RESEARCH ARTICLE Open Access

Gema Lingkungan Kesehatan
Vol. 23, No. 1 (2025), pp 14-19
e-ISSN 2407-8948 p-ISSN 16933761
Doi: https://doi.org/10.36568/gelinkes.v23i1.142 Journal Hompage: https://gelinkes.poltekkesdepkes-sby.ac.id/

# Innovative Eco-Enzyme from Fruit and Vegetable Waste for Pollution Control

Ranno Marlany Rachman[1*], Suci April Yanti[1], Nurjannah Oktorina Abdullah[2]

[1] Infrastructure and Environmental Engineering study program, Halu Oleo University, Indonesia
[2] Department of Environmental Engineering, Hasanuddin University, Indonesia

*Correspondence: rannorachman@uho.ac.id

**ABSTRACT**

Eco-enzyme is a fermentation product that uses organic waste as a base material in addition to sugar and water. The fermentation process is carried out under anaerobic conditions with the help of microorganisms from organic materials, producing a valuable liquid as an environmentally friendly pesticide, such as a termite repellent. This study aims to determine eco-enzyme characteristics made from vegetable and fruit waste with palm sugar and sap substrates. The main parameters observed include pH, aroma, color, and acetic acid content to determine the relationship between parameters and the effectiveness of eco-enzyme as a termite repellent. This quantitative and qualitative research method has an experimental approach and theory development. The experiment was conducted by fermenting a mixture of organic waste, sugar, and water in a ratio of 1:3:10 for 90 days. The variations tested involved using two substrates: palm sugar and sap. The results showed that eco-enzyme with palm sugar substrate had a pH of 2.5–3.99, a typical sour aroma of palm sugar, a brownish color, and an acetic acid content of 4–5%. In contrast, eco-enzyme with sap substrate has a pH of 3.71–4.07, a distinctive aroma of sap, a yellowish color, and an acetic acid content of 1–2%. Based on these results, eco-enzyme made from palm sugar is more effective as a termite repellent because its acetic acid content is higher and corrosive, which can affect the development of termite organs. In addition, this eco-enzyme is easily decomposed in the environment and is safe to use because its acetic acid content is at a level that meets the SNI: 01-3711-1997 standard. Thus, eco-enzymes from palm sugar can be an environmentally friendly alternative for pest control.

**Keywords:** Eco-enzyme, Fermentation, Organic waste, Palm sugar, Sap liquid

## INTRODUCTION

Community activities have increased the volume of waste and sewage because human activities cannot be separated from waste production (Hidayat et al., 2023; Rachman et al., 2020). According to Chaturvedi & Khare (2022), the remains of human activities or natural processes in solid and semi-solid forms and organic or inorganic substances no longer needed hurt the natural environment. Organic waste dominates the waste produced by the community, reaching 60% of the total waste, followed by plastic waste (14%), paper (9%), metal (4.3%), and glass, wood, and other materials (12.7%) (Yousif, 2019).

Most organic waste comes from households and markets, especially fruit and vegetable waste (Esparza et al., 2020). Without proper management, this waste has the potential to pollute the environment, triggering rot that causes unpleasant odors and methane gas emissions. (Mor & Ravindra, 2023). Methane gas contributes to global warming and destroys the ozone layer ($O_3$), which protects the Earth from harmful radiation (Sharma, 2019). Soil and water pollution from organic waste can also trigger various diseases, such as fever, digestive disorders, and the spread of dangerous viruses (Ali et al., 2021). Therefore, organic waste management is crucial to maintain environmental balance and public health.

One innovative solution to overcome this problem is to produce eco-enzymes, which are liquids resulting from the fermentation of organic waste under anaerobic conditions using sugar and water in a ratio of 3:1:10 (Abdullah et al., 2023). Eco-enzymes reduce the environmental impact of organic waste and release ozone ($O_3$), which can reduce carbon dioxide ($CO_2$) levels in the atmosphere(Muliarta & Darmawan, 2021). Thus, eco-enzymes reduce the greenhouse effect and mitigate global warming (Muliarta, 2024). In addition, eco-enzyme liquids can clean the air from toxins and pollution, eliminate unpleasant odors, and purify polluted water (Srihardyastutie & Rosmawati, 2024). This liquid also converts ammonia into nitrate ($NO_3$), which is a natural nutrient for plants, making it a liquid organic fertilizer (POC) that is rich in macro and micronutrients (Fadlilla et al., 2023).

