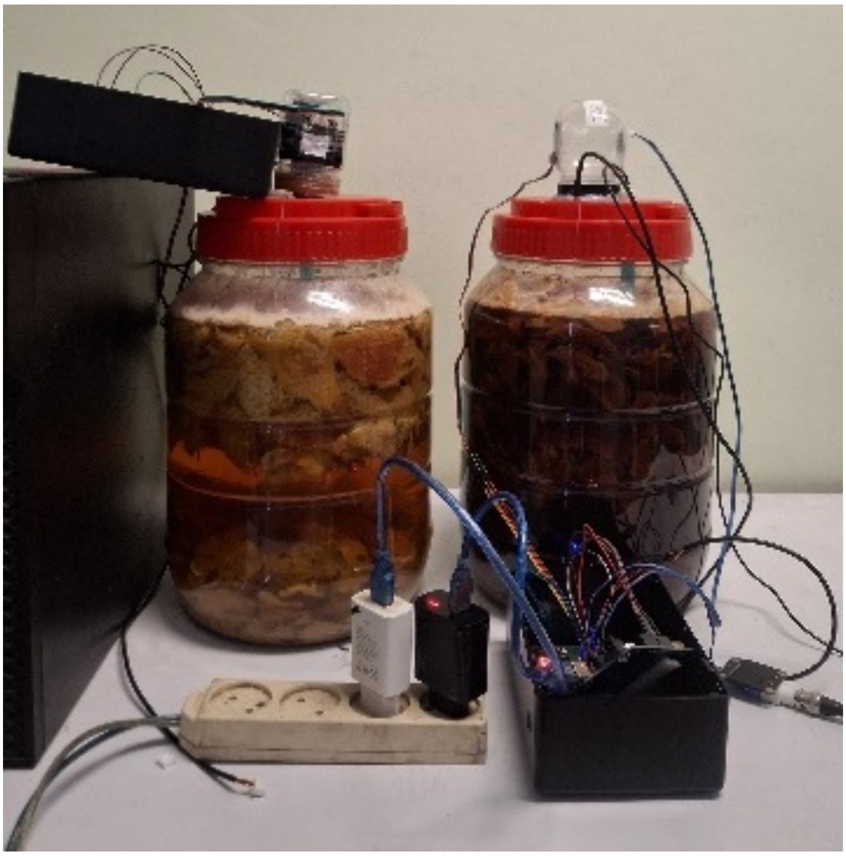


Figure 4. Eco enzyme fermentation container

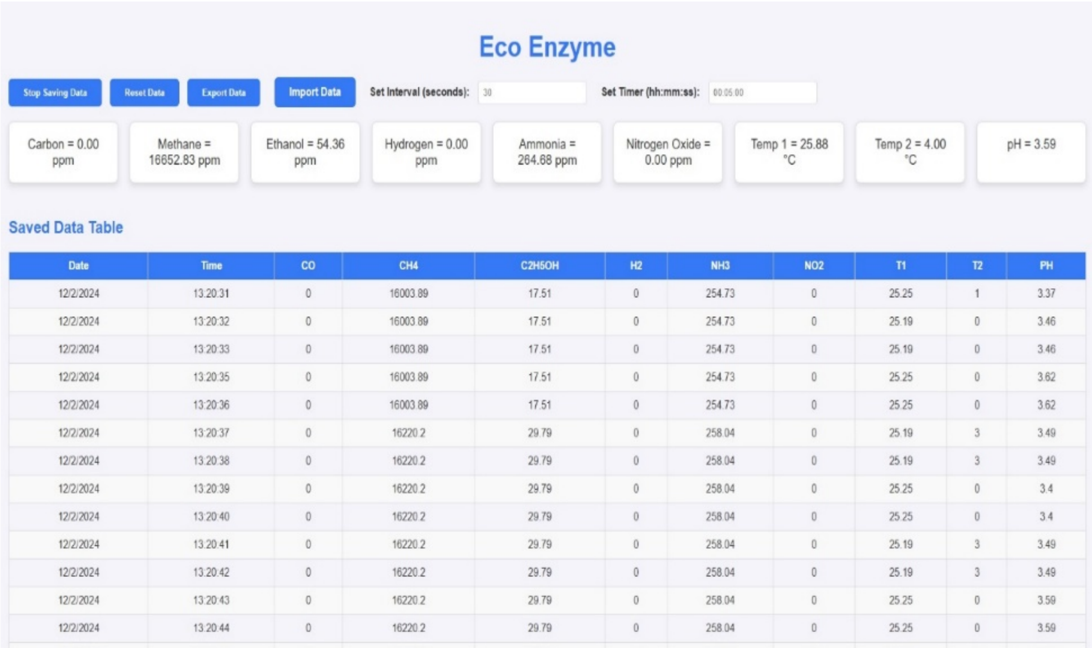
2. Hardware and Software Test Results

Here is the hardware evaluation table used in this research. Table 2. presents information about the sensors used to monitor chemical reaction data in eco enzyme. Evaluation was conducted to ensure that each sensor functions properly according to the measured parameters. The results displayed in the table show that all the sensors used have successfully read the data optimally, thereby effectively supporting the monitoring process of the chemical reaction in the eco enzyme.

Table 2. sensor performance evaluation

No	Sensor Name	*Measured Parameters*	*Data Reading Status*
1	DSB1866	Suhu	Successfully Read
2	SEN0377	Gas (CO, CH4, H2, C2H5OH, NH3, NO2)	Successfully Read
3	Gas H2S	Gas H2S	Successfully Read
4	Sensor pH	Acidity Level	Successfully Read

Next, on the user interface aspect, data sent from the microcontroller using the MQTT (Message Queuing Telemetry Transport) communication protocol can be displayed in real-time