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PRODUCTION OF ECO-ENZYMES FROM FRUIT PEEL WASTE AS AN EFFORT TO ADDRESS ORGANIC WASTE MANAGEMENT ISSUES IN INDONESIA

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ABSTRACT

Based on the data from the National Waste Management Information System of the Ministry of Environment and Forestry in 2022, the waste production in Indonesia reached 54,455 tons per day. When calculated on an annual scale, Indonesia generated a total of 19.88 million tons of waste. 41.55% of this waste was composed of food scraps. One alternative to address the issue of organic waste is by processing it into eco-enzymes. Eco-enzymes are complex organic compound solutions resulting from the fermentation of organic waste, water, and sugar. The objective of this research is to produce eco-enzymes from fruit peels as a solution to organic waste management at the household level. This study is an experimental research that employs three types of substrate variations with the following formulation: water:fruit peels:sugarcane molasses = 10:3:1. The fruit peels used in creating these eco-enzymes are pineapple rinds (*Ananas comosus*), sweet orange rinds (*Citrus sinensis*), mango rinds (*Mangifera indica* L.), mangosteen rinds (*Garcinia angostana* L.), Kepok banana rinds (*Musa paradisiaca* Linn), rambutan rinds (*Nephelium lappaceum* L.), avocado rinds (*Persea americana* Mill), guava rinds (*Psidium guajava*), water apple rinds (*Syzygium aqueum*), cucumber rinds (*Cucumis sativus*), and kedondong rinds (*Spondias dulcis*).
The research findings indicate that the fermentation process of eco-enzymes was successful. Based on the results of the organoleptic test, the characteristics of the eco-enzyme product produced in this study include a pungent and fresh aroma, and a murky brown color.

Introduction

Indonesia is a country with the fourth largest population in the world. According to the population administration data obtained from the Ministry of Home Affairs of the Republic of Indonesia (2022), the population of Indonesia as of June 2022 was approximately 275.36 million people. Given this reality, it is bound to create several issues, one of which is waste production, as the increasing population leads to a rise in the amount, volume, types, and characteristics of waste. Based on data from the National Waste Management Information System of the Ministry of Environment and Forestry (2022), the majority of the national waste generated in 2022 consists of food leftovers, accounting for 41.55% of the total. Plastic waste follows in

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second place with a proportion of 18.55%. About 13.27% of the waste is in the form of wood/branches, 11.04% is paper/cardboard waste, and metal waste comprises 2.86%. Additionally, there is 2.54% of textile waste, 1.96% of glass waste, 1.68% of rubber/leather waste, and 6.55% of other types of waste.

The issue of waste has become a national problem, necessitating a comprehensive and integrated management approach from the beginning to the end. This approach should bring economic benefits, promote the well-being of both society and the environment, and be capable of influencing changes in societal behavior. However, up until now, waste management has not been conducted in accordance with environmentally friendly disposal methods and techniques, resulting in adverse impacts on public health and the environment. Currently, waste processing in society largely relies on an end-of-pipe approach, where waste is collected, transported, and disposed of in final processing sites. Unfortunately, the accumulation of large amounts of waste in these final disposal sites has the potential to generate methane gas, contributing to greenhouse gas emissions and global warming. The waste management paradigm based on definitive approaches should be abandoned in favor of a new paradigm in waste processing. Waste management should be undertaken through a comprehensive approach, starting from the upstream phase, even before a product with potential waste is generated, to the downstream phase, which involves the safe return of waste to the environment after the product has been used (Prabekti, 2020).

According to Vika M *et al*. (2020), the composition of waste generated from human activities consists of organic waste, amounting to 60-70%, and non-organic waste, amounting to 30-40%. The issue of waste arises when its quantity increases in the environment, as it has the potential to pollute the surrounding environment. Given this problem, there is a need for management of both types of waste to prevent negative impacts on public health and the environment. Additionally, as stated by Rochyani (2020), waste from residential areas is generally diverse, but about 75% of it is composed of organic waste, with the remaining being inorganic. Organic waste is material/items that are considered no longer useful and are discarded by their previous owners/users but can still be utilized if managed properly (Chandra, 2006).