Compared to compost, eco-enzymes do not require a large area or a special composter tank. The fermentation process can be carried out using simple containers such as used bottles, supporting reuse and waste reduction efforts (Benny et al., 2023). In addition, eco-enzymes can be used as plant growth factors, detergent mixtures, pesticide residue cleaners, insecticides, scale removers, and car radiator coolants (Rathod et al., 2024).

However, studies on the characteristics and composition variations of eco-enzymes are still limited. Most previous studies have only focused on their practical benefits (Putra et al., 2023). Therefore, this study aims to answer the problems related to the effectiveness of substrate variations in eco-enzymes, concentrating on utilizing organic vegetable and fruit waste. This study also contributes to the development of science by providing alternative environmentally friendly solutions to reduce pollution while supporting the concept of a circular economy through waste utilization. The title of this study is "Eco-Enzyme Innovation from Vegetable and Fruit Waste as a Solution to Reduce Environmental Pollution."

This research is expected to provide new insights into eco-enzymes' role in reducing the negative impacts of organic waste and provide practical solutions for the community for more effective waste management.

## RESEARCH METHODS

### Research design

This type of research is experimental with a quantitative approach in the form of comparisons and qualitative research studies to develop the theory of eco-enzyme content related to the benefits produced. This research was carried out to identify the characteristics of eco enzymes from different variations of sugar, namely using palm sugar and nia liquid using types of organic waste from the market in the form of vegetables and fruit that are no longer suitable for sale/consumption to determine which eco enzyme is suitable according to the content levels of its parameters.

### Location and Time of Research

This research was conducted from December 2023 to June 2024 in the Marine Engineering Laboratory, Faculty of Engineering, Halu Oleo University. The organic waste collection location used in this research was the Mandonga Basa Market in Madonga subdistrict, Kendari City.

### Eco-Enzyme Container Design Planning

The design planning for the eco enzyme container was carried out to consider the capacity of the container to release fermentation gas, which will be carried out in this research. In planning the design of this container, the 6-litre gallon is intended for various eco-enzyme containers, and the 1.5-litre plastic bottle is designed as a water container for disposing of gas in the eco-enzyme container.

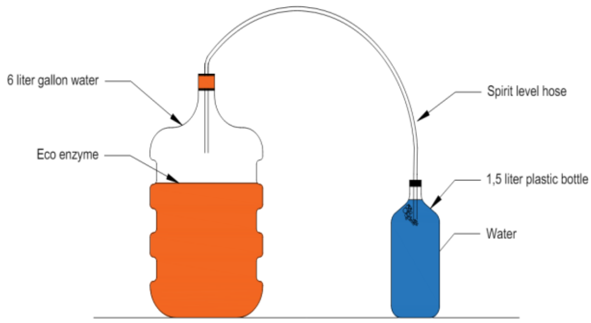


**Figure 1.** Design of Eco-enzyme Production Container

### Experiment Preparation

1. Tools and Materials

a. Tools

1. 6-litre gallon as the primary fermentation container.
2. 1.5-litre plastic bottle as a water container for gas release.
3. A waterpass hose used to connect the gallon and plastic bottles.
4. Stirring spatula to mix the ingredients.
5. Digital scales with an accuracy of up to 0.1 grams.
6. 100 ml and 250 ml measuring cups for water measurement.
7. A pH meter is used to measure the acidity level of the mixture.

### Materials

1. Organic waste of vegetables and fruits from the Mandonga Wet Market.
2. Palm sugar and palm sugar liquid (nira).
3. Clean water for fermentation media

### Making Eco Enzyme

Making eco-enzyme involves mixing the ingredients in a ratio of 1:3:10 (1 part sugar, three parts organic material, and ten parts water). The total composition of the ingredients is filled to as much as 70% of the gallon capacity (4.2 liters) to provide space for fermentation gas.

