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Insect-Assisted Biodegradation of Waste Plastics for Enhancing Sustainable Development Goals

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Abstract. The increasing use of plastic materials in daily life has led to a rise in plastic waste, contributing significantly to environmental pollution. This study aims to analyze the characteristics of insects that contribute to the eco-friendly degradation of plastic waste and to evaluate the rate of plastic waste degradation and the waste reduction index (WRI) achieved through insect larvae. The research uses a Randomized Factorial Design, investigating plastics such as styrofoam blocks, low-density polyethylene, polyurethane, polystyrene, and a control. The parameters examined include insect characteristics, larval length and weight, degradation rate, and WRI. Both *Zophobas atratus* and *Tenebrio molitor* exhibit the potential for the bioconversion of plastic waste. The weight of *T. molitor* larvae ranges from 0.07-0.09g, while *Z. atratus* larvae weigh between 0.51 and 0.60g. The WRI is directly proportional to the reduction rate, with higher reduction rates corresponding to higher WRI values. The results showed that the control using *Z. atratus* and *T. molitor* larvae achieved the highest WRI values among all treatments. Among the plastic types studied, styrofoam blocks showed the highest WRI value, indicating that a feeding rate of 1g of plastic per larva per day is optimal for efficiently reducing plastic waste. This supports circular economy initiatives for companies developing insect-based proteins for food, feed, and natural products while advancing sustainable development goals.

Keywords: Bioconversion; plastic waste; *Tenebrio molitor*; *Zophobas atratus*

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INTRODUCTION

Plastic products are an integral part of human life and are estimated to continue with economic and population growth. Plastic is considered a more accessible, durable, lighter, and cheaper material for various purposes, making it a preferred choice for many people to meet their needs in everyday life, such as medical, household, packaging, etc (Borremans et al., 2020). This has caused the production and consumption of plastics have increase. Consequently, the volumes of post-consumer plastic waste are steadily on the increase in the environment. Based on the report of the Indonesia National Plastic Action Partnership (NPAP) shows that Indonesia generates 6.8 million tons of plastic waste each year, this production figure is growing by 5% annually and around 4.8 million tons (70%) of all plastic waste in Indonesia are not managed. Without policy interventions, effective plastic use, and waste management, plastic waste will pose a danger to the global economy, humans, animals, and the environment (NPAP, 2020).

According to data from the National Waste Management Information System for 2020, daily waste generation in Cirebon Regency is 1308.06 tonnes, totalling 477,442.72 tonnes annually (https://sipsn.menlhk.go.id.) However, the waste managed by the Cirebon Regency Regional

Government is only 89 tons per day (7.4% handling), with community-based efforts like waste banks reducing an additional 18 tons per day (1.5% reduction). Much of the waste management in the Cirebon area follows conventional methods, including collection, transportation, and disposal, often through open dumping in landfills, which has adverse environmental effects such as unsightly landscapes, unpleasant odors, and public health risks. Transitioning to a zero-waste waste management system, including its development, measurement, and implementation, which aims to eliminate waste production during processing, could mitigate these issues (Wikurendra et al., 2023). Another viable approach involves bioconversion processes, where insects convert waste into biomass and organic residues. This method offers simplicity, and low energy requirements, and yields insect biomass rich in carbohydrates, proteins, and fatty acids, suitable for various industrial applications.

Innovative waste management solutions are crucial to address the growing waste crisis. One such innovation is the sustainable processing of insect-based organic and inorganic waste in an eco-friendly manner. The insect-based zero-waste approach aims to prevent waste from entering the environment while fostering economic regeneration towards greater sustainability, aligning with the 2030 Sustainable Development Goals (SDGs) such as SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). This will reinforce the significance of the research within a broader sustainability framework. Approximately 85% of the insect population plays a vital role in nature, with various species bio-converting organic waste into significant amounts of protein and fat for use as animal feed and biofuel (Surendra et al., 2016). Insects, known for their high tolerance for crude fiber, can efficiently utilize low-cost, high-fiber feed ingredients, making them economically viable.

