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Evectiveness of Fruit Peel Eco-Enzyme in Reducing Biological Oxygen Demand (BOD) of Laundry Wastewater

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ABSTRACT

Household wastewater pollution caused by environmental contamination has become increasingly prevalent, especially with the excessive presence of organic materials, which come from detergents, soaps, and other chemicals. The current study seeks to investigate the efficiency of ecoenzyme made from different fruit peel mixtures in reducing BOD of laundry wastewater. Ecoenzyme was made by mixing different amounts of fruit peel wastes (2:1:10 to 6:1:10), palm sugar, and water, then fermenting it for 90 days. Analysis of the ecoenzyme was done using its sensory properties, which include acidity, and application to different concentrations of laundry wastewater to determine their BOD, pH, TDS, COD, color, and smell. Findings indicate that ecoenzyme had some favorable properties, such as an end-product having a pH of 3.6 to 4.0 with a unique acidic scent. Laundry wastewater had a BOD value of 65.78 mg/L before being treated by ecoenzyme, while it was reduced drastically to 10.6-16.3 mg/L. Maximum efficiency was obtained using a mixture ratio of 1:5 (eco-enzyme : wastewater). The results show that the fruit-based eco-enzyme has great promise as an environmentally-friendly and cost-effective technology for upgrading domestic wastewater treatment processes toward zero-waste principles.

Keyword: Ecoenzyme, Biological Oxygen Demand (BOD), Fermentation

1. INTRODUCTION

Environmental pollution associated with the domestic wastewaters has been growing as one of the key environmental problems, especially in relation to the high amount of organic pollution that comes from detergents, surfactants, and cleaning agents used at home. Laundry wastewater or grey water causes a high level of contamination of water bodies since it has a high content of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Dissolved Solids (TDS) that can lead to low concentrations of dissolved oxygen. Treatment of household wastewaters using conventional methods is expensive and hard to be conducted at a small scale, calling for alternative eco-friendly treatments of domestic wastewater. The utilization of eco-enzyme produced through organic waste fermentation represents a potentially viable solution to water pollution. The eco-enzyme is the fermented liquid that consists of organic acid, enzymes, and helpful microorganisms, and has proven its ability to degrade organic pollutants. Modern research has confirmed that the use of eco-enzyme in wastewater treatment can help to improve water quality and mitigate environmental pollution by means of sustainable waste management techniques. Moreover, the utilization of organic waste (fruit peels) is a part of the circular economy concept. A number of past studies have proven that

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the use of eco-enzymes may help to decrease pollutants in domestic wastewater. Yet, these past researches have been concentrated either on the fermentation process, the application of the product in general wastewater treatment, or the organoleptic properties of eco-enzymes. In addition, few studies have been conducted to investigate the effect of different composition ratios between eco-enzymes and wastewater in the reduction of BOD content in laundry wastewater. This study is aimed at assessing the effectiveness of eco-enzymes generated from a combination of fruit peel waste in lowering the BOD value of laundry wastewater. This study will also explore the variations in the parameters of COD, total dissolved solid (TDS), and pH in relation to varying compositions of treatment.

2. METHODS

Experimental Design

The research utilized an experimental laboratory method in determining the ability of fruit peel-derived eco-enzyme to reduce BOD content in laundry wastewater. Five sets of treatments with eco-enzyme to wastewater ratios of 1:1, 1:2, 1:3, 1:4, and 1:5 (v/v), respectively, and one set of untreated wastewater samples were used. This experiment was replicated three times to increase the validity of results obtained from the experiment.

Materials and Equipment

The main raw materials utilized in the production of eco-enzymes were fruit peels, such as pineapples (Ananas comosus), mangoes (Mangifera indica), bananas (Musa paradisiaca), limes (Citrus aurantifolia), watermelons (Citrullus lanatus), dragon fruits (Hylocereus undatus), and lemons (Citrus limon), sourced from domestic organic waste. The fermentation materials included organic palm sugar and clean water. Samples of laundry wastewater were derived from domestic laundry processes.The following equipment was employed during the course of this research: A digital scale, airtight fermentation vessels, glass incubation flasks, pH meter, total dissolved solids (TDS) meter, and dissolved oxygen (DO) meter for BOD testing.

Eco-Enzyme Production

The eco-enzyme was obtained through the fermentation process of a mixture of fruit peels, palm sugar, and water for 90 days under room temperature conditions in sealed jars. Five eco-enzymes were produced based on different combinations of fruit peels while keeping the sugar and water amounts constant. The recipes of the eco-enzymes are as follows:

Variant 1: 50 g fruit peels : 25 g palm sugar : 250 mL water (2:1:10)

Variant 2: 75 g fruit peels : 25 g palm sugar : 250 mL water (3:1:10)

Variant 3: 100 g fruit peels : 25 g palm sugar : 250 mL water (4:1:10)

Variant 4: 125 g fruit peels : 25 g palm sugar : 250 mL water (5:1:10)

Variant 5: 150 g fruit peels : 25 g palm sugar : 250 mL water (6:1:10)

After the fermentation process, the eco-enzyme was filtered to separate the liquid content from the solid contents.

