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Characteristics and Insecticidal Potential of Ecoenzymes Derived from Vegetable Waste and Various Sugars

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ABSTRACT

Vegetable waste is the second largest category of household organic waste, following grains. Its underutilization at the household level is an environmental concern, but it also has potential as a raw material for ecoenzyme synthesis. Ecoenzymes created by fermentation may be used as environmentally friendly alternatives to chemical pesticides. However, only a few research have investigated the effect of various sugar types on the insecticidal efficiency of ecoenzymes generated from vegetable waste. The goal of this study was to create ecoenzymes from vegetable waste and assess their insecticidal properties. Ecoenzymes were prepared using a 3:1:10 ratio of vegetable waste, sugar, and water. The vegetable waste comprised of cabbage, lemongrass, and red onion peels, while the sugars were molasses, brown sugar, and granulated sugar, resulting in nine different compositions. Fermentation lasted three months. Each 10% ecoenzyme solution was tested for insecticidal activity against *Crocidolomia pavonana* larvae in their second instar stage. All ecoenzyme formulations exhibited physical characteristics associated with successful fermentation, such as an acidic pH (3.1−3.6), dark brown coloration, and a strong sour fragrance. Bioassays revealed that ecoenzymes had insecticidal effects through larval mortality and feeding inhibition. The mixture with lemongrass and molasses had the highest mortality (66.67%) and strongest antifeedant effect. Variations in waste type and sugar supply have a substantial impact on ecoenzyme performance. The findings demonstrate that vegetable waste may be effectively transformed into ecoenzymes with insecticidal characteristics, indicating their potential for application in sustainable pest management.

Keywords: *Crocidolomia pavonana*, organic waste, plant-based pesticide, sustainable agriculture

INTRODUCTION

Average household food waste in Tanah Sareal District, Bogor City was 318 g/day, with vegetable waste coming in second after cereal waste at 54.4 g/household/day (Rahmaniya *et al.* 2025). However, domestic vegetable waste management remains inadequate. Vegetable waste could provide humus, macro- and micronutrients, and soil conditioning properties. Composting (Mulyanti *et al.* 2023) and ecoenzyme synthesis (Hermawan *et al.* 2023) are common methods for utilizing vegetable waste. Such actions help to advance zero-waste movement and reduce climate change.

Ecoenzymes produced from vegetable and fruit waste have been used to clean floors, glass, and other surfaces (Galintin *et al.* 2021). These ecoenzymes contain acetic acid and enzymes such lipase, trypsin, and amylase, which have disinfecting capabilities against pathogenic microbes (Vidalia *et al.* 2023). Tuhumury *et al.* (2024) found antimicrobial substances such as phenols, flavonoids, and tannins in ecoenzymes derived from banana peel waste. Similarly, ecoenzymes from papaya peel (*Carica papaya*), which contains papain, showed strong antibacterial action against *Enterococcus faecalis* (Bhardwaj *et al.* 2014). Ecoenzymes prepared from pineapple (*Ananas comosus*) and orange (*Citrus aurantium* L.) comprised high levels of polyphenols and flavonoids, as well as antibacterial and anti-inflammatory action. According to Gunwantrao *et al.* (2016), bromelain in pineapple kills *E. faecalis* by degrading its cell wall. A 1% concentration of ecoenzyme was demonstrated to increase mortality in *Spodoptera litura* larvae by up to 40%, most likely due to the presence of flavonoids, saponins, and alkaloids (Megasari *et al.* 2025). Ecoenzymes contain nitrate (NO_3) and carbonate (CO_3), which can improve soil fertility and agricultural yield without causing pollution (Benny *et al.* 2023).

In Indonesia, ecoenzyme synthesis research has primarily focused on differences in organic waste content. However, studies into the influence of different sugar types utilized in fermentation are relatively restricted, particularly in terms of ecoenzyme efficacy as a botanical insecticide. Based on these factors, the

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goal of this study was to create ecoenzymes from vegetable waste using various types of sugar and assess their potential as botanical insecticides. The vegetable waste used were cabbage, lemongrass, and red onion peels mixed with various sugar kinds to test their insecticidal properties.

METHODS

Ecoenzyme Production

This study used Dr. Rosukon Poompanvong's approach for producing ecoenzyme. The ingredient ratio was 3:1:10, with three parts vegetable waste, one part sugar, and ten parts water (Lubis & Wasito 2023). The formulation design employed in ecoenzyme manufacturing is shown in Table 1. In total, nine distinct ingredient combinations were evaluated. The combinations were matured for three months, then stirred or opened once a month.