Biological approaches to microplastic remediation involve the use of living organisms, such as microorganisms, algae, and insects, through processes like bioaccumulation, bioaugmentation, and biodegradation (Goveas et al., 2023). However, not all insects can effectively break down plastic waste into harmless biomass, differences in their morphology and structural features play an essential role in the effectiveness of plastic remediation. Certain insect species excel at waste management and nitrogen conversion, contributing to economic circulation without waste production. For instance, termite (*Macrotermes gilvus*), cockroaches (*Periplaneta americana*) efficiently clean organic waste, while black soldier fly larvae (*Hermetia illucens*) biodegrade food and plastic waste, offering biofuel potential (Dhir et al., 2020; Nguyen et al., 2015; Singh & Kumari, 2019; Subekti & Wulandari, 2022). *Hermetia illucens* larvae, in particular, demonstrate significant potential in degrading various organic materials, surpassing other insects in effectiveness. They can degrade animal and plant-based organic waste, including feces, meat, fruit, and restaurant waste, reducing waste contamination by pathogens like *Escherichia coli*. Additionally, microorganisms present in certain insect species, such as *P. aeruginosa* in *Zophobas atratus* L., enhance their ability to degrade plastic waste, notably polystyrene (PS) and polyphenylene sulfide (PPS) (Lalander, 2018).

Mealworm insect larvae are highly suitable for waste processing due to their voracious appetite, resilience to harsh environmental conditions, and rapid weight gain. They are omnivorous and can digest materials not commonly found in their natural diet, including polyethylene, polystyrene, and cellulose waste, addressing the global plastic pollution crisis (Nukmal et al., 2018; Vigneron et al., 2019; Yang et al., 2018). These insights underscore the potential of insects in waste bioconversion, offering an effective strategy to combat plastic pollution and promote sustainable waste processing, ultimately benefiting communities. Considering the ongoing need for innovative zero-waste management solutions, this study aimed to explore Insecta with the potential for eco-friendly bioconversion of plastic waste and analyze the degradation rates of various plastic types used in the Cirebon, West Java community, along with the plastic waste reduction index using Insecta larvae. This research may help identify promising species for companies developing insect-based proteins for food, feed, and natural products, contributing to circular bioeconomy strategies and advancing sustainable development goals.

METHODS

The materials used in this study comprised yellow mealworm larvae and superworm larvae obtained from the population kept in an insect breeder in Majalengka, West Java. All larvae were kept at a temperature of 26-28°C and acclimatized in the Zoology laboratory for 7 days. Larvae used this research with feeding material made of various test plastics: Styrofoam block (SB), Low-density polyethylene (LDPE), Polyurethane (PU), and Polystyrene (PS). A control treatment consisted of concentrate feed. Other necessary materials included millimeter blocks for measuring larval length, digital scales accurate to 0.001g for weighing larval body weight, cooking oil and dexter to deter ants, sample containers, and label paper (1.1 x 3 cm) for treatment identification. Data collection equipment encompassed microscopes, cameras, and writing instruments.

Characterization and Identification of Insects
Morphological Characterization

Insect specimens were identified to the species level using the morphospecies method, which distinguishes species based on morphological characters. Identified insects were then cross-referenced with an insect identification key (Dunford et al., 2005).

Molecular Characterization

In addition to morphological characterization, the insects collected were characterized molecularly. DNA was extracted using a non-destructive method by separating the beetle's head and body and then placing them into a sterile microtube. QIAGEN Blood and Tissue Extraction Mini Kit was used for the elution process. The target gene segment was amplified using a Polymerase Chain Reaction (PCR) machine, with the mixture consisting of MyTaq Red Mix (Bioline), forward primer, reverse primer, DNA template, Nuclease-Free Water and DNA. Amplification of the mitochondria CO1 fragment using universal forward primer LCO1490 (5'-GGTCAACAAATCATAAAGAATTGG-3') and reverse primer HCO2198 (5'-TAAACTTCAGGGTGACCAAAAAAT CA-3'), with an initial 95°C for 3 minutes, then 40 cycles of denaturation at 95°C for 50s, 50°C for 1 minute 10s, 72°C for 1 minute and final extension at 72°C for 10 minutes. To determine the fragmentation level of the PCR product, electrophoresis was on 2% agarose for 25 minutes. Sequencing data were analyzed using Geneious Prime software for nucleotide sequence reading and alignment. Then the alignment data were then compared with GenBank data at NCBI (National Center for Biotechnology Information) using BLAST (Basic Local Alignment Search Tool).

Testing Insects as Bioconversion of Plastic Waste
Insect Larvae Incubation Preparation Stage

The research began with the preparation of the rearing site. Shelves were prepared for plastic containers, each equipped with a plastic container filled with cooking oil at the bottom to deter ants from disturbing the larvae. Fifty individual plastic containers were prepared for each type of larval treatment. The rearing area was adjusted to the optimal growth temperature for larvae, namely 25°C to 30°C (Park et al., 2023).

