Agro Bali : Agricultural Journal
Vol. 7 No. 2: 475-487, July 2024

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

The Nutrient Content of Eco-enzymes from Mixture of Various Fruit Peels

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Article history: submitted: December 13, 2023; accepted: July 31, 2024; available online: July 31, 2024

Abstract. Today, many institutions and individuals are paying attention to the development of technologies used in sustainable agriculture. One of the technologies is eco-enzyme that can be used as organic fertilizer. Several researchers have studied the use of eco-enzymes in agriculture, but studies on the nutrient content of eco-enzymes are still very limited. This research was conducted to investigate the nutrient content of two eco-enzyme preparations. The eco-enzymes were produced through the fermentation process of water, fruit peels, and molasses with a weight ratio of 10 : 3 : 1. Fruit peels used for Eco-enzyme A were banana, melon, watermelon, orange, and pineapple peels, while for Eco-enzyme B were banana, mango, watermelon, orange, and pineapple peels. The fermentation period for Eco-enzyme A was seven months, while for Eco-enzyme B was eight months. The results of the analysis showed that the two eco-enzymes contained various nutrients, both macro (C, N, P, K, Mg, Ca) and micro (Mn, Zn, B, Fe, Cu) ones, that were consistently higher in Eco-enzyme A. Both eco-enzymes were acidic, where the pH of Eco-enzyme A and B were 3.95 and 3.50, respectively. The data obtained were expected to be a basic reference for further research on eco-enzymes.

Keywords: eco-enzyme; fruit peels; organic fertilizer; organic waste; sustainable agriculture

INTRODUCTION

Today, agricultural programs are directed to overcome land degradation caused by farming practices during the Green Revolution. In the Law of the Republic of Indonesia Number 22 of 2019 concerning the Sustainable Agricultural Cultivation System, it was explained that a sustainable development system needed to be developed in the development in the agricultural sector through agricultural cultivation systems to achieve food sovereignty by taking into account the carrying capacity of ecosystems, mitigation, and adaptation to climate change in order to realize an advanced, efficient, resilient and sustainable agricultural system (Indonesian Law of Sustainable Agriculture Cultivation System, 2019).

Sustainable agricultural systems, including what was known as LEISA (low external input and sustainable agriculture), used a combination of organic-inorganic fertilizers, while organic farming used organic fertilizers as a source of nutrients. Organic fertilizers were very useful in increasing agricultural production both in quality and quantity, reducing environmental pollution, and improving land quality sustainably (Suriadikarta & Simanungkalit, 2006). The role of organic fertilizers was quite large in improving the physical, chemical, and biological properties of soil and the environment. Organic fertilizers made from natural materials had several advantages: they supplied and returned the organic matter to the soil, the materials were easy to obtain and inexpensive, they helped farmers to be more independent by reducing farmers' dependence on chemical fertilizers, they were efficient on production costs, and were environmentally friendly. Some of the advantages of using organic fertilizers were in line with the current initiatives for a circular economy in Indonesia and the world. In their book Future is Circular, Permata *et al*. (2022) wrote that a circular economy was an economic model that used a systems approach in production to consumption activities, which minimized the use of resources and waste generation, maintained the usability of the material, and was regenerative. Sustainable development in agriculture was a circular resource utilization model in agricultural development to reduce production costs, ensure the health impact of products, and protect the environment.

Today much attention is paid to developing technology to produce organic

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

fertilizers by utilizing organic waste (Arohman et al., 2023; Samputri et al., 2023; Setyowati et al., 2021). One of the technologies was an eco-enzyme, which in principle, was the product of fermentation from organic wastes, such as fruit and vegetable peels, mixed with water and sugar for three months. Fermentation not only extracted the components contained in the fermented media or substrate but also converted them into new compounds that were simpler and had better activity or were more functional (Srihardyastutie, 2021). Fruit and vegetable waste was one of the problems in environmental management. According to FAO (2020), there was a trend of increasing fruit and vegetable production. Sagar *et al*. (2018) reviewed that in line with an increase in the human population, there was an increase in fruit and vegetable consumption. Increasing the production and consumption of fruits and vegetables would certainly increase the waste materials from fruits and vegetables. According to data from the Ministry of Environment, no less than 50% of total wastes were organic (Sistem Informasi Pengelolaan Sampah Nasional, 2021), including vegetable and fruit wastes. In general, organic waste management was like other types of waste, using the burning method or the collect-transport-dump method. Fruits and vegetables were the most utilized commodities among all horticultural crops. Significant losses and waste in the fresh and processing industries were becoming severe nutritional, economic, and environmental problems (Sagar *et al*., 2018). If not processed further, these agro wastes would produce odor, soil pollution, and harborage for insects and were able to give rise to severe environmental pollution (Romelle *et al*., 2016). Making eco-enzymes was one of the solutions to prevent the loss of some nutrients contained in fruit and vegetable peels waste, air pollution, and health problems in the community due to the burning method, as well as preventing the formation of the greenhouse gas methane due to anaerobic decomposition in landfills area. Furthermore, Vama & Cherekar (2020) said that the novel approach to recycle and reuse natural waste, as done in the production of eco-enzymes, would help to reduce fruit waste; it was eco-friendly and economical with multipurpose applications.