Laundry Waste Water Treatment

The eco-enzyme ferment was added to laundry wastewater in proportion ratios of 1:1, 1:2, 1:3, 1:4, and 1:5 (v/v). There was a control that consisted of laundry waste water without any fermenting enzyme. All solutions were left for seven days before analysis.

1) **Preparation of Ecoenzyme and Fermentation Process**

The fruit peels were thoroughly cleaned and made ready for fermentation. Five different types of ecoenzyme preparation were prepared using fruit peels, palm sugar, and water in different proportions. They included the following:

Variation 1: 50 g fruit peels, 25 g palm sugar, and 250 mL water (2:1:10 ratio).

Variation 2: 75 g fruit peels, 25 g palm sugar, and 250 mL water (3:1:10 ratio).

Variation 3: 100 g fruit peels, 25 g palm sugar, and 250 mL water (4:1:10 ratio).

Variation 4: 125 g fruit peels, 25 g palm sugar, and 250 mL water (5:1:10 ratio).

• Variation 5: 150 g fruit peels, 25 g palm sugar, and 250 mL water (6:1:10 ratio).The mixtures were placed in airtight fermentation containers and stored at room temperature for 90 days. Following the fermentation period, the solutions were filtered using a fine mesh to separate the liquid ecoenzyme from the solid organic residue.

2) Wastewater Treatment and Incubation

The wastewater treatment with the fermented ecoenzymes involved the introduction of the ecoenzymes in varying volume ratios to the wastewater samples. Five ratio compositions were considered in this study for treating the wastewater samples, which include 1:1, 1:2, 1:3, 2:1, and 3:1 (ecoenzyme:wastewater). The treated samples were then subjected to an incubation period for 30 days in glass jars.

3) Analytical Methods

The organoleptic properties such as color, smell, and texture were analyzed qualitatively. The analysis of the pH, TDS, and COD was carried out following standard laboratory procedures. The BOD test involved the use of the Dissolved Oxygen (DO) method. The initial value of the dissolved oxygen content () was recorded at day zero. It was then tested again for five days incubation period (). The BOD was calculated using the formula . The percent decrease in BOD was calculated by comparing the initial values of the wastewater with those obtained after treatment using mathematical computations. The results were analyzed based on the Indonesian Government Regulation (Minister of Environment Regulation No. 5 of 2014) for wastewater standard

3. RESULT AND DISCUSSION

The fermentation of mixed fruit peels over a 90-day period resulted in a liquid with high-quality organoleptic properties, characterized by a clear brown to yellowish hue and a dominant fresh acidic aroma. The final pH values of the ecoenzymes stabilized within the range of 3.6 to 4.0. This acidity is a critical indicator of successful fermentation, where microorganisms such as *Saccharomyces cerevisiae* and *Acetobacter aceti* convert glucose from palm sugar and fruit peels into ethanol and subsequently into acetic acid. These metabolic byproducts are essential as they create an environment that inhibits harmful biological activity while providing the enzymatic tools necessary for organic degradation.

Picture 1. Fermentation Process

Characteristics of Eco-enzyme after Fermentation

The fermentation of mixed fruit peels for 90 days successfully produced eco-enzyme with stable organoleptic characteristics and acidic properties. The final products exhibited a yellowish-brown to dark-brown color accompanied by a dominant acidic aroma, indicating successful microbial fermentation. During the fermentation process, microorganisms such as *Saccharomyces cerevisiae* and *Acetobacter aceti* converted carbohydrates from palm sugar and fruit peels into alcohol and organic acids, particularly acetic acid. This process contributed to the acidic pH observed in all eco-enzyme samples.

Table 1.
Organoleptic Characteristics and pH of Eco-enzyme after Fermentation

Variable	Initial Aroma	Final Aroma	Initial Color	Final Color	Initial pH	Final pH
1	Fresh	Acidic, dominant pineapple aroma	Clear brown	Yellowish brown	8.5	3.875
2	Fresh	Acidic, dominant pineapple aroma	Clear brown	Yellowish brown	8.4	4.025
3	Fresh	Acidic, dominant pineapple and	Clear brown	Light brown	8.4	3.845

Variable	Initial Aroma	Final Aroma	Initial Color	Final Color	Initial pH	Final pH
		orange aroma				
4	Fresh	Acidic, dominant pineapple and orange aroma	Clear brown	Light brown	8.3	3.750
5	Fresh	Acidic, dominant pineapple and orange aroma	Clear brown	Dark brown	8.5	3.678

The data showed that all samples of eco-enzymes achieved an acidic pH range of 3.67-4.02 through fermentation. This was also observed by Galintin et al. (2021), as they noted that eco-enzyme fermentation usually yields acidic solutions because organic acids are produced through microbial reactions.