Preparation Stage for Testing Plastic Waste

The plastic types used were Styrofoam block (SB), Low-density polyethylene (LDPE), Polyurethane (PU), and Polystyrene (PS). The test plastics were cut into small pieces and each piece was weighed at 1 gram using an analytical balance with an accuracy of 0.001g (Yang et al., 2020 with modification).

Research Treatment Phase

Mealworm larvae were prepared, their length was measured, and initial body weight was recorded before placing them in plastic containers. Next, feed treatments were administered, including Styrofoam block (SB), Low-density polyethylene (LDPE), Polyurethane (PU), Polystyrene (PS), and concentrate feed as a control treatment. Each feed was weighed at 1 g and given to each larval treatment containing 50 individuals. The plastic containers housing 50 larvae and the feed treatments were covered with gauze. The remaining feed in all treatments was checked every 3 days. When the feed ran out, 1 g of feed was added to both treatment and control containers. The total feed added to each treatment varied depending on consumption. Length and body weight measurements of all larvae in each treatment were taken every 3 days over a 21-day period (Yang et al., 2018).

Data Analysis

Data was analyzed using a one-way ANOVA test at a significant rate of 0.05, followed by the Duncan test for the post hoc test. The analysis of the plastic waste degradation rate and the identification of the plastic type undergoing the most rapid degradation were determined based on the reduction levels observed for each type of plastic waste. The reduction in plastic waste by larvae is influenced by two factors: the degradation rate and the time required for degradation (Das & Kumar, 2015; Diener et al., 2011). The degradation level was assessed by calculating the difference between the initial weight and the final weight of the plastic. The Waste Reduction Index (WRI) by larvae was calculated using the following equation Diener et al. (2009) which is estimated based on the quantity of diet supplied during the experiment and the leftover residue collected afterward.

$$\mathrm{D} = \frac{\mathrm{W} - \mathrm{R}}{\mathrm{W}}$$

$$\mathrm{WRI} = \frac{\mathrm{D} \times 100}{\mathrm{t}}$$

Where *W* is the initial weight of plastic waste (g); *R* is the final weight of plastic waste (g); *t* is the time required to degrade waste or the number of days that the larvae were fed the experimental diet; *D* is the waste degradation rate; *WRI* is the Waste Reduction Index. A high WRI values indicate good reduction efficiency by larvae.

RESULTS AND DISCUSSION

Morphological and Molecular Identification of Insect Larvae

The initial stage of species identification through observation can be conducted using the morphological method, while molecular identification is employed to enhance accuracy and support the results of morphological identification. Initially, we separated the specimens into two distinct morphospecies. Using an identification key, we identified the first morphospecies as *Zophobas atratus* Fabricius, 1775 and as *Tenebrio molitor* Linnaeus, 1758. The *Zophobas atratus* larvae have a cylindrical body with short legs, two rudimentary hind prolegs, and 13 segments with yellow-brown rings at the joints. They also display a dark spot on their head and dark stripes near the tip of their tail. While the morphological characteristics of *Tenebrio molitor* larvae are cylindrical, have three pairs of legs on the thoracic segment and two additional organs such as horns at the end of the abdomen, the young larvae are white and the color will darken as the larvae age.

Researchers have observed that insects, particularly those from the Coleopteran and Lepidopteran orders, can penetrate and consume plastics. In Lepidopteran larvae, the masticatory system composed of a pair of jaws becomes atrophied in adulthood. Additionally, these larvae possess a functional chewing apparatus (Pivato et al., 2022). Besides *Zophobas atratus* and *Tenebrio molitor*, several insects have shown the ability to break down waste plastics such as the Coleoptera order: *Tenebrio obscurus* (Peng et al., 2019), *Rhyzopertha dominica*, *Sitophilus oryzae*, *Lasioderma serricorne*, *Tribolium castaneum* (Wang et al., 2020), *Alphitobius diaperinus* (Cucini et al., 2020), *Plesiophthalmus davidis* (Woo et al., 2020), the Lepidoptera order: *Achroia grisella* (Kundungal et al., 2019), *Plodia interpunctella*, *Galleria mellonella* (Boschi et al., 2024), *Corcyra cephalonica* (Kesti & Thimmappa, 2019) and *Spodoptera frugiperda* (Zhang et al., 2022). Insect plastivores facilitate biological remediation by utilizing natural microbes and enzymes within their gut to digest plastic. Natural microbes could significantly aid in catalyzing the plastic degradation process. Additionally, much of this research relies on genomic analysis of the 16S gene to identify shifts in the microbiome of larvae exposed to various diets.