Eco-enzyme has been reported to be used for various purposes, including as fertilizer (Vama & Cherekar, 2020). Quality standards of fertilizer included an emphasis on public health and environmental sustainability (Indonesian Law of Sustainable Agriculture Cultivation System, 2019). Eco-enzyme had the potential to meet these quality standards because it was made from organic materials that were easily decomposed (biodegradable). The production process was easy and inexpensive. Several studies have examined the use of eco-enzymes in agriculture, including on lettuce plants (*Lactuca sativa* L.) in hydroponic systems (Yuliandewi *et al*., 2018) and on soil (Manurung, 2021), turi (*Sesbania grandiflora*) (Ginting & Mirwandhono, 2021), butterfly pea flower (*Clitoria ternatea* L.) (Sembiring *et al*., 2021), and shallot (*Allium ascalonicum* L) (Hasanah *et al*., 2022; Novianto, 2022). However, observations on the nutrient content of eco-enzymes were still very limited. Hasanah *et al*. (2022) analyzed several nutrients as follows: N (%), P (%) Total-K (%), organic-C (%), pH, and C/N ratio. Based on the research results of (Tong & Liu, 2020) and (Hasanah *et al*., 2022), it was assumed that the type of fruit peels could influence variations in nutrient content. Fermentation time was an important factor in the fermentation process because it was related to the microbial growth phase that will develop from time to time, so it was going to affect the product content to be produced (Srihardyastutie, 2021). The duration of the fermentation was thought to affect the nutrient content in line with the decomposition process and the possibility of other microbe reactions while the fermentation was still ongoing.

Therefore, this research was conducted to determine the nutrient composition of eco-enzyme preparations using various types of fruit peels and sugar sources with different

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

duration of fermentation. Through this research, the nutrient content of eco-enzymes can be revealed, not only some macronutrients as in previous studies, but also micronutrients. It is hoped that the data obtained can fill in the lack information and become a basic reference for further research on eco-enzymes, including their use in agriculture, particularly for sustainable agriculture.

METHODS

The research was carried out from September 2021 to July 2022. The materials used were organic waste from several types of fruit peels, molasses, palm sugar, water, plastic sheet, scales, beaker glass, a plastic container with cover, jerry cans, and a knife.

Eco-enzyme was made by mixing organic waste, water, and sugar in a weight ratio of 3: 10: 1. Eco-enzyme was prepared in two preparations: Eco-enzyme A and Eco-enzyme B. In making both eco-enzyme preparations, five types of organic waste were used, each with the same weight. The organic wastes used to make Eco-enzyme A were the peels of banana, melon, watermelon, orange, and pineapple, while the ones used to make Eco-enzyme B were of banana, mango, watermelon, orange, and pineapple. For Eco-enzyme A, molasses was used as the source of sugar (glucose), while for Eco-enzyme B, palm sugar was used. After the fruit peels were cut on the plastic sheet, all the ingredients were put in a plastic container and mixed thoroughly. Then the container was tightly closed and stored in a room with well-circulated air.

According to Srihardyastutie & Rosmawati (2023), eco enzymes can be harvested after fermentation for 3 months. Eco-enzyme A was harvested after a 100-days fermentation process, while Eco-enzyme B was harvested after 92 days. Harvesting was done by filtering the materials to obtain the filtrate called eco-enzyme. The eco-enzymes were then put in tightly closed jerry cans.