Calculation of the composition of the ingredients:

- Total capacity of ingredients: 70% × 6 liters = 4.2 liters
- Molasses (sugar): (1/14) × 4.2 liters = 0.3 liters
- Organic materials: (3/14) × 4.2 liters = 0.9 liters
- Water: (10/14) × 4.2 liters = 3 liters

**Table 1.**
Variations in experiments for making eco-enzymes

| Sample Number | Palm sugar | | Enau Bar Sugar Liquid (Nira) | |
|---|---|---|---|---|
| | vegetable | fruit | vegetable | fruit |
| 1 | 25% | 75% | 25% | 75% |
| 2 | 50% | 50% | 50% | 50% |
| 3 | 75% | 25% | 75% | 25% |

### Fermentation Process

All ingredients are mixed evenly in a fermentation container and stored for three months. The container is tightly closed to create anaerobic conditions, and the fermentation gas is released through a water bottle using a water hose.

**Figure 2.** Fermentation Process in sample storage for 3 Months

**Sample Testing Process**

1. pH Level Testing

The pH measurement follows the SNI 6989.11:2019 method using a pH meter.

Procedure:

1. Rinse the electrode with mineral-free water and dry it with tissue.
2. Dip the electrode into the sample until the reading is stable.
3. Record the pH and temperature values during measurement.

2. Color Testing

Color testing is done visually by comparing color changes before and after fermentation.

3. Aroma Testing

Aroma testing is done organoleptically using the sense of smell, assessing the typical aroma of fermentation.

4. Acetic Acid Content Analysis

The measurement of acetic acid levels follows the SNI 01-3711-1995 method through alkalimetric titration.

Procedure:

1. Pipette 10 ml of sample into an Erlenmeyer flask and add phenolphthalein indicator.
2. Titrate with NaOH solution until a stable pink color appears.
3. Record the titrant volume and repeat the process three times for validation.

**Data Analysis**

The research data were analyzed using descriptive and comparative statistical methods to compare eco-enzyme effectiveness with variations in palm sugar and palm sap liquids. Testing of pH, color, aroma, and acetic acid content was analyzed to determine the effect of material composition on fermentation results.

**RESULTS AND DISCUSSION**

1. Test Result Data

This study produced eco-enzymes using two variations: palm sugar and palm sap liquid as fermentation substrates, with the labels:

- GAO (Organic Palm Sugar)
- CNO (Organic Palm Sap Liquid)

**Table 2.**
Variations Of Eco-Enzyme Samples Used

| Sample | Composition of Organic Waste | Label |
|---|---|---|
| Eco-enzyme Palm sugar 1 | 25% vegetables, 75% fruit | GAO 1 |
| Eco-enzyme Palm sugar 2 | 50% vegetables, 50% fruit | GAO 2 |
| Eco-enzyme Palm sugar 3 | 75% vegetables, 25% fruit | GAO 3 |
| Eco-enzyme Palm sap liquid 1 | 25% vegetables, 75% fruit | CNO 1 |
| Eco-enzyme Palm sap liquid 2 | 50% vegetables, 50% fruit | CNO 2 |
| Eco-enzyme Palm sap liquid 3 | 75% vegetables, 25% fruit | CNO 3 |

2. pH analysis

**Table 3.**
pH levels every 5 days for 90 days for all samples.

| Day to | GAO 1 | GAO 2 | GAO 3 | CNO 1 | CNO 2 | CNO 3 |
|---|---|---|---|---|---|---|
| 5 | 3.64 | 3.71 | 3.64 | 3.71 | 3.64 | 3.64 |
| 10 | 3.63 | 3.63 | 3.63 | 3.71 | 3.64 | 3.64 |
| 15 | 3.49 | 3.42 | 3.42 | 3.57 | 3.53 | 3.52 |
| 20 | 3.11 | 3.11 | 3.13 | 3.29 | 3.26 | 3.22 |
| 25 | 3.09 | 3.08 | 3.09 | 3.27 | 3.26 | 3.21 |
| 30 | 2.96 | 2.99 | 2.98 | 3.31 | 3.27 | 3.22 |
| 35 | 2.71 | 2.72 | 2.78 | 3.39 | 3.38 | 3.35 |
| 40 | 2.67 | 2.64 | 2.77 | 3.42 | 3.42 | 3.37 |
| 45 | 2.70 | 2.70 | 2.67 | 3.52 | 3.51 | 3.44 |
| 50 | 2.61 | 2.61 | 2.57 | 3.55 | 3.52 | 3.44 |
| 55 | 2.50 | 2.50 | 2.50 | 3.63 | 3.55 | 3.52 |
| 60 | 2.50 | 2.50 | 2.50 | 3.71 | 3.62 | 3.59 |
| 65 | 2.90 | 2.90 | 2.90 | 3.79 | 3.79 | 3.72 |
| 70 | 2.81 | 2.90 | 2.90 | 3.88 | 3.86 | 3.82 |
| 75 | 2.99 | 2.99 | 2.99 | 3.86 | 3.98 | 4.01 |
| 80 | 2.99 | 2.99 | 2.99 | 4.01 | 4.07 | 3.98 |
| 85 | 3.08 | 3.08 | 3.08 | 4.07 | 4.07 | 4.01 |
| 90 | 2.90 | 2.99 | 2.99 | 3.90 | 4.07 | 4.07 |