We further validated the identifications by analyzing their cytochrome oxidase subunit I (Cox1) gene of each species (Table 1). Based on molecular analysis through DNA barcoding using the CoxI gene and phylogenetic comparison with the NCBI GenBank database, the inference of the neighbor-joining phylogenetic tree using the p-distance method from the four sequences shows a clear delineation of two types, each grouped into its respective clade. The intraspecific distance within each type is nearly identical, while the interspecific distance between types is approximately 20%, indicating a strong genus-level difference. Furthermore, BLAST analysis shows that the sequences of the two mealworm types have an average percentage identity of >99%, confirming their identification as *Zophobas atratus* and *Tenebrio molitor* (Figure 1).

Table 1. NCBI accession number of cox1 gene from *Zophobas atratus* and *Tenebrio molitor*

Species	Accession number
Zophobas atratus	PP946841, PP946842
Tenebrio molitor	PP946839, PP946840

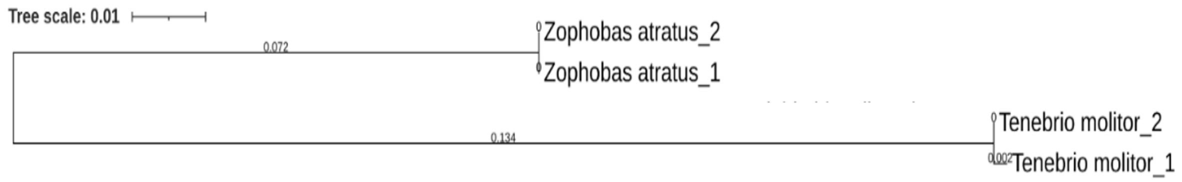
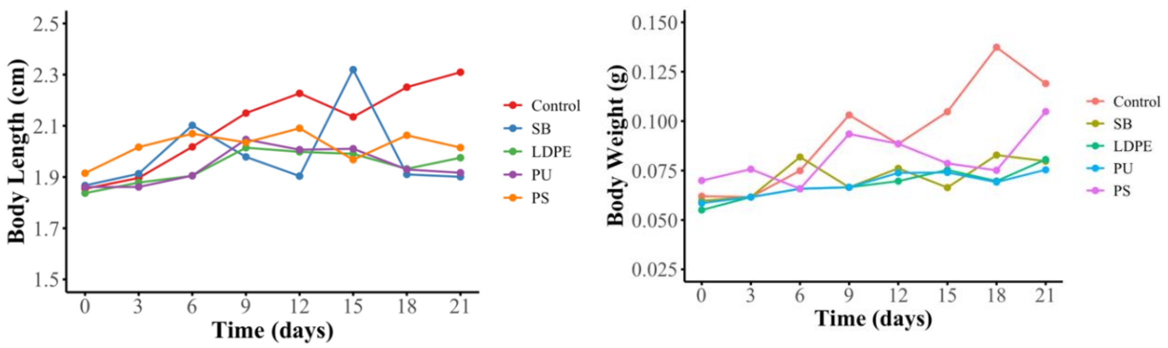


Figure 1. Neighbor-Joining phylogenetic tree of two mealworm types in the family Tenebrionidae

Growth and Development of Insect Larvae

Tenebrio molitor larvae

The length measurement of *T. molitor* larvae revealed that the highest average length was observed in the control group (2.11±0.17 cm) and the PS plastic group (2.02 ± 0.06 cm), while the lowest was recorded in the LDPE group (1.94 ± 0.06 cm) (Figure.2). The control treatment, utilizing concentrate feed, yielded the longest larvae, followed by those fed PS plastic. However, both the control and PS plastic groups experienced some larval mortality. Additionally, individual larval length during the study influenced the average length in these groups. To prevent larval stacking and limit movement restriction, the deceased larvae in the control and PS plastic groups were not piled up in the maintenance containers. Conversely, the LDPE plastic feed resulted in the lowest average length. This outcome may be attributed to larval mortality, which was notably higher in the LDPE treatment due to excessive plastic accumulation in the containers. The accumulation of plastic led to increased larval population density, resulting in limited space for movement. Densely packed feed spaces restrict larval movement, intensifying competition for space among the caterpillars. In addition to length, another variable assessed in this study was the increase in body weight. Measurements of *T. molitor* larvae body weight across the four types of plastic and the control revealed that the control treatment (0.09 ± 0.03 g), as well as PS (0.08 ± 0.01 g), SB, PU, and LPDE, exhibited a consistent weight of 0.07 ± 0.01 g (Figure 2). This research indicates that the heaviest average body weight was observed in larvae provided with concentrate feed (control), as it contains carbohydrates utilized for energy metabolism.