Analysis of the pH value and nutrients was carried out four months and five months after Eco-enzyme A and Eco-enzyme B were harvested, respectively. So the fermentation time before analysis for eco-enzyme A was seven months and for eco-enzyme B was eight months. Analysis of the nutrient content of the two preparations was done on the following parameters: organic-C, N, P, K, Mg, Ca, Mn, Zn, B, Fe, and Cu. Analytical methods used were as follows: H20 (1:5) – Electrometry for pH, Walkley and Black with Spectrophotometer for organic-C, Kjedahl with Spectrophotometer for N, Dry Ashing-HNO3 with Spectrophotometer for P and B, Dry Ashing- HCl with AAS for K, Mg, Ca, Mn and Zn, and Dry Ashing- HCl for Fe and Cu.

RESULTS AND DISCUSSION

The results of the analysis of Eco-enzyme A and Eco-enzyme B with the analysis method for each parameter are presented in **Table 1** and **Table 2**. The pH value of Eco-enzyme A was 3.95, and of Eco-enzyme B was 3.50. The organic-C content of the two eco-enzyme samples was 1.74% and 1.67%, respectively. The analysis showed that both eco-enzymes contained various macronutrients of N, P, K, Mg, and Ca (**Table 1**). The macronutrient content in Eco-enzyme A was as follows: N 0.8400%, P 0.2015%, K 0.2650%, Mg 0.0120%, and Ca 0.0440%. The macronutrient content in Eco-enzyme B was as follows: N 0.0300%, P 0.0180%, K 0.1014%, Mg 0.0042%, dan Ca 0.0200%.

The results of the analysis showed that the two eco-enzyme preparations contained micronutrients Mn, Zn, B, Fe, and Cu (**Table 2**). The micronutrients in Eco-enzyme A were as follows: B 32.5100 ppm, Fe 94.7900 $mg.kg^{-1}$, Cu 15.7100 $mg.kg^{-1}$, Mn 3.6500 $mg.kg^{-1}$, and Zn 25.9400 $mg.kg^{-1}$. The nutrient content in Eco-enzyme B was as follows: B 34.7100 $mg.kg^{-1}$, Fe 26.9531 $mg.L^{-1}$, Cu 0.0804 $mg.L^{-1}$, Mn 1.1980 $mg.L^{-1}$, and Zn 1.0839 $mg.L^{-1}$.

In general, the content of macro and micronutrients was higher in Eco-enzyme A than in Eco-enzyme B (**Table 1** and **Table 2**).

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

pH value

The pH values obtained were below 4, where the pH of Eco-enzyme A and Eco-enzyme B were 3.95 and 3.50, respectively (**Table 1**). This pH value was also found in several other studies (Hasanah *et al*., 2022; Nurlatifah *et al*., 2022; Rochyani *et al*., 2020; Samriti *et al*., 2019). Samriti *et al*. (2019) reported that the pH value of eco-enzymes obtained from different fruit peels (papaya, banana, sapodilla, and pomegranate) was 4.3$\pm$0.4 and the pH value of eco-enzyme obtained from vegetable peels (potato, gourd, eggplant, and turnip) was 3.3$\pm$0.2. The results of Rochyani *et al*. (2020) showed that the pH value for eco-enzyme with pineapple and papaya waste was 3.15 and 3.29, respectively. The characterization results by Nurlatifah *et al*. (2022) showed that the pH values of eco-enzymes from the peels of several types of fruit were as follows: banana peels 3.88; watermelon peels 3.30; orange peels 3.21, and pineapple peels 3.23. Hasanah *et al*. (2022) showed that the pH of eco-enzyme made from chicory peels was 3.81, from orange peels was 3.57, and from pineapple peels was 3.58.

The process of eco-enzyme production took place anaerobically. According to an explanation by Srihardyastutie (2021), the fermentation process happens in two stages, namely alcoholic fermentation and acid fermentation. Alcoholic fermentation was carried out by bacteria and some fungi, such as yeast, under conditions of reduced oxygen levels, involving the partial breakdown of glucose (Glucose → 2 Ethanol + 2 CO2). Acid fermentation was carried out by several anaerobic bacteria and fungi under conditions of very limited or very low oxygen levels, producing lactic acid and other organic acids (Glucose → 2 Lactic Acid + Organic Acid). Since lactic acid and other organic acids were produced during the fermentation, a good EE standard was: had a pH value less than 4 and had a fresh sour odor.

