



**ASSESSMENT ON THE POTENTIAL OF
PLASTICS BIODEGRADATION BY IMMATURE
RICE BEETLES *Sitophilus Oryzae*, (COLEOPTERA
CURCULIONIDAE)**

by

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DECLARATION

I declare that this thesis entitled "Assessment on The Potential of Plastics Biodegradation by Immature Rice Beetles *Sitophilus Oryzae*, (Coleoptera Curculionidae) " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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**Assessment on The Potential of Plastics Biodegradation by Immature Rice
Beetles *Sitophilus Oryzae*, (Coleoptera Curculionidae)**

ABSTRACT

The widespread use of plastics has led to significant environmental issues, necessitating innovative approaches to address their persistence in the environment. This study investigated the potential of rice beetles (*Sitophilus oryzae*) for the biodegradation of various types of plastics, focusing on their preferences and the biodegradation rates of different plastics. The plastics examined included polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC). In controlled laboratory experiments, 100 grams of each type of plastic were exposed to rice beetles in glass petri dishes over a period of five days, with detailed recording of any changes in weight. Our findings indicate that the interaction of rice beetles with plastics primarily resulted in slight weight reductions in PE and PS, with reductions of 1.4% and 1.0% respectively. No measurable weight reduction was observed in PP, PET, and PVC. These interactions suggest that the reductions may be more attributable to physical displacement caused by the beetles' activities rather than actual biodegradation. The beetles exhibited a preference for interacting with PE and PS, which could be due to the physical characteristics of these plastics such as their texture and potential odors emitted that attract the beetles. Despite these interactions, the capacity of rice beetles to biodegrade plastics appears limited, as the primary mechanism observed was physical displacement rather than chemical breakdown or consumption. The study underscores the importance of considering physical and behavioral interactions in evaluating the potential of biological agents like rice beetles in mitigating plastic pollution. This research highlights the need for further studies to more accurately classify the nature of insect-plastic interactions and to explore other biological methods or organisms that might offer more efficient and scalable solutions for plastic waste degradation.

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**Penilaian Potensi Biodegradasi Plastik oleh Kutu Beras *Sitophilus Oryzae*,
(Coleoptera Curculionidae)**

ABSTRAK

Penggunaan plastik yang meluas telah mengakibatkan pencemaran alam sekitar yang serius, memerlukan penyelesaian inovatif termasuk penyelidikan tentang kemampuan kutu beras (*Sitophilus oryzae*) dalam mendegradasi bahan plastik. Penyelidikan ini bertujuan menilai potensi kutu beras dalam biodegradasi pelbagai jenis plastik, dengan memberi tumpuan kepada kadar interaksi dan biodegradasi terhadap jenis-jenis plastik seperti polipropilena (PP), polietilena (PE), polietilena tereftalat (PET), polistirena (PS), dan polivinil klorida (PVC). Dalam eksperimen makmal yang terkawal, 100 gram setiap jenis plastik ditempatkan dalam gelas petri dan didedahkan kepada kutu beras selama lima hari. Perubahan berat plastik tersebut diperhatikan. Hasilnya, hanya PE dan PS yang menunjukkan pengurangan berat yang sedikit tetapi ketara, masing-masing sebanyak 1.4% dan 1.0%. Sementara itu, PP, PET, dan PVC tidak menunjukkan sebarang pengurangan berat. Pengurangan berat pada PE dan PS lebih cenderung disebabkan oleh pergerakan fizikal kutu beras daripada proses biodegradasi yang sebenar. Walaupun kutu beras menunjukkan keutamaan terhadap PE dan PS, potensi mereka untuk biodegradasi plastik secara keseluruhan kelihatan terhad. Pengurangan berat yang diperhatikan kemungkinan besar disebabkan oleh aktiviti fizikal daripada degradasi biologi. Penemuan ini menekankan pentingnya mempertimbangkan aspek tingkah laku kutu beras dalam menilai kemungkinan penggunaannya dalam mengatasi masalah pencemaran plastik. Walaupun kutu beras mungkin berinteraksi dengan jenis-jenis plastik tertentu, kemampuan mereka dalam biodegradasi tampaknya sangat terbatas. Oleh itu, disarankan agar kajian lebih lanjut dijalankan untuk memperdalam pemahaman mengenai interaksi ini dan untuk mengeksplorasi kebolehskalaan penggunaannya dalam konteks yang lebih luas dalam pengurusan alam sekitar.