(A) (B)

Figure 2. Result of average increase in body length (A) and body weight (B) of *Tenebrio molitor* larvae. Styrofoam block (SB); Polystyrene (PS); Polyurethane (PU); Low-density Polyethylene (LPDE)

Zophobas atratus larvae

Length measurements of *Zophobas atratus* mealworm larvae were obtained from four types of plastic treatment and the control. The average larval body length revealed the highest values in the control (4.08 ± 0.21 cm) and SB plastic (4.08 ± 0.19 cm), and the lowest in PU (3.98 ± 0.23 cm) (Figure 3). The control feed showed the highest average length increase compared to other feeds. This can be attributed to the use of a commonly used concentrate feed, which promotes better survival rates with fewer larvae dying during the research. Additionally, the physiological condition of the larvae influences growth and reproduction. The results also indicated that the Styrofoam block treatment had the highest average length. This may be due to the lower density of polystyrene plastic used in the styrofoam block in this study. In addition to length, another variable assessed in this study was the increase in body weight. Measurement of *Zophobas atratus* larvae body weight across the four types of plastic and the control revealed that the control treatment (0.60 ± 0.08 g), LPDE (0.56±0.06 g), SB and PU (0.54 ± 0.04 g), showed similar values, while PS (0.51±0.06g) (Figure. 3) exhibited slightly lower weight. This research suggests that the heaviest average body weight was observed in larvae provided with concentrate feed (control), as it contains carbohydrates utilized for energy metabolism.

Based on the observation show that concentrate feeding (control) yielded the highest average body length for each type of insect larvae compared to other feedings because concentrate contains protein, fat, crude fiber, carbohydrates, antioxidants, vitamins, carotenoids and minerals essential such as calcium, iron, or zinc for larval development and growth (Oonincx & Finke, 2021). This likely explains why larvae fed with concentrate and Styrofoam blocks tended to live longer due to the ingestion of plastic residues. The food present in the larvae's intestines influences larval body size. A wider space for larvae to move reduces competition among individuals, resulting in fewer larval deaths. The styrofoam block feed, characterized by thicker and denser plastic, also led to a few dead larvae, but excess food was not piled up in the rearing container, thus avoiding movement restriction for larvae. The starch material frequently used as a raw material for biodegradable plastics in Indonesia is cassava. Cassava starch contains water, starch, fiber, protein, and other components such as minerals, fats, and sugars, which contribute to larval growth and development (Kundungal et al., 2019). Larvae fed with this plastic may receive more nutrition, promoting their growth and development. Research suggests that differences in larval growth may result from variations in nutritional value in the feed (Yang et al., 2018). Overall, both *T. molitor* and *Z. atratus* larvae showed fluctuating changes in average body weight over time, but by the study's end, the average body weight had increased. Decreases in body weight may occur during the molting phases when larval feed consumption decreases, but weight typically increases after molting. The growth pattern of *Tenebrionidae* family caterpillars prioritizes increasing length in early instars and increasing body weight in later instars (Kaleka et al., 2019). Molting frequency in insects is influenced by temperature, food quality, and quantity. Disruptions in metabolic processes may occur if insects experience deficiencies in certain nutrients in their feed. Molting is regulated by three hormones: Protoasicotropic Hormone (PTTH), juvenile hormone, and ecdysone hormone. The absence of juvenile hormone triggers larvae to enter the pupal stage (Truman, 2019).