through the user interface platform. Thus, the connection between the MQTT communication protocol and the eco enzyme monitoring website has been successfully established, providing researchers with the convenience of periodically monitoring chemical reaction data shown in Figur 5.



Date	Time	CO	CH4	C2H5OH	H2	NH3	NO2	T1	T2	PH
12/2/2024	13:20:31	0	16003.89	17.51	0	254.73	0	25.25	1	3.37
12/2/2024	13:20:32	0	16003.89	17.51	0	254.73	0	25.19	0	3.46
12/2/2024	13:20:33	0	16003.89	17.51	0	254.73	0	25.19	0	3.46
12/2/2024	13:20:35	0	16003.89	17.51	0	254.73	0	25.25	0	3.62
12/2/2024	13:20:36	0	16003.89	17.51	0	254.73	0	25.25	0	3.62
12/2/2024	13:20:37	0	16220.2	29.79	0	258.04	0	25.19	3	3.49
12/2/2024	13:20:38	0	16220.2	29.79	0	258.04	0	25.19	3	3.49
12/2/2024	13:20:39	0	16220.2	29.79	0	258.04	0	25.25	0	3.4
12/2/2024	13:20:40	0	16220.2	29.79	0	258.04	0	25.25	0	3.4
12/2/2024	13:20:41	0	16220.2	29.79	0	258.04	0	25.19	3	3.49
12/2/2024	13:20:42	0	16220.2	29.79	0	258.04	0	25.19	3	3.49
12/2/2024	13:20:43	0	16220.2	29.79	0	258.04	0	25.25	0	3.59
12/2/2024	13:20:44	0	16220.2	29.79	0	258.04	0	25.25	0	3.59