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LIST OF ABBREVIATIONS

PP	Polypropylene
PE	Polyethylene
PET	Polyethylene terephthalate
PS	Polystyrene
PVC	Polyvinyl chloride
LDPE	Low-density polyethylene
VOCs	Volatile organic compounds



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LIST OF SYMBOLS

°C	Temperature (degree Celsius)
%	Percent sign



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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Since it began in the 1950s, the commercial manufacturing of plastics has expanded at an astounding rate. Between 1950 and 2018, an estimated 6.3 billion tonnes of plastic were manufactured (Alabi et al., 2019). At the current rate of increase, plastics production is predicted to treble over the next 20 years (Lebreton and Andrady, 2019). Pollution from plastic garbage is now widely recognised as a serious environmental problem. According to a recent study, plastic trash production to date has reached up to 6,300 million metric tonnes (Geyer et al., 2017). Nevertheless, less than half of the plastic garbage created was recycled or dumped in landfills. Our planet is a “Plastic World” because so much of the leftover plastic garbage clogs our oceans, continents, and other natural areas (Rochman et al., 2013).

Hazardous chemicals are released into the air due to the careless disposal of plastics on land and open-air burning, endangering public health as well as all living things (Alabi et al., 2019). Given this difficulty, it is imperative to look for ecologically appropriate methods for its degradation, such as biodegradation, rather than traditional disposal (Ali et al., 2021). According to Wierckx et al. (2018), plastic biodegradation plays a significant role in mitigating the impacts of plastic pollution. Nevertheless, little is known about the methods and effectiveness of plastic biodegradation. The idea of invertebrates, such as insects, in the breakdown of plastics is also covered in the current assessment, with an emphasis on the crucial role they might play in the future.

The idea that insects can help break down plastic could be very useful in the recycling and waste management industries. It provides a long-lasting and environmentally friendly way to break down plastic, lowering the damage that plastic trash does to the environment. Also, the waste products that are made when insects break down plastic can be used in different industrial and farming sectors.

1.2 Problem Statement

Plastic pollution has a serious damaging impact on ecosystems, wildlife, and human health, making it a significant environmental concern. A number of studies have shown the considerable negative influence of plastic pollution on the environment. One of its most alarming features is the persistence of plastic pollution in ecosystems. Because plastics are robust and slow to biodegrade, they remain in ecosystems for a long time after they are introduced.

For instance, research conducted in 2004 by Thompson et al. discovered that plastic waste breaks down into ever-tinier particles known as microplastics, which remain in marine habitats for decades, if not centuries. These tiny plastic particles can penetrate the food chain and be consumed by marine species, impacting both human consumers and aquatic life.

Animals are directly threatened by the physical presence of plastic waste in natural settings. Plastic items are frequently mistaken for food by animals, leading to consumption and potential harm. This has been noted in numerous species, from marine animals tangled in fishing nets and other plastic waste to seabirds consuming pieces of plastic (Laist, 1997; van Franeker et al., 2011).

Many aquatic animals may be injured, suffocated, or even killed in such confrontations. Plastic contamination in terrestrial environments can affect plant

development and disturb soil health. Microplastics in soil can negatively impact nutrient cycling and soil-dwelling species, potentially reducing agricultural output and causing ecological disruption (Zhu et al., 2019).

Efforts to curb microplastic waste have included individual actions, government regulations, and industry-led programmes. These steps are necessary but may not always be effective and come with costs and challenges for long-term use (Wright et al., 2013). Compliance with regulations may vary, and businesses may face higher costs to switch to eco-friendly packaging and products, which can be passed on to consumers. Balancing business and environmental goals can be challenging.

Given the global challenge of plastic pollution, it is essential to find long-lasting and effective ways to reduce its effects. The potential of rice beetles (*Sitophilus oryzae*) to break down plastic is a promising area for investigation. While past studies have examined the plastic-degrading abilities of mealworms, waxworms, and other insects, little is known about the contribution of rice beetles.

Despite various efforts to mitigate plastic pollution, it remains a persistent environmental challenge due to the slow biodegradation of plastics. Existing research has explored the plastic-degrading abilities of insects like mealworms and waxworms, yet the potential role of rice beetles in this process is not well understood.

This study aims to address the knowledge gap by investigating the biodegradation mechanisms of rice beetles, including their capacity to consume and break down different types of plastics and the factors that influence this biodegradation process. Understanding these mechanisms could contribute to the development of innovative, sustainable methods for managing plastic waste.

1.3 Objective

- To assess the potential of plastics biodegradation by rice beetles.
- To compare the plastics preferences and biodegradation by rice beetles (*Sitophilus oryzae*).