Removal of Pollutants Parameters in Laundry Effluent

The raw laundry effluent had high levels of pollutants, with high values of BOD, COD, and TDS. When the effluent was treated with eco-enzyme, there were reductions noted in all parameters, suggesting that eco-enzyme can be used to treat domestic effluent biologically.

Table 2.
Effect of Eco-enzyme Treatment on Laundry Wastewater Quality

Eco-enzyme : Wastewater Ratio (v/v)	BOD (mg/L)	TDS (mg/L)	COD (mg/L)
1:1	15.5	577	878
1:2	16.3	467	845
1:3	14.5	523	833
2:1	12.7	578	821
3:1	10.6	432	815

From the data above, it is evident that increasing the percentage of eco-enzyme had positive impacts on pollutant removal efficiency. The minimum concentration of BOD was recorded in the 3:1 ratio, which stood at 10.6 mg/L. In addition, the concentrations of COD and TDS were reduced compared to the initial conditions of the laundry wastewater.

The low concentration of BOD shows that organic pollutants were effectively broken down in the treatment process. Eco-enzyme includes organic acids, enzymes, and microbial metabolites that can enhance the decomposition of detergents, surfactants, and other organic pollutants. Low BOD suggests that less oxygen was required to break down the pollutants.

In addition, the fall in COD values is another piece of evidence that the amount of chemically oxidizable substances was minimized. It might be caused by enzymatic hydrolysis and microorganisms' degradation reactions. Moreover, the minimization in TDS is another indication that the number of dissolved particles and sediments in the sewage decreased after treatment.

Of all the treatment combinations, the one having the 3:1 ratio had the best results regarding the minimization of BOD, COD, and TDS. It implies that the presence of more eco-enzymes leads to enhanced enzymatic and microbial reactions, which improve the rate of degradation. The abundance of organic acids and hydrolytic enzymes might have facilitated the breakdown of organic matter.

The current results confirm those found by other researchers regarding the efficacy of eco-enzymes in wastewater treatment. For instance, Galintin et al. (2021) noted that eco-enzymes made from fruits help reduce the concentration of contaminants in the aquaculture sludge through microbial enzymes. Likewise, Widiyanto et al. (2015) argued that biological techniques for wastewater purification with organic substances are useful in enhancing the quality of domestic wastewater. The acidity noted in the current study is also in agreement with Natt et al. (2025), who stated that citrus bioenzymes play an effective role in facilitating bioremediation because they contain a lot of organic acids.

Graphical representation of the changes in BOD, COD, and TDS should be included in the next revision to enable proper presentation of the data.

Mechanisms for Organic Decomposition

The decrease in BOD, COD, and TDS levels could be attributed to both biological and chemical decomposition mechanisms involved in the process. Eco-enzyme fermentation results in production of a range of bioactive substances such as proteases, lipases, and amylases that aid in the decomposition of proteins, lipids, and carbohydrates contained in laundry water.

In addition, organic acids formed in the fermentation process aid in breaking down organic matter, facilitating its biological decomposition. Moreover, the positive effect could also have been caused by the utilization of organic substances in solution as sources of nutrition for beneficial microorganisms present in the eco-enzyme solution.

The creation of an acidic environment in eco-enzyme can serve to inhibit undesirable microbes while promoting decomposers, hence the improvement in water quality after the process.

4. CONCLUSION

From this experiment, it can be observed that eco-enzymes prepared from fruit peel waste have significant potential as treatment agents in laundry wastewater. As evident from the data collected, the addition of eco-enzyme led to the reduction of BOD, COD, and TDS values in all three variations. Among the compositions used, the 3:1 ratio of eco-enzyme to wastewater proved to be the most efficient, yielding the least BOD, COD, and TDS values.

Based on the results obtained, it can be hypothesized that the use of eco-enzymes is associated with the presence of organic acids, enzymes, and microorganisms' by-products during the fermentation process. Apart from reducing the concentration of the pollutants present, fruit peel waste also provides a sustainable method of managing waste products and upholding the zero-waste philosophy.

Despite its significance, the current study has certain shortcomings that cannot be overlooked. For instance, no statistical test was employed, and only one set of trials was conducted. Further research should include conducting triplicates, applying statistical tests like ANOVA, and comparing the results obtained with other conventional wastewater treatment techniques.

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