The Impact of Temperature Sensors in IoT on Fermentation in Eco-Enzymes

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***Abstract*— The Internet of Things (IoT) has presented significant opportunities in recent years. Many fermentation processes have been monitored and controlled with IoT to improve them, for example, eco-enzyme production. Fermenting organic waste with eco-enzymes with consistent results has been proven to provide significant benefits to the economy and the environment. Temperature is a key parameter in fermentation. Uncontrolled temperature can cause unwanted microbial activity and even death, ultimately reducing the quality of eco-enzymes. This study examine how IoT-based monitoring can help us control the temperature during the eco-enzyme fermentation process. By using temperature and humidity sensors connected to an Arduino microcontroller and the Blynk platform, it helps enable real-time monitoring and helps maintain stable conditions throughout fermentation. The results show that this approach of implementing IoT into the eco-enzyme not only help improve efficiency and consistency of eco-enzyme production but also demonstrates the potential IoT solutions for small-scale or household applications in sustainable organic waste management. In short the data collected shows that with the Eco-Enzyme Tracker it helps monitor the fermentation process.**

Keywords*— *IoT, temperature sensor, fermentation, eco-enzyme, real-time monitoring

I. Introduction

The production of eco-enzymes from organic waste has been gaining some popularity because it helps at reduce household waste. And since the fermentation process relies heavily on environmental conditions like temperature, maintaining the right temperature is very important, as it will directly affect the microbial activity that is responsible for breaking down the organic waste in eco-enzymes. This also means the failure of trying to maintain an ideal temperature can slow down or contaminate the fermentation process which can lead to a failed product[1], [2].

The Internet of Things (IoT) offers a solution with the help of sensor systems capable of automatically and lets the user have real-time monitoring of the environmental conditions. Temperature sensors that are integrated with wireless connectivity allow users to access data directly through digital platforms or applications[3], [4], [5], [6]. For eco-enzyme fermentation, this can help the user have more control over the fermentation process and ensure the quality of the final product. Recent research by Januardi et al. [7]] "also explored the uses of IoT to monitor chemical changes during the eco-enzyme fermentation process, supporting the potential of such IoT systems for tracking microbial activity effectively."

Recent studies have also shown that integrating Artificial Intelligence (AI) into IoT systems can significantly assist humans in making decisions and predicting various possibilities in the fermentation process. Furthermore, the development of new nanotechnology-based sensors and the use of more energy-efficient devices can support a more optimal and accurate continuous monitoring system [8]. Innovation in wireless visibility devices and the selection of more energy-efficient devices are also key to developing systems that are not only intelligent but also energy-efficient [9], [10].

Against this background, the aim of this study is to develop and implement an IoT-based monitoring system for producing eco-enzymes from organic waste, allowing for more accurate monitoring of fermentation results and maximizing yields. This system will be designed to automatically monitor eco-enzyme development, particularly temperature, and assist users in consistently maintaining good fermentation conditions. Thus, this project aims to support a more controlled, efficient, and sustainable eco-enzyme production process for users. Then, this study will inform users how environmental factors such as temperature can affect the quality of fermentation results and examine how IoT integration can help users to create a smarter and more environmentally friendly approach to managing organic waste in the future [11], [12].

II. LITERATURE REVIEW

The production of eco-enzymes by fermenting organic waste has recently become viral, representing a new way to sustainably manage waste in households and small businesses. Eco-enzymes, produced through the fermentation of organic materials, contain enzymes, organic acids, and beneficial microorganisms. These substances have many uses, such as in agriculture as fertilizers, natural disinfectants for cleaning the house, and many more.[13]. The quality of eco-enzymes is highly dependent on the environmental conditions that must be met during the fermentation process. Especially on temperature, which is one of the keys to maintaining proper microbial activity and stable reactions[14],[15].

Many studies have also proven how important temperature conditions are in the eco-enzyme fermentation process. [15] We found that unstable temperatures can reduce the quality of the fermentation results, such as changes in pH, odor, and the appearance of the eco-enzyme. Similarly, [14] found that optimal temperature enhances enzyme activity and microbial composition during food waste fermentation. Recent developments in real-time fermentation monitoring show the value of continuous tracking, especially with the use of viable cell sensors that allow researchers to observe microbial activity as it happens. This provides instant data on how the fermentation is going and key quality factors [16]. Therefore, a system capable of monitoring and maintaining temperature within an optimal range throughout the fermentation process is essential.

One promising solution is the use of Internet of Things (IoT) technology. Which allows automated and real-time temperature tracking. As a matter of fact, some studies have successfully implemented cloud-based IoT systems that helps keep temperatures stable during fermentation processes [17]. A similar system was implemented in an IoT-based composting setup, which continuously recorded temperature and humidity[2]. In addition, a researcher applied IoT technology to eco-enzyme fermentation and observed improvements in product quality consistency.