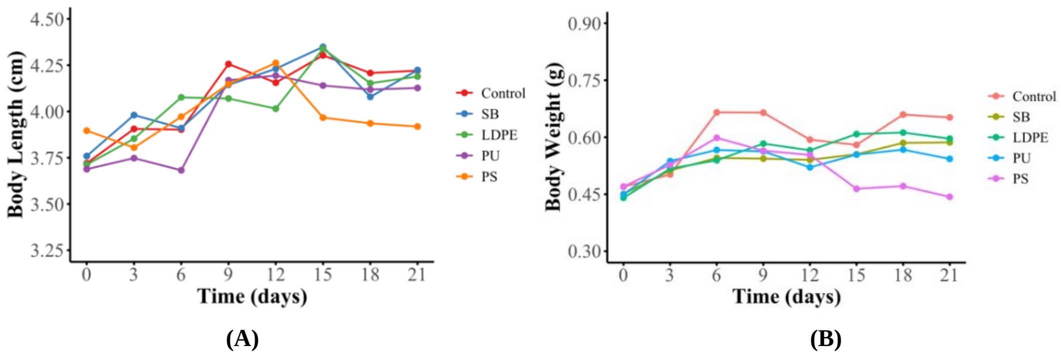


Figure 3. Result of average increase in body length (A) and body weight (B) of *Zophobas atratus* larvae. Styrofoam block (SB); Polystyrene (PS); Polyurethane (PU); Low-density Polyethylene (LPDE)

The control treatment exhibited the highest value, as concentrate is the typical feed used during rearing, a practice observed in both *Tenebrio molitor* and *Zophobas atratus*. As for the feed treatment on the various types of plastic, styrofoam block feed has a higher value than LDPE, polyurethane, and polystyrene feed. The choice of plastic affects degradation rates, with lower-density plastics degrading at a higher rate and vice versa. The consumption of styrofoam block plastic by *T. molitor* and *Z. atratus* larvae is more influenced by plastic density than molecular weight (Yang et al., 2018). Density correlates with product hardness, influencing the plastic's digestibility; lower-density plastics are easier to digest. For instance, styrofoam block has a density of 0.05 g/cm^3, while LDPE ranges from 0.912 to 0.925 g/cm^3 and HDPE from 0.94 to 0.965 g/cm^3 (Andreev et al., 2020).

Degradation Rate of Plastic Waste Using Various Types of Insects

The degradation rate values for *T. molitor* obtained from the four types of plastic and the control showed the highest to lowest results in sequence, namely, control (0.49), SB (0.23), PU (0.18), PS (0.14) and LDPE (0.06), while *Z. atratus* showed the highest to lowest degradation rates in sequence, namely control (0.65), SB (0.44), LDPE (0.33), PU (0.17) and PS (0.15) (Figure.4). In addition to the degradation rate, the Waste Reduction Index (WRI) value was also calculated. For *T. molitor* larvae, the highest WRI was observed in the control (2.33%), and the lowest in PS (0.65%). In *Z. atratus* larvae, the highest WRI was found in the control (3.10%), while the lowest was in PS (0.73%) (Figure. 5) that was observed for the 21st days (Figure.6). The WRI value is directly proportional to the reduction value (degradation rate), a higher reduction value corresponds to a higher WRI value. Consequently, a high WRI value indicates a larvae's enhanced ability to reduce food waste.

Before insect larvae can effectively degrade plastics, the breakdown of various types (SB, PS, PU, and LDPE) is significantly influenced by abiotic factors such as weather, heat, humidity, and UV radiation. These environmental conditions facilitate the subsequent degradation of plastics by microbes and enzymes when introduced into insect diets (Siddiqui et al., 2024). For example, plastics that have been weathered through prolonged exposure to high temperatures and ultraviolet light degrade faster than newly manufactured counterparts of the same type. Additionally, studies by Du et al. (2021) have shown that insect exposure to various plastics induces significant structural changes, such as cracks and holes, which result in reduced molecular weight and altered morphology. The ability of insect larvae to degrade plastics suggests that the enzymatic systems they use to break down plant-based and resilient polymers could also be adapted for the degradation of synthetic polymers (Al-Tohamy et al., 2023).