3. Aroma Analysis

**Table 4.**
Aroma test results

| **Variable** | **Sample Condition** |
|---|---|
| 1 | sour aroma like a combination of orange and pineapple and fresh |
| GAO 2 | an aromatic combination of sour and sweet |

| | |
|---|---|
| GAO 3 | sour but slightly sharp, like the aroma of wilted vegetables |
| CNO 1 | thick and sour aroma |
| CNO 2 | thick and sour aroma |
| CNO 3 | has a strong, sour, and slightly pungent aroma |

4. Color Analysis

**Table 5.**
Color test results

| Variable | Sample Condition | |
|---|---|---|
| | Beginning | Harvest Time |
| GAO 1 | dark brown and clear | dark brown and cloudy |
| GAO 2 | dark brown and clear | reddish brown and cloudy |
| GAO 3 | dark brown and clear | reddish brown and cloudy |
| CNO 1 | Pale yellow and clear | pale yellow and cloudy |
| CNO 2 | Pale yellow and clear | greenish yellow |
| CNO 3 | Pale yellow and clear | brownish yellow |

5. Acetic Acid Level Analysis

**Table 6.**
Test results for acetic acid levels

| Sample | Acetic Acid Content (%) |
|---|---|
| Eco-enzyme Palm sugar variation 1 (25% vegetables and 75% fruit) | 4.97 |
| eco-enzyme Palm sugar variation 2 (50% vegetables and 50% fruit) | 4.36 |
| eco-enzyme Palm sugar variation 3 (75% vegetables and 25% fruit) | 4.83 |
| eco-enzyme Nira liquid variation 1 (25% vegetables and 75% fruit) | 1.54 |
| eco-enzyme Liquid Nira variation 2 (50% vegetables and 50% fruit) | 1.72 |
| eco-enzyme Liquid Nira variation 3 (75% vegetables and 25% fruit) | 1.38 |

Based on Table 3, it can be seen that each eco-enzyme sample experienced inconsistent changes in each test carried out. The pH level produced by the palm sugar eco-enzyme sample was 2.5 - 3.7, while the pH level produced by the sap liquid eco-enzyme sample was 3.21 - 4.07. The difference in the increase in pH levels experienced by the two types of eco-enzyme samples that have been made is influenced by the sugar content contained in each sugar used.

(Kee et al., 2022), explain that the uniqueness of palm sugar from a chemical perspective is that it contains approximately 84% sucrose compared to cane sugar and beet sugar, which are only 20% and 17%, respectively, so palm sugar can provide higher energy than beet sugar and cane sugar. Meanwhile (Saengkrajang et al., 2021), based on the results of glucose content analysis using a spectrophotometer, can see that the glucose content of palm sap water is 7.61%.

Mendes Ferreira & Mendes-Faia (2020), also stated that low pH indicates higher levels of organic acids produced by sugar microbes. Thus, a low pH will indicate a lower sucrose content. In the juice fermentation process, the sugar content will decrease rapidly, while the acid content, such as acetic and lactic acid, tends to increase. This change is characterized by decreased pH and sugar content (Pinto et al., 2022). Based on the pH level testing data obtained, it can be seen that palm sugar eco-enzyme samples with three different variations meet the requirements of termite exterminator liquid. The resulting pH level is below number 3, namely 2.99, which has corrosive solid properties—high enough to damage the body organs of termites. Meanwhile, the palm sugar eco-enzyme sample is at numbers 4-6, which has a lower speed than the palm sugar eco-enzyme sample in terms of destroying termite organs.

Table 4 shows a significant difference in the aroma of these two types of samples. The sample that uses palm sugar has a sour and sweet aroma, while the sample that uses liquid sap has a sour, thick, and pungent aroma, making it less pleasant to eat.