One of the ways that can be employed to utilize organic waste is by creating ecoenzymes. Ecoenzymes are liquid extracts produced from the fermentation of vegetable and fruit remnants with red sugar or molasses as substrates (Nazim & Meera, 2013). And according to Tang & Tong (2013), the process requires three months.The process of ecoenzyme production is similar to composting, but with the addition of water as a growth medium, resulting in a preferred liquid product that is easier to use and has numerous benefits (Luthfiyyah *et al.*, 2010 cited in Junaidi 2021). The final product of ecoenzymes yields suspended residues (sediment) at the bottom, which consists of vegetable and fruit leftovers that can be utilized as organic fertilizer. Meanwhile, the liquid eco-enzyme can be used for the following purposes: 1) Floor cleaner, highly effective for household floor cleaning, 2) Disinfectant, can be used as an antibacterial agent in bathrooms, 3) Insecticide, utilized to exterminate insects (by mixing enzymes with water and using it in a spray form), 4) Drain cleaner, especially for small drains as channels for disposing of wastewater (Rochyani, 2020).

Based on the aforementioned exposition, this research is conducted as an effort to provide a comprehensive solution for handling organic waste circulating in the community by converting it into eco enzymes. This program is expected to bring about greater benefits for various parties.

Materials and Methods

Tools

The instruments utilized in this research comprised ; a knife, scissors, a cutting board, analytical scales, three 4-liter plastic

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jars equipped with lids designated as fermenter tubes, hanging labels, a measuring cylinder or measuring cup, a glass stirring rod, a filter, several 250 ml-sized bottles, napkins, tissues, gloves, masks, a camera, and stationery.

Materials

The materials utilized in the production of eco-enzymes for this study consisted of various organic waste from fruits, including pineapple rinds (*Ananas comosus*), orange rinds (*Citrus sinensis*), mango rinds (*Mangifera indica* L.), mangosteen rinds (*Garcinia angostana* L.), kepok banana rinds (*Musa paradisiaca* Linn), rambutan rinds (*Nephelium lappaceum* L.), avocado rinds (*Persea americana* Mill), guava rinds (*Psidium guajava*), water apple rinds (*Syzygium aqueum*), cucumber rinds (*Cucumis sativus*), and kedondong rinds (*Spondias dulcis*). Additionally, mineral water and molasses (derived from sugar cane) were used in the process.

Method of Ecoenzymes Production

The first step in the process of producing this ecoenzyme involves thoroughly washing all fruit peels with running water to remove any adhering dirt. Subsequently, they are drained and cut into small pieces, approximately 1 - 2 cm in size. Plastic bottles, which will be used as fermentor tubes, are also washed with running water to eliminate any residue of soap or chemicals that could potentially damage the ecoenzyme product, and then left to dry. Moving on to the second step, the cleaned fruit peels of the five different types are weighed. In this experiment, to observe variations in aroma and color of the resulting ecoenzyme, these five organic waste materials (fruit peels) are divided into three variables, as presented in Table 1 below:

Table 1. Composition of Ecoenzym Production Materials

Variable	**Materials**	**Quantity**
V1	Pineapple rinds	200 grams
	Orange rinds	200 gram
	Mango rinds	200 gram
	Mangosteen rinds	100 gram
	Kepok banana rinds	100 gram
	Rambutan rinds	100 gram
	Sugarcane molasses	300 gram
	Mineral water	3 liter
V2	Mango rinds	120 gram
	Orange rinds	85 gram
	Pineapple rinds	165 gram
	Kepok banana rinds	30 gram
	Rambutan rinds	50 gram
	Sugarcane molasses	150 gram
	Mineral water	1,5 liter
V3	Pineapple rinds	150 gram
	Avocado rinds	100 gram
	Guava rinds	50 gram
	Water guava rinds	20 gram
	Kedondong rinds	30 gram
	Cucumber rinds	100 gram
	Sugarcane molasses	150 gram
	Mineral water	1,5 liter

Next step, the three cleaned fermentor tubes are labeled individually with the symbols V1 (Variable 1), V2 (Variable 2), and V3 (Variable 3). Mineral water, organic waste, and sugarcane molasses are then added into the fermentor tubes, with the composition ratio for each treatment being 1 part molasses: 3 parts fruit peels, and 10 parts mineral water (1:3:10). Afterward, the mixture is thoroughly stirred and tightly sealed. Stirring should be performed every week. In addition to weekly stirring, the drum lid is routinely opened three times a week to release by-products of fermentation. Wait and store the content for 3

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months in a dry and cool place, away from direct sunlight and protected from contaminants with strong odors, to ensure a complete fermentation process and the production of eco-enzymes. Upon completion of fermentation, the eco-enzymes are ready for harvesting. The matured Eco-Enzymes are characterized by a brownish color and possess a sour aroma. Store the fermented liquid in plastic or glass bottles, then securely seal the bottles. The leftover residue from the eco-enzyme production can be used as organic fertilizer, rich in nitrogen elements, beneficial for plants, and environmentally safe.