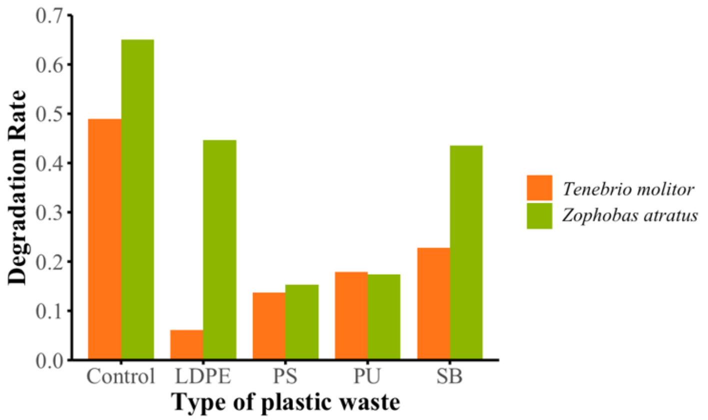


Figure 4. The rate of degradation of types of plastic waste using insect larvae. Styrofoam block (SB); Polystyrene (PS); Polyurethane (PU); Low-density Polyethylene (LPDE)

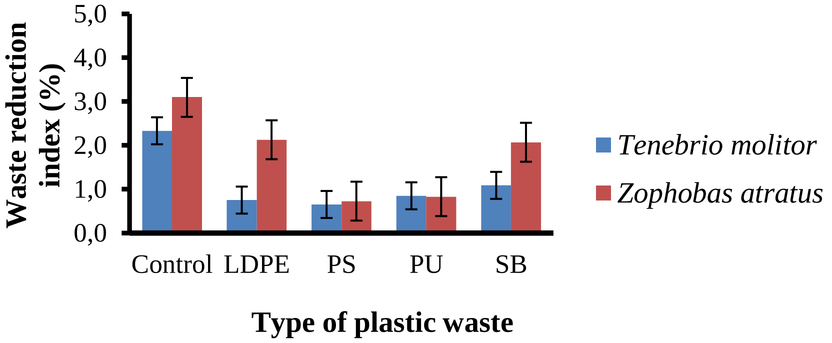


Figure 5. The result of waste reduction index using insect larvae. Styrofoam block (SB); Polystyrene (PS); Polyurethane (PU); Low-density Polyethylene (LPDE)