Temperature sensors used in IoT systems vary, ranging from digital sensors like the DS18B20 to nanotechnology-based sensors with high accuracy and fast response times [14], [18]. Platforms such as ESP32 and Arduino are commonly used due to their Wi-Fi connectivity and data processing capabilities [17], [19]. For long-term usability, several studies have emphasized the importance of energy efficiency. For example, Xu et al.[6] developed low-power systems for wireless fermentation monitoring.

Here is a table of comparison from other IoT Inventions regarding fermentation and temperature

Research Object	Parameters Monitored	Platform/Hardware	Strengths	Limitations
Food waste fermentation	Temperature & ph	Digital temperature sensor, IoT module	More stable product quality	Focus only on temperature & pH
Eco-enzyme	Temperature, & Ph	IoT with DS18B20 sensor	Improved product consistency	Does not monitor other parameters
IoT with nanotechnology sensors	Temperature	High precision nanosensor	Better accuracy	Limited widespread application
Industrial fermentation Industrial fermentation	Temperature	Low-power IoT system	Suitable for long-term use	Complex implementation
IoT with Arduino & ESP32	Temperature	Arduino/ESP32	Easy to develop	Less energy efficient

Overall, the literature indicates that IoT-based temperature monitoring not only improves the efficiency of the fermentation process but also enables more consistent and sustainable quality control of eco-enzyme products. One existing gap is the full integration of IoT systems for temperature with other parameters such as gas and pH, to create a more holistic and intelligent fermentation system.

III. METHODOLOGY

A.Research Methodology

This study uses a qualitative-descriptive approach with a literature review method to examine the effect of temperature on the eco-enzyme production process, specifically through the implementation of an Internet of Things (IoT)-based system. The purpose of this methodology is to identify the technological approaches used in temperature monitoring during organic waste fermentation and to assess their effectiveness in producing the final product from the eco-enzyme fermentation itself.

The authors have held meetings during the planning and prototyping stages to identify potential issues that need to be addressed in this research, where the research focuses on how temperature fluctuations can significantly affect the eco-enzyme fermentation process, and potentially alter microbial activity that can ultimately affect the final outcome of this eco-enzyme fermentation. From these issues, the authors decided to design an IoT-based temperature monitoring system as a solution to prevent potential adverse events that may occur during the fermentation process. During the requirements and analysis phase, the authors explored and studied many studies related to existing monitoring systems to determine what components are needed to accurately track temperatures for the fermentation process [8], [10]. Based on these findings, the authors selected appropriate sensors, microcontrollers, and other supporting hardware that would enable them to achieve the objectives of this research. In the design phase, the initial idea was inspired by other researchers' projects that also focused on fermentation monitoring, especially those that had features for collecting real-time data and connected to wireless communication. This reference helps guide the authors in developing a system designed to monitor temperature levels so as to maintain them stable during the fermentation process, which is one of the important factors for producing eco-enzyme products with maximum and consistent quality. In the design stage, the authors also made a prototype design that includes the device and sensors that the authors have found to be important. As also shown in Fig.1 the authors concluded that their design was perfect for the goal they are trying to achieve.

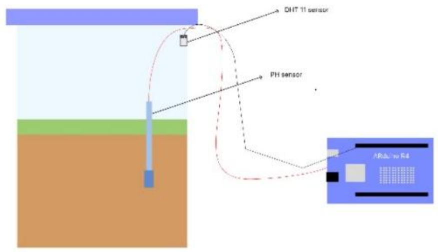

Fig. 1. Prototype Design

B. Preparation of Materials and Fermentation

The raw materials for eco-enzyme production were obtained from household organic waste, primarily consisting of fruit and vegetable scraps, palm sugar, and water, in a ratio of 3:1:10[13], [20]. The raw materials we used were honeydew and watermelons.

C. Eco-Enzyme Tracker

The components used in the prototype design are an Arduino microcontroller and, a DHT11 sensor. The DHT11 sensor is responsible for measuring environmental temperature and humidity which are the two critical that can influence microbial activity during fermentation. The Arduino processes the sensor data and activates the system accordingly.

D. Data Validation

In this study, Field Testing was used to test the accuracy of humidity and temperature sensors and systems. Different environments were tested to determine the optimal temperature range for achieving the best fermentation results. The results of this test were to determine whether the system collected the data as expected and had no errors.

E. Software

The software used in this system are IDE Arduino, and Blynk.

F. Hardware

The hardware used in this system is Arduino Uno R4, Breadboard, DHT 11and Breadboard jumper wire.