Results and Discussion

The following presents the data on the quality of eco-enzymes obtained in this research, specifically focusing on their physical characteristics. Physical quality refers to the state of an object based on observations made through the senses. The physical quality of the eco-enzyme product derived from fruit peel waste includes color and aroma. Color is determined through visual observation, while aroma is assessed through olfactory perception (Rijal et al., 2021).

a. Color

According to the literature, the fermentation of Ecoenzym can be considered successful if it produces a brownish-colored solution with an odor corresponding to the fruit used and a pH value below 4 or within the acidic range (Win, 2011). This aligns with the results of the conducted experiment, where all the colors of the Ecoenzym products underwent a change from the initial clear brown color (the original color of the sugarcane sap solution) to a murky brown color. Based on the observation results, it was found that the average color of the eco-enzyme from fruit peel waste is brown. For further clarity, refer to Table 2 below:

Table 2. Physical Quality (Color of Eco-Enzyme) from the used fruit peel waste.

Week	Color		
	Variabel 1 (V1)	**Variabel 2 (V2)**	**Variabel 3 (V3)**
2	Slightly clear brown	Slightly clear brown	Slightly clear brown
4	Light brown	Light brown	Light brown
6	Slightly turbid light brown	Slightly turbid light brown	Slightly turbid light brown
8	Turbid brown	Turbid brown	Slightly turbid light brown
10	Brownish-yellow	Dark brownish-black	Turbid brown
12	Brownish-yellow	Dark brownish-black	Brownish-yellow

Based on Table 2 above, it is evident that the color of the solution undergoes changes from the second to the tenth week in all three Variables - Variable 1 (V1), Variable 2 (V2), and Variable 3 (V3). During the initial fermentation in the second week, the eco-enzymes exhibit a slightly translucent brown color, across all Variables (V1, V2, and V3). However, at the end of the fermentation process in the twelfth week, the eco-enzyme product assumes a brown color. This observation aligns with Rivo Yulse Viza's research in 2022, which highlights the correlation between the color emitted by eco-enzymes and the fermentation process. An eco-enzyme is considered satisfactory when the resulting solution exhibits a brown color. At the conclusion of the fermentation process in the twelfth week, the eco-enzyme products obtained from all Variables exhibit different shades of brown. Specifically, Variables 1 (V1) and 3 (V3) display a brown color, while Variable 2 (V2) appears to have a darker brown hue. For a more detailed illustration, please refer to Figure 1 below:

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Image 1A. Ecoenzyme V1 Product.

Image 1B. Ecoenzyme V2 Product.

Image 1C. Ecoenzyme V3 Product.

The difference in color can occur due to variations in the chemical composition of the respective materials employed (Rijal *et al*., 2021). As known, the eco-enzyme products in Variable 1 (V1) consist of waste from pineapple rinds (*Ananas comosus*), sweet orange rinds (*Citrus sinensis*), mango rinds (Mangifera indica L.), mangosteen rinds (Garcinia angostana L.), kepok banana rinds (*Musa paradisiaca* Linn), and rambutan rinds (*Nephelium lappaceum* L.). In Ecoenzym Variable 2 (V2), the composition of fruit peel waste remains the same as in eco-enzyme V1, except for the absence of mangosteen peel waste (*Garcinia angostana* L.). On the other hand, eco-enzyme product Variable 3 (V3) comprises fruit peel waste, namely, pineapple rinds (*Ananas comosus*), avocado rinds (*Persea americana* Mill), guava rinds (Psidium guajava), water guava rinds (*Syzygium aqueum*), cucumber rinds (*Cucumis sativus*), and Kedondong rinds (*Spondias dulcis*).

b. Aroma

In addition to color, aroma is also a physical quality examined in this research. The aroma of ecoenzyme can originate from fermentation results, such as acidic aromas, and from the breakdown of the utilized substances. The following data presents the information concerning the ecoenzyme aroma obtained for each variable:

Table 3. Aroma of ecoenzyme products.

Variable	Before (0 week fermentation)	After (12 weeks of fermentation)
V1	Fresh fruit rinds aroma	Fresh and tangy aroma with more dominant sweet orange rinds aroma
V2	Fresh fruit rinds aroma	Fresh and tangy aroma with more dominant pineapple rinds aroma
V3	Fresh fruit rinds aroma	Fresh and tangy aroma with more dominant pineapple rinds aroma

Based on Table 3 above, it can be observed that the aroma of each variable exhibits acidity along with additional aromas corresponding to the dominant raw materials used. These aromas are derived from by-products produced by microorganisms during the fermentation process (Rijal *et al*., 2021). The results of this experiment align with previous research, where the acidic aroma in the ecoenzyme liquid originates from organic acids, such as acetic acid present in the ecoenzyme product (Larasati *et al*., 2020). Acetic acid typically imparts a sour taste and aroma to liquids or food items (Buckle, 2009).