Table 1. Results of pH and macronutrients analysis of Eco-enzyme A and Eco-enzyme B

Parameter	Results				Analytical Method
	Eco-enzyme A		Eco-enzyme B		
C-organic	1.7400	%	1.6700	%	Walkley and Black with Spectrophotometer
pH	3.9500		3.5000		H20 (1:5) – Electrometry
N	0.8400	%	0.0300	%	Kjeldahl with Spectrophotometer
P	0.2015	%	0.0180	%	Dry Ashing- HNO3 with Spectrophotometer
K	0.2650	%	0.1014	%	Dry Ashing- HCl with AAS
Mg	0.0120	%	0.0042	%	Dry Ashing- HCl with AAS
Ca	0.0440	%	0.0200	%	Dry Ashing- HCl with AAS

Source: Laboratory of Socfindo (2022)

Table 2. Results of micronutrients analysis of Eco-enzyme A and Eco-enzyme B

Parameter	Results				Analytical Method
	Eco-enzyme A		Eco-enzyme B		
Mn	3.6500	$mg.kg^{-1}$	1.1980	$mg.L^{-1}$	Dry Ashing- HCl with AAS
Zn	25.9400	$mg.kg^{-1}$	1.0839	$mg.L^{-1}$	Dry Ashing- HCl with AAS
B	32.5100	ppm	34.7100	$mg.L^{-1}$	Dry Ashing- HNO3 with Spectrophotometer
Fe	94.7900	$mg.kg^{-1}$	26.9531	$mg.L^{-1}$	Dry Ashing- HCl
Cu	15.7100	$mg.kg^{-1}$	0,0804	$mg.L^{-1}$	Dry Ashing- HCl

Source: Laboratory of Socfindo (2022)

C organic

The C-organic content of Eco-enzyme A and Eco-enzyme B was 1.74% and 1.67%, respectively (**Table 1**). The C-organic content of Eco-enzyme B was relatively lower than that of Eco-enzyme A. This difference was

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

expected to be due to the longer fermentation (harvest + storage) period of Eco-enzyme B, which was 8 months, compared to the fermentation period of Eco-enzyme B, which was 7 months (**Table 3**). During the fermentation period, decomposition and mineralization continued, in which some C-organic was converted into primary metabolites, secondary metabolites, and C-inorganic.

Table 3. General description of Eco-enzyme A and Eco-enzyme B

Description	Eco-enzyme A	Eco-enzyme B
Type of fruit peels	banana, melon, watermelon, orange, and pineapple	banana, mango, watermelon, orange, and pineapple
Source of sugar	molasses	brown sugar
Eco-enzyme harvest age	100 days	92 days
Chemical analysis time	4 months after harvesting	5 months after harvesting
Total fermentation time	7 months	8 months

Fermentation is a process of chemical changes in an organic substrate due to the action of biochemical catalysts, namely enzymes produced by certain living microbes. Fermentation occurs due to microbial activity causing fermentation on suitable organic substrates (Rochani *et al*., 2015). According to Srihardyastutie (2021), fermentation produces microbial metabolites consisting of primary and secondary metabolites. The type of product increased with time, as presented in **Figure 1** (Gokulan *et al*., 2014). The longer the fermentation time, the lower the total C-organic of the eco-enzyme due to the change in C-organic into primary and secondary metabolites.

The C-organic content of the two eco-enzyme preparations was lower than the C-organic content of eco-enzymes produced by another researcher. Hasanah *et al*. (2022) found that the C-organic content of eco-enzyme made from chicory was 1.94%, from orange peels was 2.62%, and from pineapple peels was 2.38% (**Table 4**). The lower C-organic content of the two eco-enzyme preparations compared to that of eco-enzymes produced by Hasanah *et al*. (2022) is presumably due to the longer fermentation period. The fermentation period of eco-enzymes made by Hasanah *et al*. (2022) was 2-3 months only.