Cundari et al. (2024) explain that a good eco-enzyme meets the requirements: a pH below 4.0 and a fresh sour aroma typical of fermentation. In this case, all eco-enzyme samples meet the criteria for eco-enzyme aroma characteristics, namely sour aroma. This is due to the research results of Muktiarni et al. (2022), which show that all eco-enzyme products produced have a distinctive sour aroma.

Based on Table 5, testing the two types of eco-enzyme samples made, there are significant differences. The eco-enzyme samples using palm sugar (GAO) with the three variations produce a cloudy and reddish-brown color. In contrast, the samples that use sap liquid (CNO) with three different variations produce a cloudy yellow color.

This difference is influenced by the color of the sugar group used, where palm sugar has a dark brown or sometimes reddish color, while the sap liquid is cloudy white, sometimes pale yellow, and overcast. The composition of the organic waste used also affects the color produced after the fermentation period. Therefore, there is a significant color difference between the two types of eco-enzyme samples that have been made (Hanifah et al., 2022).

According to Nafilah et al. (2024), Eco-enzyme results from the fermentation of organic waste such as fruit and vegetable dregs, sugar (palm sugar, brown sugar, or cane sugar), and water. It is dark brown and has a strong, sweet, sour, fermented odor. Basodourn this, it can be seen that the eco-enzyme samples that meet the criteria for the color characteristics of the eco-enzyme liquid are the eco-enzyme samples that use palm sugar clusters with three variations made and the eco-enzyme samples that use three variations of palm sugar clusters (which produce brownish yellow) (Jagaba et al., 2024).

Based on Table 6, the acetic acid content of the palm sugar eco-enzyme sample is at 4-5%, while for the palm sugar eco-enzyme sample, it is at 1-2%.

The sugar content of each sample type influences the difference in acetic acid levels between the two samples. According to Derman et al. (2018), the higher the sugar content in the raw material, the more ethanol will be produced as a substrate for fermentation into acetic acid. This is due to the palm sugar content, which is higher than sugar's. According to Elfriede et al. (2023), palm sugar contains approximately 84% sucrose. Palm sap includes 10-15% of the sugar in male and female flowers (Sarma et al., 2022).

Apart from that, Farma et al. (2024) state that this study's eco-enzyme with a low pH value results from the high content of organic acids such as acetic acid or acid. Citric. Rasit et al. (2019), explained that there is a relationship between pH value and acetate content. The higher the acetic acid level, the lower the pH value of the eco-enzyme.

Based on the data from the results of the acetic acid level testing that has been carried out, it can be seen that the palm sugar eco-enzyme samples with three different variations meet the requirements for the safe use of acetic acid based on SNI: 01-3711-1995 regarding food vinegar, that the safe level of acetic acid is figure 4%-12.5%. The test results prove that the acetic acid content of the palm sugar eco-enzyme sample is 4.36% - 4.97%. Meanwhile, the sap liquid eco-enzyme sample was at 1.38%-1.72%; this concentration level can only be used as a household cleaning fluid at less than 5%.

## CONCLUSION

This study shows that eco-enzyme from palm sugar (GAO) has a lower pH (2.5–3.7) and higher acetic acid content (4.36%–4.97%), making it effective as a corrosive liquid for pest control, such as termites. In contrast, eco-enzyme from palm sap liquid (CNO) has a more neutral pH (3.21–4.07) and lower acetic acid content (1.38%–1.72%), suitable for use as a household cleaner. Both types of eco-enzymes meet the requirements of fermentation aroma and show color changes consistent with the composition of organic materials and the type of sugar used. Eco-enzyme from palm sugar is recommended for pest control due to its acidic and corrosive properties. In contrast, eco-enzyme from palm sap liquid is ideal as an environmentally friendly cleaner. Further product development can create a unique formulation for more practical applications. Using eco-enzymes also supports environmental sustainability by reducing dependence on chemicals and utilizing organic waste, reducing waste volume and providing additional economic benefits.

## SUGGESTION

Based on this study's findings, future research could explore several areas to optimize eco-enzymes' effectiveness and applications. First, varying the fermentation duration or environmental conditions (e.g., temperature and humidity) may provide insights into extending shelf life or enhancing the performance of eco-enzyme formulations. Additionally, more comprehensive testing of eco-enzymes' effectiveness against various pests beyond termites, including a broader range of harmful insects and fungi, is recommended.