Figure 5. User interface display

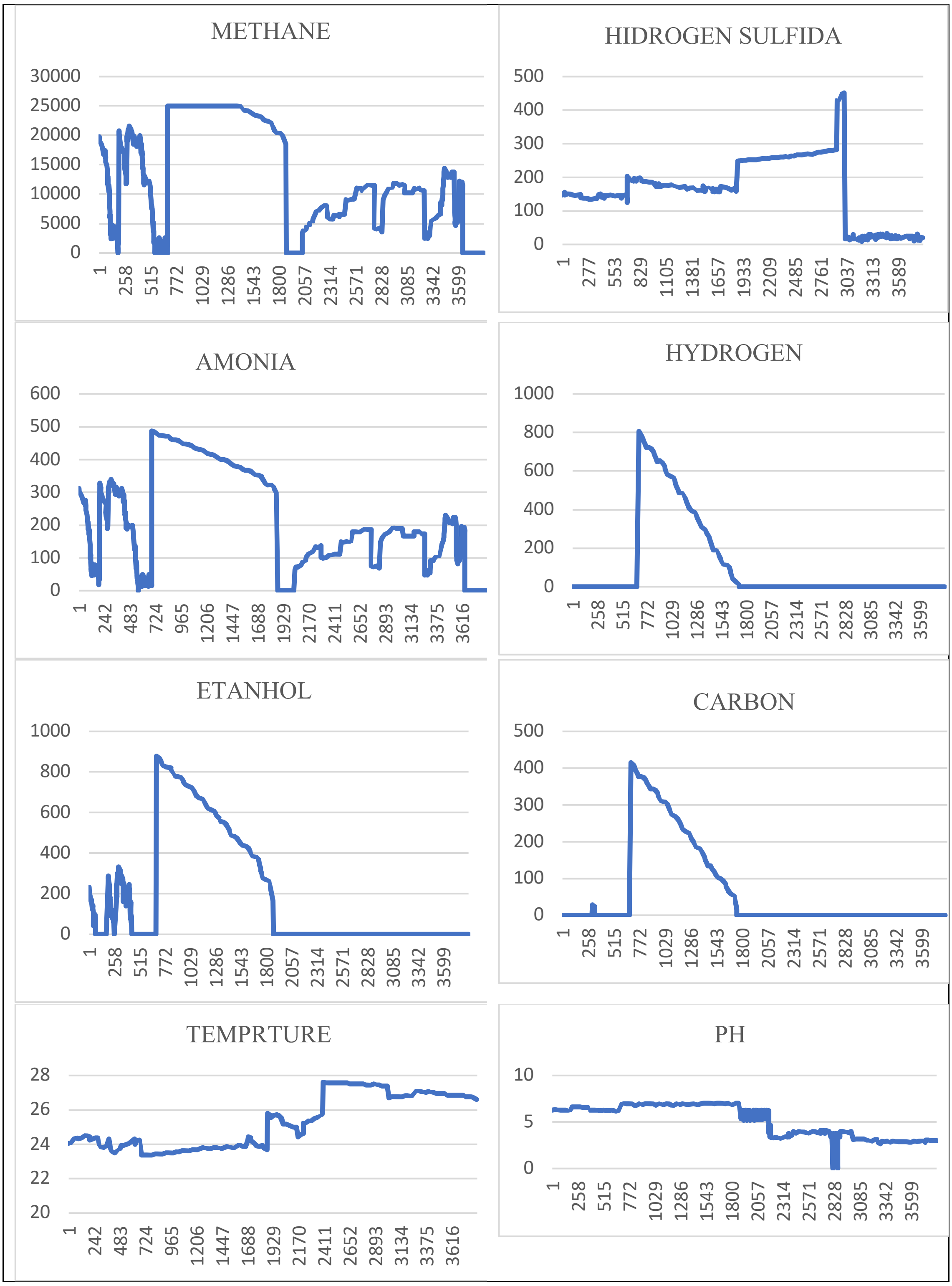
3. Result of IoT

The IoT-based monitoring system has demonstrated effective performance at both the hardware layer and communication layer, as well as providing a functional interface for users. At the hardware layer, the evaluation confirmed the successful integration of sensors and data acquisition, where all sensors achieved consistent data readings throughout the monitoring period. The DSB1866 temperature sensor maintained an accuracy of ±0.5°C, while the SEN0377 multi-gas sensor array was able to detect multiple gas variants simultaneously. The SEN0566 H2S gas sensor provided reliable sulfide measurements, and the pH sensor consistently monitored acidity levels. At the communication layer, the MQTT protocol implementation successfully demonstrated reliable data transmission, including real-time data transfer from the microcontroller to the web interface. The implemented multi-threaded approach proved effective for simultaneous sensor readings, with the primary thread handling temperature and pH readings, the secondary