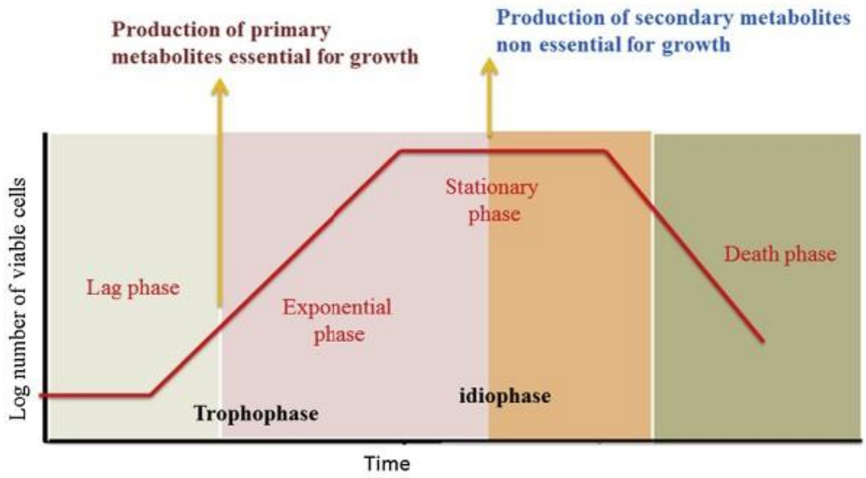

Figure 1. Various phases of bacterial growth and production of primary and secondary metabolites (Gokulan *et al*., 2014)

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

Table 4. Chemical analysis results of several eco-enzymes

Parameter	Eco-enzyme A The mixture of banana, melon, watermelon, orange, and pineapple peels	Eco-enzyme B The mixture of banana, mango, watermelon, orange, and pineapple peels	Eco-enzyme by Hasanah et al. (2022)		
			Chicory	Orange peels	Pineapple peels
pH	3.95	3.50	3.81	3.57	3.58
C-organic (%)	1.74	1.67	1.94	2.62	2.38
N (%)	0.84	0.03	3.12	0.68	0.49
P (%)	0.2015	0.0180	0.10	0.01	0.01
K-total (%)	0.2650	0.1014	0.15	0.11	0.11

Note: N: Nitrogen, P: Phosphor, K: Potassium, C-organic: Carbon-organic

Nutrient content

Based on the results of the analysis, in general, the nutrient content of Eco-enzyme A was higher than that of Eco-enzyme B. The difference in nutrient content presumably due to several differences in materials and production processes between the two eco-enzymes (**Table 3**). First, there was a difference in one type of the whole five types of organic waste, where the organic material used in Eco-Enzyme A was melon peels and in Eco-enzyme B was mango peels, while the other four types of organic waste, namely banana, watermelon, orange, and pineapple peels, were used in both. Second, the difference in the source of sugar, where in Eco-enzyme A molasses was used while in Eco-enzyme B palm sugar was used. Third, the harvesting time of the two materials, where Eco-enzyme A was harvested 100 days after manufacture and eco-enzyme B at 92 days. Fourth, the difference in storage time before analysis, where eco-enzyme A analysis was carried out 4 months after harvesting time, while eco-enzyme B analysis was carried out 5 months after harvesting time.

Differences in nutrient content might be attributed to differences in harvesting and storage time before analysis because eco-enzymes contained microbes that made the decomposition of organic waste continue as long as organic waste and sugar as energy sources were still available. Fluctuations in nutrient content based on harvest age and storage time needed to be studied further to provide information on eco-enzymes utilization as nutrient providers. The dynamics that took place during the fermentation process, where various decomposition and mineralization processes occurred (**Figure 1**), were thought to make the content of various nutrients change according to the time of fermentation.

Based on the results of analysis on the content of several nutrients (N, P, K) of Eco-enzyme A and Eco-enzyme B, as well as the research conducted by Hasanah *et al*. (2022), there were variations in nutrient content, especially for elements N and P (**Table 4**). This variation was thought to be due to differences in the type of waste in the form of fruit peels used (**Table 3 dan Table 4**). This conjecture was supported by Romelle *et al*. (2016) who observed the content of elements of Ca, Zn, Fe, and Mn in the peels of several fruits. The content of Ca, Zn, Fe, and Mn in pineapple was 8.30±0.54, 6.46 ± 0.43, 25.52± 3.38, and 5.32 ± 0.49 mg/100 g dry peel, respectively. In mango, it was 60.63± 4.58, 0.66 ± 0.06, 12.79±1.56, and 4.77 ± 0.22 mg/100 g dry peel, respectively. In bananas, it was 19.86 ± 0.24, 1.72 ± 0.17, 15.15 ± 0.36, and 9.05 ± 0.34 mg/100 g dry peel, respectively. In watermelon, it was 11.21±0.58, 3.78 ± 0.27, 45.58 ± 2.37, and 1.25 ± 0.34 mg/100 g dry peel, respectively. Romelle *et al*. (2016) concluded that watermelon, pawpaw, orange, pineapple, banana, apple, mango, and pomegranate had important proportions of peels. Those peels