Apart from the acidic aroma, each variant provides additional aromas specific to the dominant raw materials employed (Rijal *et al*., 2021). Ecoenzyme product Variable 1 (V1) exhibits a fresh acidic aroma, with a more pronounced scent of sweet orange peel. As known, one of the fundamental components of ecoenzyme raw material in Variable 1 (V1) is sweet orange peel (*Citrus sinensis*). According to Yustinah and Dena (2016),

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orange peel contains essential oils composed of various compounds, including terpenes, sesquiterpenes, aldehydes, esters, and sterols. Orange peel harbors varying compound compositions, contingent on the variety, leading to distinct aromas. However, limonene (C10H16), classified as a monoterpene, stands out as the dominant compound. The essential oil from sweet orange peel (*Citrus sinensis*) is characterized by its propensity to evaporate at room temperature, comprising several diverse compound components, and possessing the distinctive scent of oranges. Hence, the presence of the orange rinds aroma in ecoenzyme product Variable 1 (V1) is attributed to the influence of the essential oil compounds from sweet orange peel (*Citrus sinensis*).

Ecoenzyme products variable 2 (V2) and variable 3 (V3) possess a fresh acidic aroma along with a more dominant pineapple peel aroma. As we know, one of the main components of ecoenzyme in Variable 2 (V2) is pineapple peel waste (Ananas comosus). The acids present in pineapple fruit include citric acid, malic acid, and oxalic acid. The most dominant acid is citric acid, constituting 78% of the total acids (Irfandi, 2005). Arun and Sivashanmugam (2015) as well as Sambaraju and Lakshmi (2020) have reported that ecoenzyme fermentation can produce several important organic acids, such as acetic acid, lactic acid, malic acid, oxalic acid, and citric acid.

Compounds found in orange and pineapple peels are known to have phenolic and polyphenolic properties (Hanis, M., *et al*., 2017). These compounds disrupt the process of cell wall formation and organization, working by damaging the proteins present in bacterial cell walls, thereby disrupting the transportation between the exterior and interior of the cell, leading to cell death.

During ecoenzyme fermentation, the production of acetic acid is highly influenced by the types of bacteria involved in the fermentation process (Islami, 2022). However, to date, there have been limited studies on the microbiology of the bacteria types engaged in ecoenzyme fermentation. Acetic acid is an organic compound that contains a carboxylic acid group, it is colorless, pungent-smelling, and has a sharp acidic taste. It is soluble in water, alcohol, glycerol, and ether. Acetic acid is produced through fermentation. The fermentation process converts sucrose present in the fermentation solution into alcohol, which subsequently continues to transform into acetic acid (Pradnyandari *et al*., 2017). According to Nugrahani *et al* (2021), acetic acid is obtained through the fermentation process of carbohydrate-rich food materials such as fruits and vegetables.

Organic acids play a crucial role in determining acidity levels. This means that the higher the content of organic acids, the lower the pH value. Hence, the ecoenzyme in this research project possesses a low pH value due to its high content of organic acids, such as acetic acid or citric acid (Etienne, 2013). In the fermentation process, glucose is broken down into pyruvic acid. Under anaerobic conditions, pyruvic acid is degraded by Pyruvate decarboxylase into acetaldehyde, which is then converted to ethanol and carbon dioxide by Alcohol dehydrogenase. The bacterium Acetobacter converts alcohol into acetaldehyde and water, leading to the formation of acetic acid (Madigan, 2002). After a complete fermentation process, the ecoenzyme (dark brown liquid) is formed. Besides yielding the dark brown liquid, there is also a by-product in the form of residue that settles at the bottom, consisting of vegetable and fruit remains. This residue can be utilized as organic fertilizer.

Conclusions

The combination of fruit peel waste utilized as a raw material for eco-enzymes production significantly influences the color and aroma of the resulting eco-enzymes. The aroma of all eco-enzyme variants is characterized by a fresh acidic scent. Additionally, each variant provides additional aroma notes based on the dominant raw material used. Eco-enzyme product variable 1 (V1) exhibits a fresh acidic aroma, along with

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a more prominent aroma of sweet orange peel, displaying a brown color. Eco-enzyme products variable 2 (V2) and variable 3 (V3) both feature a fresh acidic aroma, accompanied by a dominant pineapple peel scent. The color of eco-enzyme product in variable 2 (V2) is a dark brown, while in variable 3 (V3), it appears brown. The observed differences in color can be attributed to variations in the chemical composition of each respective raw material employed.

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