thread processing gas sensor data at 5-minute intervals, and the communication thread managing MQTT publication/subscription operations.In addition, the interface layer successfully provided real-time dashboard visualization of sensor data, historical data tracking capabilities, data export functionality in CSV format, as well as continuous monitoring of chemical reactions throughout the 60-day fermentation period.Overall, the system maintained stable performance on both fermentation samples, demonstrating consistent data collection and transmission capabilities.

4. Visualization of Fermentation

The results of the visualization of measurements on fermentation samples consisted of a mixture of water, sugar, orange peel, pineapple peel, and papaya peel shown in Table 3. Observations were conducted over a sixty-day fermentation period to evaluate the changes occurring in each parameter, which can be summarized in the table below.

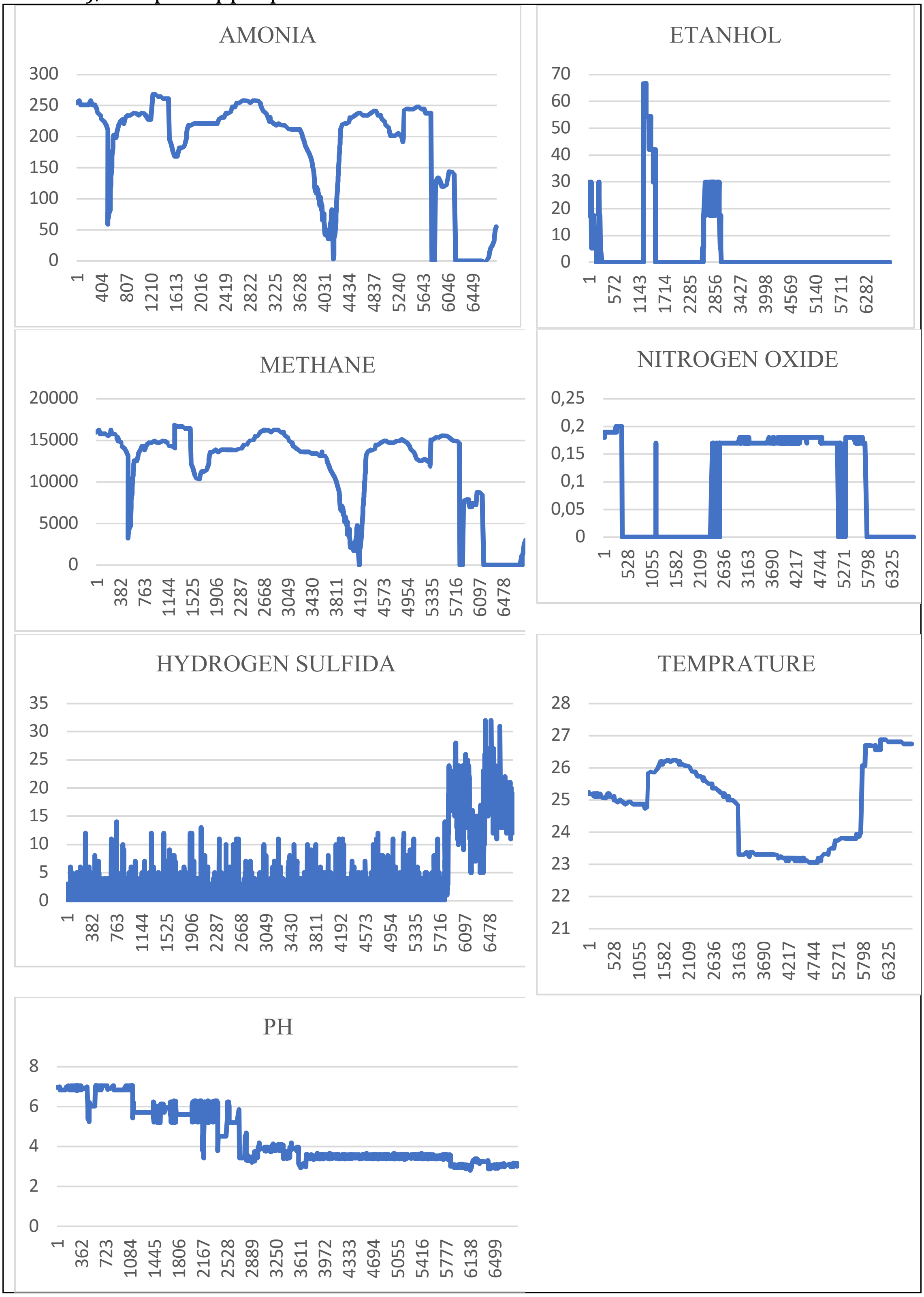
Table 3. Visualization of data from the fermentation of water, brown sugar, orange peel, pineapple peel, and papaya peel