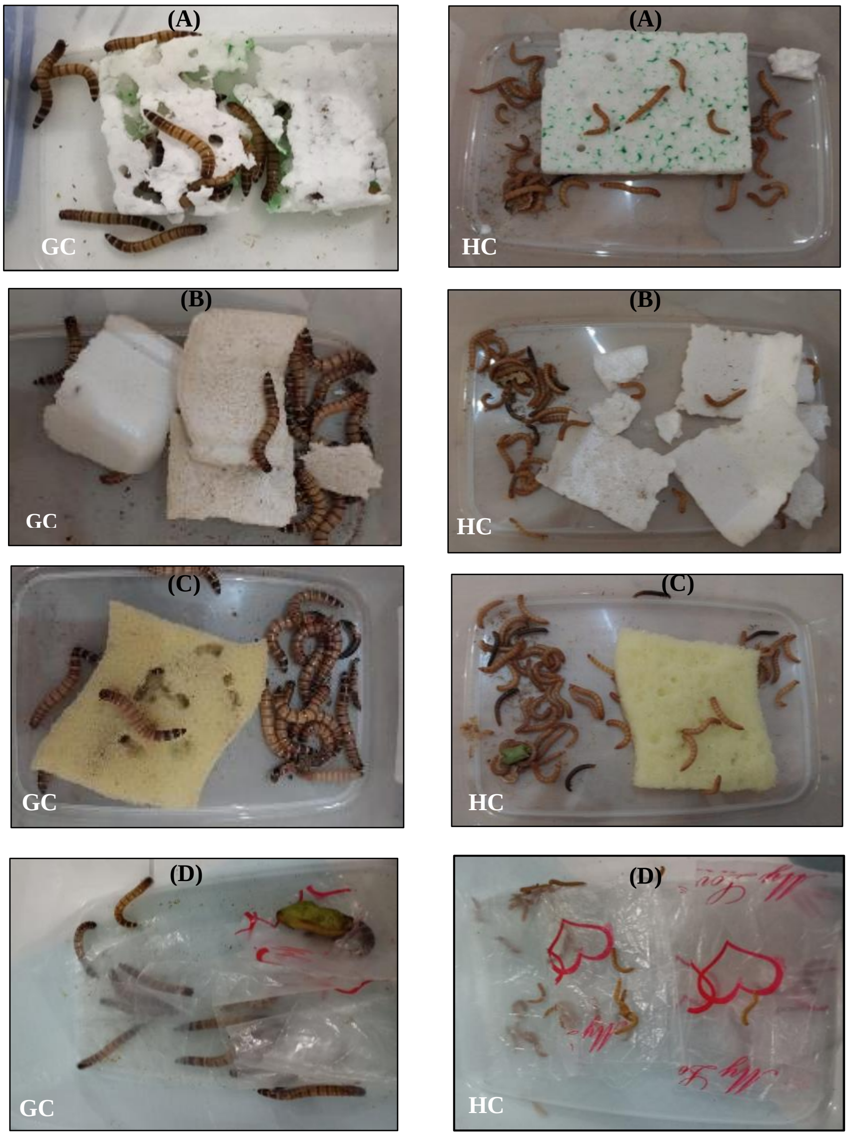


Figure 6. Observation of *Zophobas atratus* larvae (GC) and *Tenebrio molitor* larvae (HC) from various plastic waste treatments on day 21st (A). Styrofoam Block (SB); (B). Polystyrene (PS); (C). Polyurethane (PU) and (D). Low-density polyethylene (LDPE).

The control treatment showed the highest Waste Reduction Index (WRI) value among all treatments. Among the types of plastics observed, Styrofoam block showed the highest WRI value, indicating that a feeding rate of 1 gram of food per larva per day is optimal for efficient waste reduction. WRI is directly linked to the degradation rate; higher degradation rates correspond to higher WRI values. Similar to *T. molitor*, plastic density influences the digestibility of plastic in *Z. atratus* larvae. Optimal WRI values were observed in *T. molitor* larvae fed control feed and *Z. atratus* larvae fed both control feed and SB plastic. *Z. atratus* larvae, being larger in size, exhibit greater feed consumption capacity, attributed to their aggressive feeding habits (Peng et al., 2020). *Z. atratus* digestive systems adapt to digest various food types, with intestinal microbiota aiding in the breakdown of lignocellulosic waste (Przemieniecki et al., 2020). While *T. molitor* larvae maintain high survival rates, feeding them PS or LDPE plastics results in increased survival rates but decreased body fat content. Ingested PS and LDPE plastics are degraded into microplastic particles, with the particle size reaching a maximum threshold without nanoplastic production (Borremans et al., 2020; Peng et al., 2022). *Pseudomonas* sp. effectively degrades PS, converting its surface from hydrophobic to hydrophilic through biofilm formation (Cassone et al., 2020). In *Z. atratus* larvae, LDPE feeding in the early stages resulted in increased microbial presence, including bacteria from genera such as *Pseudomonas*, *Enterococcus*, *Bacillus*, and *Staphylococcus*. Several bacterial species, including *Acinetobacter septicus*, *Agrobacterium tumefaciens*, *Klebsiella grimontii*, *Pseudomonas multiresinivorans*, *Pseudomonas nitroreducens*, *Pseudomonas plecoglossicida*, *Serratia marcescens*, and *Yokenella regensburgei*, play significant roles in the biodegradation process (Park et al., 2023; Voirol et al., 2018).

This research is the information that the degradation rate of plastic waste in the form of Styrofoam blocks waste is higher compared to other types of plastic such as low-density polyethylene, polystyrene, and polyurethane when using both *Z. atratus* and *T. molitor* larvae for 21st days. Meanwhile, the degradation rate of LDPE plastic waste is higher than that of PU and PS when using *Z. atratus* larvae. This indicates that *Zophobas atratus* larvae have the highest potential for the bioconversion of plastic waste especially styrofoam blocks and LDPE waste. This approach can serve as an innovative waste management solution, minimizing visual pollution, environmental disruptions, and potential health risks for diverse plant and animal species. However, further research is needed to identify and characterize the intestinal microorganisms that enhance the potential of *Z. atratus* and *T. molitor* larvae for eco-friendly waste bioconversion. This research can serve as a reference for developing innovative, effective, and environmentally friendly biotechnology for plastic waste processing.

CONCLUSION

Morphological and molecular identification methods confirmed two species from the Tenebrionidae family namely *Zophobas atratus* and *Tenebrio molitor*. These species show great promise for eco-friendly insect-assisted biodegradation of waste plastics. Control treatment using larvae of these insects showed the highest waste reduction index (WRI) values among all treatments. Among the various types of plastics, styrofoam blocks showed the highest WRI indicating that a feeding rate of 1 gram of waste plastic per larva per day is optimal for efficiently reducing plastic waste and promoting circular economy initiatives. Further research is needed to identify and characterize the intestinal microorganisms that enhance these larvae's potential for sustainable and eco-friendly waste bioconversion.

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