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

were sources of nutrients (lipids, proteins, minerals, etc.). Different sources of organic waste produced a variety of fermented products. This was in line with the results of a study by (Romelle *et al*., 2016). Using the peels of papaya, pineapple, mango, apple, banana, orange, pomegranate, and watermelon, the study by (Romelle et al., 2016) showed that the protein content ranged from 2.80 ± 0.17 to 18.96 ± 0.92%; the minimum level was found in apple peels and the maximum in pawpaw peels; the lipids content ranged from 3.36 ± 0.37 to 12.61 ± 0.63 % with pomegranate peels having the lowest content and watermelon peels the highest level; the ash content of fruit peels under study varied from 1.39 ± 0.14% in apple peels to 12.45 ± 0.38% in banana peels, and the crude fiber and carbohydrates content of fruit peels respectively ranged from 11.81 ± 0.06 to 26.31 ± 0.01% and from 32.16 ± 1.22 to 63.80 ± 0.16%.

Sugar was chemically a carbohydrate compound belonging to the monosaccharide and disaccharide groups. Sugar contains the elements carbon (C), hydrogen (H), and oxygen (O). Sugar was a group of nutrients and energy sources (Rochani *et al*., 2015). Sugar was the substrate used to produce alcohol. In general, basic ingredients that contained organic compounds, especially glucose or starch, were able to be used as substrates in the alcoholic fermentation process (Supriyani *et al*., 2020). The sugar sources used for Eco-enzyme A and Eco-enzyme B are molasses and palm sugar, respectively (**Table 3**). The sugar sources were thought to not affect the variation of nutrients contained in the two eco-enzyme preparations because both types of sugar contain sucrose and minerals that was not much different. Molasses was a by-product in the process of sugar production. Molasses was a viscous liquid obtained from the sugar crystal separation stage. Molasses contained most of the sugars, amino acids, and minerals. The sucrose contained in molasses varied between 25-40%, and the reducing sugar content was 12-35% (Rochani *et al*., 2015). The sugar content in molasses consisted of 35% sucrose, 7% glucose, 9% fructose, and 4% other carbohydrates (Santosa *et al*., 2019), whereas according to Rochani *et al*. (2015), molasses had a high sugar compound content, ranging from 50-65%. Meanwhile, according to the National Standardization Agency (1995), palm sugar was sugar produced from the processing of palm tree sap, namely aren (*Arenga pinata* Merr), coconut (*Cocos nucifera*), siwalan (*Borassus flabellifer* L) or other types of palm, and had a form of mold or powder/granule. One of the quality requirements for palm sugar was that the sucrose content in palm sugar (including brown sugar) was a maximum of 70%, while the reducing sugar content was a maximum of 10%. The nutritional richness and the similarities between molasses and brown sugar have made these two types of sugar recommended for use in eco-enzyme production.

The difference in the quality of the eco-enzyme was observed when granulated sugar was used as the sugar source. According to Supriyani *et al*. (2020), compared to those using other types of sugar, eco-enzymes using granulated sugar produced eco-enzyme solutions with lower yields and more gas. According to a study by Munir *et al.* (2021) on the production of eco-enzyme using pomelo orange peels, the highest pH value was in the brown sugar treatment of 4.35 and the lowest in the granulated sugar treatment of 4.05, while the highest alcohol content was found in the palm sugar treatment of 4.56% and the lowest was in the granulated sugar treatment of 3.40%. These facts made granulated sugar not to be used as a source of sugar in the production of eco-enzymes.

Potential for development of eco-enzyme as organic fertilizer

Fermentation was a process of chemical changes in an organic substrate that took place due to the action of biochemical catalysts, namely enzymes, produced by certain living microbes. Fermentation occurred due to microbial activity that caused fermentation on

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

suitable organic substrates (Rochani *et al*., 2015). Fermentation time was an important factor in the fermentation process because it was related to the microbial growth phase that developed over time. Gokulan *et al*. (2014) presented various phases of bacterial growth which showed that the duration of fermentation would affect the production of metabolites (**Figure 1**). The production of primary metabolites generally occurred at the late lag phase and the middle of the exponential phase, while the production of secondary metabolites took place at the end of the stationary phase.