G. System Flowchart

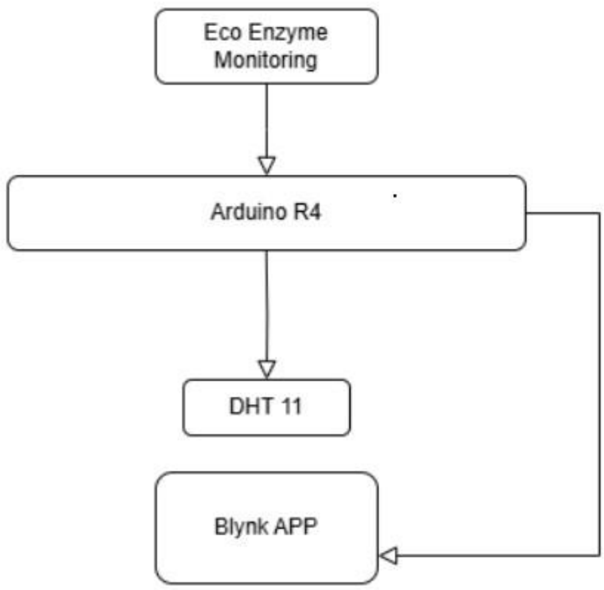

Fig. 2. Eco-Enzyme Tracker Flowchart

Fig.2 Has shown the flow of process that happens when the Eco-Enzyme Trackers run. At the start of the process, the Arduino R4 runs and lets DHT 11 run. DHT 11 would then check the temperature and humidity of the eco-enzyme. Then, the data will be processed by the to see what temperature is best for achieving the best fermentation results.

IV. Experiment and Result

The research conducted can be concluded that the DHT11 sensor as a Temperature tracking sensor works optimally by utilizing the Arduino R4 microcontroller and Blynk as the software that displays temperature data to the user.

Day	Temp (°C)
1	22.0
2	27.5
3	27.1
4	27.4
5	27.6
6	27.3
7	27.5
8	25.3
9	26.8
10	27.4
11	27.6
12	27.2
13	27.5
14	27.8
15	27.8
16	28.2
17	28.2
18	27.8

Table. 1. Temperature

Table. 1 shows the day and temperature result shown in the Blynk app is slightly delayed, due to fluctuation of the internet connection used. The temperature level and day displayed in the Blynk app didn't significantly change, because of the time it takes is quite long for the eco-enzyme to mature. Furthermore, as seen in Table .1 on certain days the temperature fluctuates, due to rain affecting the temperature and on the first day the AC was still on when the data was taken.

Fig. 3 Shows the final prototype of the Eco-Enzyme Tracker. The final model follows the initial prototype designed by the authors, with several additions, including the addition of sensors such as a pH sensor. The IoT components were housed in a compact box securely attached to the side of the fermentation bucket, allowing continuous monitoring of the eco-enzyme environment without interfering with the fermentation process.

Fig. 3 Final Prototype of Eco-Enzyme Tracker

Fig. 4 shows the data collected from the authors Eco-Enzyme Tracker sensors via the Blynk app, which the authors got by connecting their Eco-Enzyme Tracker to the Blynk platform. The results shown were considered by the authors to be the most optimal environmental conditions except for the temperatures because the AC was on when the results was taken at the fermentation process of the eco-enzyme.

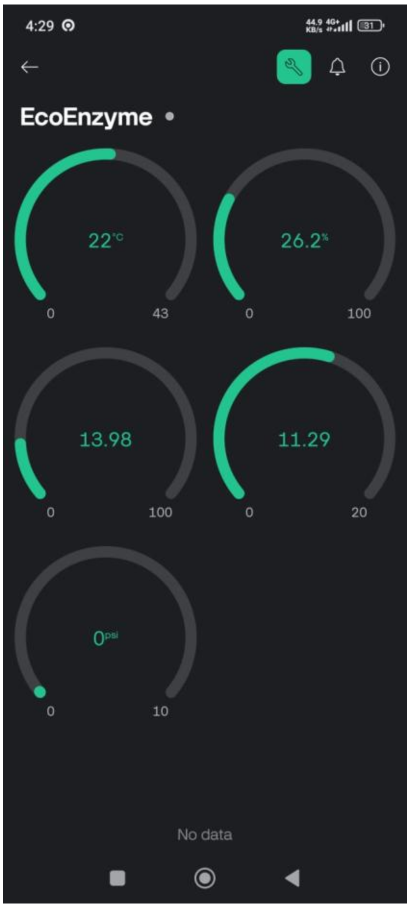

Fig.4 Data from the Blynk App

Conclusion

In conclusion, this study shows that integrating IoT technology into the eco-enzyme fermentation process can significantly improve temperature monitoring and overall control. By using temperature connected to an Arduino microcontroller and the Blynk platform, the system can provide real-time data, helping maintain a stable condition throughout fermentation. This contributes to better microbial activity and more consistent product quality. The results from our field tests confirm that the system worked effectively in detecting environmental changes and supported optimal fermentation conditions. This research also highlights the potential of affordable and small-scale IoT solutions for sustainable organic waste management.

AUTHOR CONTRIBUTION

Princen Putra Kurniawan did the writing, introduction, and methodology. Jason Yoswara handled the literature review, results, and provided critical revisions. Mochammad Haldi Widianto completed the scientific paper by considering revisions from reviewers until completion. Therefore, all authors contributed to the final discussion and results analysis.

DATA AVAILABILITY

The data used for this study are openly available at: https://github.com/Zewy05/EcoEnzyme.git

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