

CHAPTER 1

INTRODUCTION

1.1 Background

The problem of waste, especially organic waste, is still a serious issue in urban areas in Indonesia [1]. The high volume of organic waste produced every day has not been fully balanced with an optimal management system, resulting in an increase in the burden of landfills (TPA) and a decrease in environmental quality [2]. This condition is exacerbated by the low level of organic waste utilization at the household level, so that most of the waste still ends up in landfills without going through advanced processing processes [1]. Based on data from the East Java Provincial Environment Agency, the city of Surabaya in 2023 will generate 116,349.0 tons of waste, with only around 20.98% recorded as managed waste, while the rest is still not handled optimally [3].

One of the approaches that has developed to overcome this problem is the processing of organic waste into eco-enzymes. Eco-enzymes are liquids that are fermented from organic waste, such as fruit and vegetable residues, which are mixed with sugar and water in a certain ratio [2]. This process allows the conversion of organic waste into products that have useful value for the environment and society. Various studies show that eco-enzymes have the potential to be an environmentally friendly solution because they are able to reduce the volume of organic waste while producing value-added products that can be used in various applications [4].

The potential of eco-enzymes is becoming increasingly relevant considering that the composition of household waste in Indonesia is dominated by food waste. Data from the National Waste Management Information System shows that food waste can account for more than half of the total waste composition in urban areas [5]. After going through the fermentation process for approximately three months, the resulting eco-enzyme can be used as a natural cleaner, organic disinfectant, and liquid fertilizer, thus providing economic and environmental benefits simultaneously [6].

Despite its great potential, the process of making eco-enzymes in practice still faces various obstacles [4]. The fermentation process is generally carried out manually and subjectively, where the success of fermentation is assessed based on qualitative indicators such as changes in color, aroma, or the appearance of certain layers on the surface of the liquid [6]. In addition, eco-enzyme fermentation is a biological process that is influenced by many factors, including the activity of microorganisms, environmental conditions, and the characteristics of the raw materials used. The inconsistency of these factors causes fermentation results to be often inconsistent and difficult to validate objectively [7].

This problem is felt directly by business actors who use eco-enzymes as the main raw material, one of which is the "Mamah Endut" MSME in Surabaya owned by Mrs. Dyah. These MSMEs are engaged in the production of environmentally friendly hygiene products, such as liquid soaps and detergents, with eco-enzymes as the main component. Based on the results of observations and interviews with partners, the eco-enzyme fermentation process is still carried out manually without the support of adequate measuring instruments. The determination of fermentation success is carried out based on experience and intuition, so the quality of the raw materials produced is often inconsistent.

In addition to having an impact on quality consistency, manual fermentation methods also pose safety risks and inefficiencies due to limitations in controlling process parameters in an ongoing manner [8]. The absence of temperature control causes the fermentation process to be susceptible to being disrupted by environmental conditions that are not ideal for the activity of microorganisms, thus affecting the stability and success of the fermentation process [7]. On the other hand, anaerobic fermentation produces gases as a byproduct, which when accumulated in a closed container can increase internal pressure and potentially cause damage to the container, even structural failures such as rupture or explosion of the fermentation container [9]. Studies related to anaerobic fermentation also show that monitoring process parameters such as gas accumulation, temperature, and acidity level (pH) is an important aspect to maintain the safety and stability of the fermentation process [10].

In this context, the application of Internet of Things (IoT) technology offers a promising solution. IoT allows the integration of sensors and actuators to monitor environmental parameters in real-time as well as transmit data over the internet network for analysis and action [8]. Various studies have shown that the application of IoT in the fermentation process is able to improve yield consistency, operational efficiency, and minimize reliance on manual monitoring [11]. Parameters such as temperature, pH, and gas are the main variables commonly monitored in IoT-based fermentation systems [10].

However, the eco-enzyme fermentation process is a bioprocess that has a high level of uncertainty. Fluctuations in sensor data, raw material variations, and dynamics of microorganism activity make changes in fermentation parameters difficult to predict with certainty [12]. This condition indicates that a rigid value-bound-based control approach or deterministic model is not suitable to be applied. Therefore, adaptive decision-making methods are needed and are able to handle data uncertainty more flexibly.