According to Samriti *et al*. (2019) eco-enzyme observation revealed the presence of acetic acid, sugars, proteins, alcohol, and enzyme activities like protease, amylase, lipase and papain, which were known as primary metabolites. Enzymes produced by microbes from fruit peels were also known as playing a role in the availability of nutrients in the rhizosphere area. Meanwhile, secondary metabolites produced by microbes, including active ingredients in pesticides and growth regulators, represented a high potential of eco-enzymes in promoting plant growth and crop disease management. A great opportunity for microbial technology was the substitution of biopesticides, which were widely used in modern organic agriculture (Aguilar et al., 2019). In line with that, Srihardyastutie (2021) stated that one of the applications of eco-enzymes was for natural herbicides or pesticides and fertilizers because in eco-enzymes biomass products (microbial cells) were obtained and acted as biological agents. These biological agents functioned as natural fungicides and insecticides, potential microbes that were able to improve conditions of soil that had been already saturated with inorganic fertilizers. The biomass contained in eco-enzyme also enriched the content of organic fertilizer when it was mixed in organic fertilizers such as compost. Oladipo *et al*. (2022) wrote that pesticides and growth regulators of microbial origin had proved their significant potential in sustainable agricultural development and accordingly in the development of a green environment.

The importance of the type of fruit peels as the source of energy for the microorganisms during the fermentation time was also revealed. The results of this study showed that there were differences in the content of various nutrients between the two eco-enzyme preparations, which were thought to be caused by differences in one type of the total five types of fruit peel material. Hasanah *et al*. (2022) also found variations in nutrient content, especially of elements N and P, between eco-enzymes from different types of fruit peels (**Table 4**). This conjecture was supported by the results of Romelle *et al*. (2016) that showed that there were not only variations in the mineral composition of various fruit peels but also in primary metabolites (lipids, proteins, ash, crude fiber, and carbohydrate contents) and secondary metabolites. This certainly would affect the use of eco-enzymes. Tong & Liu (2020) studied the effect of adding three types of eco-enzymes into irrigation water on soil properties. The levels of organic C and total N in the soil were influenced by the type of fruit peels. Eco-enzymes made from eggplant peels increased soil organic matter, while apple and dragon fruit peels did not. In the study, the three eco-enzymes of eggplant, dragon fruit, and apple peels increased total soil nitrogen. Eco-enzymes made from eggplant and dragon fruit peels had almost the same effect on total soil nitrogen, which was higher than apple peels. Based on the findings of Romelle *et al*. (2016) regarding variations in mineral, primary metabolites, and secondary metabolites content between various fruits, it was able to be suggested that in the production of eco-enzymes, it is better to use a variety of fruit peels. The use of various types of fruit peels will complement each other to produce a better quality.

There were several studies that had examined the use of eco-enzymes in agriculture, both in hydroponic systems (Yuliandewi *et al*., 2018) and on soil (Manurung, 2021). The studies were also

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

done on the application of eco-enzyme on turi (*Sesbania grandiflora*) (Ginting & Mirwandhono, 2021), butterfly pea (*Clitoria ternatea* L.) (Sembiring *et al*., 2021), and shallot (*Allium ascalonicum* L) (Hasanah *et al*., 2022; Novianto, 2022). Vama & Cherekar (2020), stated that there were many applicability of eco-enzyme. One of them was to enhance plant growth. It was observed that the generation time of seedlings was 6 days with eco-enzyme while seedlings took 9 days to grow without eco-enzyme. Also, seedling vigor was more with eco-enzyme than seedling without it. These facts suggested that eco-enzyme was of good benefit for plant growth and yield, and was considered to be a good organic fertilizer.

Based on the results of the analysis of nutrient content presented in **Table 1** and **Table 2**, it was able to be seen that eco-enzymes contained quite complete nutrients. Therefore, the potential of eco-enzymes as complementary fertilizers needed to be studied. In **Table 5**, the nutrient content of the two eco-enzyme preparations together with one of the well-known complementary fertilizers from the trademark of Plant Catalyst 2006 was presented. The content of some of the Eco-enzyme micronutrients was higher than that of the Plant Catalyst 2006 supplementary fertilizer, especially the elements of boron (B) and iron (Fe) (**Table 5)**. The nutrient content of boron (B) in eco-enzyme A was 32.5100 ppm and in eco-enzyme B was 34.7100 $mg.L^{-1}$, which was higher than that of Plant Catalyst 2006 0.76%. The nutrient content of Iron (Fe) in eco-enzyme A was 94.7900 $mg.kg^{-1}$ and in eco-enzyme B 26.9531 $mg.L^{-1}$, which was higher than that of Plant Catalyst 0.01%. Even the nutrient content of N, Mn, Zn, and Cu eco-enzyme A were higher than that of Plant Catalyst (**Table 5**).