Further research could also investigate combining other organic materials or alternative sugars to create specialized formulations tailored for specific applications, such as agricultural pesticides or industrial cleaning agents. Finally, a life-cycle assessment (LCA) of eco-enzyme production could evaluate its long-term environmental impact and economic feasibility, promoting the widespread adoption of eco-friendly products in both household and industrial settings.

## REFERENCES


Abdullah, N. O., Zubair, A., Mangarengi, N. A. P., Rachman, R. M., Tumpu, M., & Djamaluddin, D. (2023). Identification of eco enzyme characteristics from organic waste. *IOP Conference Series: Earth and Environmental Science*, *1268*(1), 12015. [Crossreff], [Publisher]

Ali, S., Amir, S., Ali, S., Rehman, M. U., Majid, S., & Yatoo, A. M. (2021). Water pollution: Diseases and health impacts. In *Freshwater Pollution and Aquatic Ecosystems* (pp. 1–23). Apple Academic Press. [Crossreff], [Publisher]

Benny, N., Shams, R., Dash, K. K., Pandey, V. K., & Bashir, O. (2023). Recent trends in utilization of citrus fruits in production of eco-enzyme. *Journal of Agriculture and Food Research*, *13*, 100657. [Crossreff], [Publisher]

Chaturvedi, S., & Khare, A. (2022). Solid Wastes: Characteristics, Composition and Adverse Effects on Environment and Public Health. *Asian Journal of Advanced Research and Reports*, *16*(7), 9–30. [Crossreff], [Publisher]

Cundari, L., Amaliah, S. P., Azzahra, F., Komariah, L. N., & Afrah, B. D. (2024). Novel Organic Preservative Made from Eco-Enzyme of Tempeh Waste: The Effect of Substrate and Fermenter Types. *Ecological Engineering & Environmental Technology*, *25*. [Crossreff], [Publisher]

Derman, E., Abdulla, R., Marbawi, H., & Sabullah, M. K. (2018). Oil palm empty fruit bunches as a promising feedstock for bioethanol production in Malaysia. *Renewable Energy*, *129*, 285–298. [Crossreff], [Publisher]

Elfriede, D. P., Fransisca, Dewi, R. T. K., & Widiastuti, N. N. A. (2023). *Quality characteristic analysis of baduy palm sugar.* [Crossreff], [Publisher]

Esparza, I., Jiménez-Moreno, N., Bimbela, F., Ancín-Azpilicueta, C., & Gandía, L. M. (2020). Fruit and vegetable waste management: Conventional and emerging approaches. *Journal of Environmental Management*, *265*, 110510. [Crossreff], [Publisher]

Fadlilla, T., Budiastuti, Mt. S., & Rosariastuti, M. M. A. R. (2023). Potential of fruit and vegetable waste as eco-enzyme fertilizer for plants. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 2191–2200. [Crossreff], [Publisher]

Farma, S. A., Islami, A., Putri, I. L. E., Handayani, D., Putri, D. H., & Anhar, A. (2024). Identification of acetic acid levels in ecoenzyme from organic materials of orange peel with acid-base titration method. *IOP Conference Series: Earth and Environmental Science*, *1312*(1), 12055. [Crossreff], [Publisher]

Hanifah, I. A., Primarista, N. P. V., Prasetyawan, S., Safitri, A., Adyati, T., & Srihadyastutie, A. (2022). The effect of variations in sugar types and fermentation time on enzyme activity and total titrated acid on eco-enzyme results of fermentation. *7th International Conference on Biological Science (ICBS 2021)*, 585–589. [Crossreff], [Publisher]

Hidayat, A., Bungin, E. R., Muliawan, I. W., Masgode, M. B., Rachman, R. M., Sarie, F., Serang, R., Hadid, M., & Rustam, M. S. P. A. (2023). *Polusi dan Lingkungan*. TOHAR MEDIA. [Publisher]

Jagaba, A. H., Lawal, D. U., Abdulazeez, I., Lawal, I. M., Mu'azu, N. D., Birniwa, A. H., Usman, A. K., Hagar, H. S., Yaro, N. S. A., & Noor, A. (2024). Advancements and prospects in the utilization of metal ions and polymers for enhancing aerobic granulation during industrial effluent treatment and resource recovery. *Journal of Water Process Engineering*, *66*, 105972. [Crossreff], [Publisher]