Type-2 Fuzzy Logic is a development of conventional fuzzy logic (Type-1) designed to handle higher levels of uncertainty in dynamic and complex systems. In contrast to Type-1 Fuzzy Logic which uses a single and definite membership function, Fuzzy Type-2 introduces the concept of Footprint of Uncertainty (FOU) which allows the representation of uncertainty on the membership function itself. This approach makes Type-2 Fuzzy Logic more adaptive in dealing with sensor data fluctuations, measurement noise, and variations in system characteristics that cannot be precisely modeled. Studies have shown that Type-2 Fuzzy Logic has more robust performance than Type-1 Fuzzy Logic in a control system based on sensor data that contains high uncertainty [12].

Based on these problems, this study proposes the development of an eco-enzyme bioreactor system based on the Internet of Things (IoT) which is equipped with an automatic monitoring and control mechanism. This system is expected to be able to monitor pH, temperature, and gas parameters in real-time, improve the consistency of eco-enzyme quality, and minimize safety risks during the fermentation process. Thus, the eco-enzyme production process in Mamah Endut

MSMEs can take place in a more standardized, safe, and efficient manner as raw materials for environmentally friendly hygiene products.

1.2 Problem Formulation

Based on the background that has been described above, there are some formulations of problems that will be discussed, namely:

1. How to design an Internet of Things (IoT) system based on Type-2 Fuzzy Logic to monitor and control the eco-enzyme fermentation process in real-time?
2. How can Fuzzy Logic's Type-2-based IoT system maintain the stability of key parameters of eco-enzyme fermentation, specifically pH as a quality indicator and temperature and gas as a process safety aspect?
3. How does the Type-2 Fuzzy Logic-based IoT system perform in improving the consistency of the quality and safety of the eco-enzyme fermentation process on the MSME scale?

1.3 Purpose

In accordance with the formulation of the problem, the objectives of this study are:

1. Designing and building an Internet of Things (IoT) system based on Type-2 Fuzzy Logic that is able to monitor and control the eco-enzyme fermentation process in real-time.
2. Implementing an IoT system based on Type-2 Fuzzy Logic to maintain the stability of the main parameters of eco-enzyme fermentation, with pH as a quality indicator and temperature and gas as supporting aspects of the fermentation process safety.
3. Evaluating the performance of the Type-2 Fuzzy Logic-based IoT system in improving the consistency of the quality and safety of the eco-enzyme fermentation process at the MSME scale.

1.4 Scope and Limitations

To keep this research focused and can be completed properly, this research is limited to the following:

1. This research is focused on the MSME-scale eco-enzyme fermentation process, with the object of study on MSMEs "Mamah Endut" in Surabaya as a research partner.
2. The fermentation parameters studied include pH as the main indicator of fermentation quality, as well as temperature and gas as supporting parameters to maintain the stability and safety of the fermentation process.
3. This research focuses on the development of an Internet of Things (IoT)-based system that includes the function of monitoring and controlling the fermentation process in real-time, without discussing in depth the biological aspects of microorganisms.
4. The decision-making method on the control system uses Type-2 Fuzzy Logic to handle the uncertainty of sensor data during the fermentation process.
5. Data collection and system testing are carried out in one active fermentation cycle, which is for 30 days.

1.5 Benefits

This research is expected to provide the following benefits:

1. For the Author

This research is a means of applying and developing knowledge in the field of Informatics, especially in the application of Internet of Things (IoT) and Type-2 Fuzzy Logic in the fermentation process monitoring and control system, as well as experience in solving real problems on the MSME scale.

2. For Partners (Mrs. Dyah - MSMEs Mamah Endut)

This research is expected to help partners in improving the safety, efficiency, and consistency of the fermentation process eco-enzyme. The implementation of an IoT system integrated with an automatic control mechanism can reduce reliance on manual processes, minimize risks due to gas accumulation, and help partners obtain more objective fermentation data as the basis for determining the quality of product raw materials.

3. For the Next Researcher

The results of this research are expected to be a reference for future research, especially in the development of a control system based on Internet of Things (IoT) and adoption Type-2 Fuzzy Logic in small-scale bioprocess processes that have high parameter uncertainty.