The application of eco-enzyme on irrigation water was also done and the study revealed some interesting facts. The results of the research by Tong & Liu (2020) showed that after 4 weeks of irrigation with the application of eco-enzyme made from eggplant peels, the organic matter of the soil samples began to increase gradually and reached a peak at 49.33 $g.kg^{-1}$ after 4 weeks. The organic content was higher than the control (24.32 $g.kg^{-1}$). There was a possibility that soil organic C would rise and fall. Organic C increased due to an increase in humus and organic C decreased due to mineralization.

The results of the research by Tong & Liu (2020) also described that eco-enzymes gradually increased total soil nitrogen and organic matter with an increase in the length of irrigation time application. The total nitrogen of the soil samples of apple, dragon fruit, and eggplant peels began to increase gradually and reached a peak after 4 weeks of irrigation. The decrease in total N was due to ongoing denitrification and ammonification. Eco-enzyme anaerobic bacteria had an effect on denitrification and an effect that reduced total nitrogen. In the denitrification reaction, nitrate was reduced to nitrite, which was then converted to ammonia by microorganisms. In the ammonification reaction, organic nitrogen was decomposed into ammonia by microorganisms. On the other hand, microorganisms promote the mineralization of soil organic matter, leading to an increase in effective nitrogen.

The study of eco-enzyme on water samples also showed that the eco-enzyme treatment reduced the concentration of nitrate ion (NO^{3-}). This reduction might be caused by the presence of nitrate reductase which catalyzed the reduction of nitrate (NO^{3-}) (Wen et al., 2021). The results of other studies on the application of eco-enzymes in sludge treatment stated that eco-enzymes removed total N and total P contained in sludge (Galintin *et al*., 2021). Total N which was quite different between Eco-enzyme B compared to in Eco-enzyme A also indicated the need to study the possibility of N being reduced during the fermentation period due to denitrification and ammonification. This study was going to be taken into consideration when harvesting eco-enzymes to be used as a source of N.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v7i2.1646

Table 5. Nutrient content of eco-enzyme and Plant Catalyst 2006

Parameters	Eco-enzyme A		Eco-enzyme B		Plant Catalyst 2006 (Sucofindo, 2016)	
C-organic	1.7400	%	1.6700	%	6.37	%
pH	3.95		3.5		Basa	
N	0.8400	%	0.0300	%	0.26	%
P	0.2015	%	0.0180	%	17.85	%
K	0.2650	%	0.1014	%	0.08	%
Mg	0.0120	%	0.0042	%	0.49	%
Ca	0.0440	%	0.0200	%	0.09	%
Mn	3.6500	$mg.kg^{-1}$	1.1980	$mg.L^{-1}$	1.69	%
Zn	25.9400	$mg.kg^{-1}$	1.0839	$mg.L^{-1}$	2.02	%
B	32.5100	ppm	34.7100	$mg.L^{-1}$	0.76	%
Fe	94.7900	$mg.kg^{-1}$	26.9531	$mg.L^{-1}$	0.01	%
Cu	15.7100	$mg.kg^{-1}$	0.0804	$mg.L^{-1}$	3.00	ppm

According to a review by Singh *et al.* (2017), microorganisms and their products have played an important role in the development of sustainable agriculture. In addition to providing nutrients, eco-enzymes also produce microbes and microbial products in the form of primary metabolites such as various enzymes, and secondary metabolites, as pesticides and growth regulators, depending on the length of the fermentation period. The simple and inexpensive eco-enzyme technology made it accessible for farmers to produce primary and secondary metabolites quickly. This technology will encourage farmers to be more independent. Therefore, it is essential to conduct detailed research on fermentation time, including harvest and storage times.

CONCLUSION

Two eco-enzymes contained various nutrients, both macro (C, N, P, K, Mg, Ca) and micro (Mn, Zn, B, Fe, Cu) ones, and the macro and micronutrients were consistently higher in Eco-enzyme A than in Eco-enzyme B. Both eco-enzymes were acidic, where the pH of Eco-enzyme A and B were 3.95 and 3.50, respectively. The data obtained were expected to be a basic reference for further research on eco-enzymes, related to their use in agriculture, particularly for sustainable agriculture.

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