The following is a visualization of the measurement results obtained from the eco enzyme fermentation process, which uses the main ingredients consisting of a mixture of water, molasses (sugar cane syrup), and pineapple peel shown in Table

4. The presented graph illustrates the changes in gas concentration and the changes in temperature and pH that occur during the fermentation process.

Table 4. Visualization of data from the fermentation of water, molasses (sugarcane residue), and pineapple peel



5. Fermentation Measurement Results

In order to evaluate the processes that take place during the fermentation process, this study used two distinct fermentation samples. Water, palm sugar, and organic waste (such pineapple, papaya, and orange peels) made up the first sample, while pineapple peels, sugar, and water made up the second.The monitoring results of the first sample showed several chemical reactions, including compounds such as methane, sulfur hydrogen, ammonia, hydrogen, ethanol, and carbon. In addition, parameters such as temperature and pH were also recorded during the process. In the second fermentation sample, various chemical reactions occurred during the fermentation process. Production materials included ammonia, ethanol, methane, nitrous oxide, and hydrogen sulfide. Furthermore, the parameters that were successfully measured were temperature and pH.

The results of this study show that the composition of the material has a different effect on the fermentation results. The first sample produces more types of gas, while the second sample produces gas that is more subtle and distinct. Both samples also have pH and suhu changes that are produced by the two samples.

D. Conclusion

This innovation is an important step in the development of organic waste driven by technological advancements and information. At this point, the researchers have successfully developed a system to monitor the chemical reaction parameters of the eco enzyme during the fermentation process, such as pH levels, temperature changes, and the composition of the gases produced.

In this experiment, two different eco enzyme samples were used: the first sample consisted of a mixture of water, palm sugar, orange peel, papaya peel, and pineapple peel, while the second sample used water, molasses, and pineapple peel. The research results show that the composition of the raw materials makes a difference in influencing the fermentation process and the types of gases produced. The IoT-based monitoring system developed is not only capable of collecting data sets but also provides a website interface that facilitates researchers in monitoring the chemical reactions occurring during the eco-enzyme fermentation process.

This discovery offers a significant solution to the problems associated with managing organic waste, which goes beyond merely being a creative technological improvement. This study demonstrates how contemporary technology can work in concert with conventional techniques to produce a waste management strategy that is more environmentally friendly, efficient, and sustainable. Therefore, this study also creates new avenues for the creation of novel and cutting-edge eco-enzymes.

E. Acknowledgment

The authors would like to express their sincere gratitude to Politeknik Elektronika Negeri Surabaya (PENS) and Universitas Katolik Indonesia Ruteng for their valuable support and facilities provided during this research. Special appreciation is extended to all faculty members and staff of the Graduate Program at Politeknik Elektronika Negeri Surabaya for their guidance, expertise, and continuous assistance throughout the research process. This work would not have been possible without their dedicated support and collaboration.

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