Physical Characterization of Ecoenzyme

Physical characterization was carried out by measuring temperature with a digital immersion thermometer and pH using a pH meter. In addition, the color and odor of the ecoenzyme were recorded. A brownish color, a distinctive acidic fermentation odor, and a constant temperature were all indicators of successful fermentation (Sutrisnawati *et al.* 2022).

Ecoenzyme Bioassay as an Insecticide

Each ecoenzyme variant was tested for insecticidal activity. The cabbage cluster caterpillar (*C. pavonana*) was employed as the test insect. The nine pre-prepared ecoenzyme formulations were used at a 10% concentration. Maryanti *et al.* (2024) detailed the procedure used in the bioassay. Observations were carried out on 24, 48, and 72 h after application. The number of dead larvae was recorded, and the larval mortality rate was estimated using the method from Permadi *et al.* (2018):

$$\text{Larval mortality (\%)} = \left(\frac{\text{Number of dead larvae}}{\text{Number of total larvae}}\right) \times 100\%$$

Experimental Design and Data Analysis

The experiment to determine the effect of ecoenzyme treatments on *C. pavonana* used a completely randomized design (CRD). The study comprised of nine treatments, each with 10 test larvae and reproduced three times, for a total of 27 experimental units. The collected data was tabulated in Microsoft Excel 2016 and then processed with RStudio software. The data were analyzed using the analysis of variance (ANOVA) and *F*-test functions. If a significant effect was found, Duncan's Multiple Range Test (DMRT) was applied at a 95% confidence level (Górecki & Smaga 2019).

RESULTS AND DISCUSSION

Characteristics of Ecoenzymes

The production of ecoenzymes is fundamentally reliant on fermentation. Stable ambient temperature, acidic pH, a strong acidic scent, and brownish color are all indicators of effective ecoenzyme fermentation (Table 2, Figure 1). pH assays revealed that all ecoenzymes derived from cabbage, lemongrass, and red onion skins were very acidic, with pH values ranging from 3.1 to 3.6. According to Islami (2022), ecoenzymes often have high quantities of acetic acid after 100 d of fermentation and a pH of around 3.5. After three months of fermentation, the ecoenzymes obtained a brown to dark brown color (Figure 2). Through organoleptic examination, Larasati *et al.* (2020) discovered that ecoenzymes have a strong to extremely strong acidic fragrance and dark brown color.

Insecticidal Effects of Ecoenzymes

The insecticidal bioassay was carried out on second-instar cabbage cluster caterpillar larvae (*C. pavonana*). The results showed that ecoenzymes produced from vegetable waste had insecticidal and antifeedant capabilities. The treatments containing lemongrass fermented with molasses (Smo) and red onion peel fermented with brown sugar (BmGm) had the highest larval death rate (66.67%). The high content of organic acids in ecoenzymes, notably lactic and acetic acids, is thought to be associated with larval

Table 1 Composition of ingredients for ecoenzyme production

Type of waste	Type of sugar	Treatment code
Cabbage peel	Brown sugar	KGm
	Molasses	KMo
	Granulated sugar	KGp
Lemongrass leaves	Brown sugar	SGm
	Molasses	SMo
	Granulated sugar	SGp
Red onion skins	Brown sugar	BGm
	Molasses	BMo
	Granulated sugar	BGp

Table 2 Comparison of pH and temperature between initial and final conditions of ecoenzyme fermentation

Treatment	Initial measurement		Final measurement	
	pH	Temp (°C)	pH	Temp (°C)
KGm	5.4	26.1	3.2	29.3
KGp	7.0	25.8	3.2	29.5
KMo	4.7	26.1	3.5	29.5
SGm	5.4	25.8	3.4	28.5
SGp	6.6	26.6	3.2	27.9
SMo	4.7	25.6	3.5	27.1
BGm	5.5	25.8	3.3	28.6
BGp	6.8	26.7	3.1	28.3
BMo	4.7	26.1	3.6	28.8