Kee, S. H., Ganeson, K., Rashid, N. F. M., Yatim, A. F. M., Vigneswari, S., Amirul, A.-A. A., Ramakrishna, S., & Bhubalan, K. (2022). A review on biorefining of palm oil and sugar cane agro-industrial residues by bacteria into commercially viable bioplastics and biosurfactants. *Fuel*, *321*, 124039. [Crossreff], [Publisher]

Mendes Ferreira, A., & Mendes-Faia, A. (2020). The role of yeasts and lactic acid bacteria on the metabolism of organic acids during winemaking. *Foods*, *9*(9), 1231. [Crossreff], [Publisher]

Mor, S., & Ravindra, K. (2023). Municipal solid waste landfills in lower-and middle-income countries: Environmental impacts, challenges and sustainable management practices. *Process Safety and Environmental Protection*, *174*, 510–530. [Crossreff], [Publisher]

Muktiarni, M., Rahayu, N., & Maryanti, R. (2022). Orange and strawberry skins for eco-enzyme: Experiment and bibliometric analysis. *Journal of Engineering Science and Technology Special Issue on ISCoE, 2022*, 195–206. [Publisher]

Muliarta, I. N. (2024). Global Warming Mitigation Innovation Through Household Waste Management Becomes Eco-Enzyme: A Review. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 515–525. [Crossreff], [Publisher]

Muliarta, I. N., & Darmawan, I. K. (2021). Processing household organic waste into eco-enzyme as an effort to realize zero waste. *Agriwar Journal*, *1*(1), 6–11. [Crossreff], [Publisher]

Nafilah, D. U., Rahmawati, F., Tafrikan, M., & Khasanah, N. (2024). Making A Multi Purpose Liquid (Eco-Enzyme) as An Alternative for Prosesing Household Organic Waste and Reviewing Its Benefits. *Jurnal Pengabdian KOLABORATIF*, *2*(2), 17–26. [Crossreff], [Publisher]

Pinto, T., Vilela, A., & Cosme, F. (2022). Chemical and sensory characteristics of fruit juice and fruit fermented beverages and their consumer acceptance. *Beverages*, *8*(2), 33. [Crossreff], [Publisher]

Putra, A. K., Mutia, T., Sahrina, A., Osman, S., Sholeha, A. W., Wibowo, N. A., & Khairunisa, T. (2023). *A technocreativity learning model based on environmental volunteers for waste management*. [Crossreff], [Publisher]

Rachman, R., Sya'ban, A. R., & Setiawan, T. A. (2020). Faktor-Faktor yang Berhubungan dengan Pengelolaan Sampah Rumah Tangga di Kelurahan Sanua Kota Kendari Tahun 2018. *Jurnal Ilmiah Teknik Sipil*, *8*(1), 37–49. [Crossreff], [Publisher]

Rasit, N., Hwe Fern, L., & Ab Karim Ghani, W. A. W. (2019). Production and characterization of eco enzyme produced from tomato and orange wastes and its influence on the aquaculture sludge. *International Journal of Civil Engineering and Technology*, *10*(3). [Publisher]

Rathod, B. G., Giridhar, P. V., & Shivshetty, N. (2024). Enzyme extraction from fruits waste. In *Adding Value to Fruit Wastes* (pp. 189–213). Elsevier. [Crossreff], [Publisher]

Saengkrajang, W., Chaijan, M., & Panpipat, W. (2021). Physicochemical properties and nutritional compositions of nipa palm (Nypa fruticans Wurmb) syrup. *NFS Journal*, *23*, 58–65. [Crossreff], [Publisher]

Sarma, C., Mummaleti, G., Sivanandham, V., Kalakandan, S., Rawson, A., & Anandharaj, A. (2022). Anthology of palm sap: The global status, nutritional composition, health benefits & value added products. *Trends in Food Science & Technology*, *119*, 530–549. [Crossreff], [Publisher]

Sharma, K. (2019). Causes and Harmful Effects of Ozone Layer Depletion. *International Journal of Research and Analytical Reviews*, *6*(1), 478–482. [Publisher]

Srihardyastutie, A., & Rosmawati, A. (2024). *The Miracle of Eco-Enzyme from Waste to Grace*. Nas Media Pustaka. [Publisher]

Yousif, N. A. M. (2019). *Analysis of the municipal solid waste management and treatment in Khartoum state and design of a mixed waste processing facility*. [Publisher]