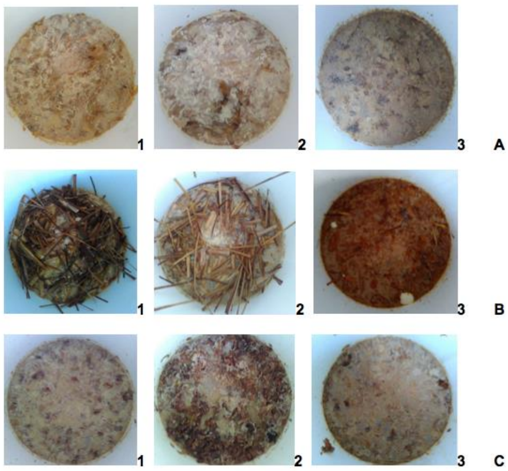

Figure 1 Ecoenzyme appearance after three months of fermentation prior to filtration. (A = cabbage waste, B = lemongrass waste, C = red onion skin waste; 1 = brown sugar, 2 = granulated sugar, and 3 = molasses).

Figure 2 Appearance of the ecoenzyme after filtration, showing brown to dark brown coloration.

mortality. Mursyid *et al.* (2022) obtained similar results, demonstrating that both lactic and acetic acids can cause mite mortality. Islami (2022) also discovered that ecoenzymes derived from *Citrus hystrix* had acetic acid concentrations ranging from 3.32 to 5.53%. Acetic acid is renowned for its corrosive qualities, which destroy insect cuticle structures and eventually lead to death (Hastuti *et al.* 2019). Lactic acid, at high quantities, can also impair larval development and cause death (He *et al.* 2021). In addition to organic acids, ecoenzymes contain saponins, flavonoids, and tannins, which may contribute to insect death (Salsabila *et al.* 2024).

The amount of uneaten feed provided evidence of the antifeedant effect. Among all treatments, the ecoenzyme produced from lemongrass fermented with molasses (Smo) showed the greatest feeding deterrence (Table 3). This antifeedant activity refers to the capacity of certain chemicals to deter insect herbivory. According to Megasari *et al.* (2015), feeding deterrence can keep insects from eating plant material, resulting in mortality. This impact could be attributable to substances including saponins, flavonoids, and tannins. Saponins have an indirect effect on insect gut microbiota and can create strong interactions with digesting enzymes, causing gut mucosa injury (Qasim *et al.* 2020). Flavonoids serve multiple functions as insecticides, including acting as antifeedants, interrupting detoxification pathways, interfering with development and reproduction, and influencing the neurological system (Pereira *et al.* 2024). Tannins, according to Ainiyah *et al.* (2023), can bind to digesting proteins, reducing protein absorption and inhibiting development.

The feeding deterrence effect was strongly influenced by both the type of waste and the type of sugar used (Table 4), with the waste type having the greatest impact. According to Natsir *et al.* (2024), the type of sugar used influences the quality of the ecoenzyme produced. However, additional research is needed to correctly quantify the active ingredient amount across the various formulations.

CONCLUSION

This study concluded that ecoenzymes can be made from vegetable wastes such as red onion peels, cabbage, and lemongrass by combining molasses, granulated sugar, and brown sugar. The resulting ecoenzymes had insecticidal properties, causing mortality in *C. pavonana* larvae and reducing their feeding activity. The most effective formulation was the ecoenzyme derived from lemongrass fermented with molasses, which resulted in the highest larval mortality and the greatest feed reduction. More study is needed to determine the active ingredient content in each treatment formulation.

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Table 3 Effect of ecoenzyme treatments on mortality and feeding activity of *C. pavonana*

Treatment code	Mortality (%)	Mean residual feed (g)
KGm	44.44	0.88 cde
Kmo	44.44	0.93 cde
KGp	55.56	0.63 e
SGm	22.22	1.59 ab
SMo	66.67	1.93 a
SGp	44.44	1.28 bc
BGm	66.67	1.31 bc
BMo	44.44	1.25 bcd
BGp	55.56	0.72 de

Remarks: Numbers followed by the same letter within the same column are not significantly different according to Duncan's test at the 95% confidence level.

Table 4 Analysis of variance (ANOVA) of the effect of ecoenzyme treatments on feeding activity

	df	Sum sq.	Mean sq.	*F* value	*Pr>F*	Sig.
Type of waste	2	2.8703	1.4351	17.136	6.8105e-05	***
Type of sugar	2	1.2011	0.6005	7.171	0.0051	**
Waste:sugar	4	0.2079	0.0520	0.621	0.6536	
Residual	18	1.5075	0.0837			

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