1.4 Scope of Study

The research was conducted at the Microbiology and Biochemistry Laboratory, Faculty of Earth Science (FSB) at Universiti Malaysia Kelantan (UMK), Jeli campus. The study will investigate the capability of rice beetles to break down plastics, considering factors such as the types of plastics tested and the environmental conditions, including temperature and humidity.

1.5 Significant of Study

Plastic waste is one of the most critical environmental challenges today. The widespread use of plastic, due to its versatility and convenience, has led to an alarming accumulation of plastic waste globally. Traditional disposal methods, such as incineration and landfilling, have significant drawbacks, including environmental pollution, resource depletion, and greenhouse gas emissions. Consequently, there is an urgent need for innovative and sustainable plastic waste management solutions.

Exploring the potential of organisms, especially microbes, for plastic degradation is a promising area of research. Although certain microbes have demonstrated the ability to degrade plastics, the process is usually slow, and some microbes may pose health risks. Therefore, investigating whether rice beetles, a

common insect species, can facilitate faster and safer plastic degradation is highly intriguing.

A major advantage of studying rice beetles for plastic degradation is their abundance. These insects are prevalent in agricultural areas and easy to cultivate in laboratories, making them a practical and accessible option for plastic waste management. Additionally, their natural exposure to plastics in the environment may have enabled them to develop plastic-degrading capabilities.

The concept of utilizing rice beetles for plastic degradation presents a novel and potentially effective solution for recycling and reducing plastic waste. If successful, this approach could offer a faster, safer, and more environmentally friendly method for managing plastic waste.

CHAPTER 2

LITERATURE REVIEW

2.1 Related Research

Even though these studies don't directly involve rice beetles (*Sitophilus Oryzae*), they still teach us a lot about how different species and enzymes break down plastics. These earlier research projects show that a wide range of organisms and enzymes have been shown to be able to break down plastics. More study is needed to fully use this potential and deal with practical issues, but it does give us hope for new ways to solve the problem of plastic pollution around the world. To help this area of study grow, researchers can use rice beetles to understand how plastic breaks down.

Table 2.1 Several studies related to the biodegradation of plastics by insects

Year	Author	Previous Studies
2014	Yu Yang, Jun Yang, Weimin Wu & Jiao Zhao	Biodegradation of polyethylene by wax moth larvae (<i>Galleria mellonella</i>)
2015	Yu Yang, Shan-Shan Yang, Daliang Ning, Anja Malawi Brandon, Jie Ren & Jun Yang	Mealworm beetles (<i>Tenebrio molitor</i>) and polystyrene biodegradation
2017	Paolo Bombelli, Christopher J. Howe & Federica Bertocchini	Plastic degradation by waxworms (<i>Galleria mellonella</i>)
2018	Seongjoon Joo, In Jin Cho, Hogyun Seo, Hyeoncheol	Enzymatic plastic degradation (PETase)

	Francis Son, Sang Yup Lee & Kyung Jin Kim	
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Even though these studies don't directly involve rice beetles (*Sitophilus Oryzae*), they still teach us a lot about how different species and enzymes break down plastics. These earlier research projects show that a wide range of organisms and enzymes have been shown to be able to break down plastics. More study is needed to fully use this potential and deal with practical issues, but it does give us hope for new ways to solve the problem of plastic pollution around the world. To help this area of study grow, studies using rice beetles (*Sitophilus oryzae*) to study how plastic breaks down can be useful.

2.1.1 Introduction to Plastics

Plastics, which are man-made polymers made from different organic compounds, are used in almost every part of modern life and have changed many businesses. People love them because they can be used for many things, last a long time, and don't cost much. This makes them important in electronics, building, transportation, packaging, and many other areas. The heavy use of plastics, on the other hand, has caused many problems for the environment and long-term survival.

Plastics have a big effect on the world because they stay in natural ecosystems for a long time. Most plastics don't break down easily, which means they can stay in the environment for hundreds of years, building up in landfills, seas, rivers, and even wild places (Jambeck et al., 2015). A world crisis of plastic pollution has been caused by too much plastic waste, which is bad for wildlife, ecosystems, and people's health.

Plastic waste is especially bad for marine life because animals can eat or get caught in plastic, which can hurt or kill them (Rochman et al., 2016).

Additionally, making plastics uses a lot of resources and adds to greenhouse gas pollution. Getting raw materials like oil and natural gas for making plastic, along with manufacturing methods that use a lot of energy, leaves a big carbon footprint (Geyer et al., 2017). When plastics break down in the world, they give off greenhouse gases that make climate change worse. More people are interested in biodegradable and long-lasting options because of efforts to solve the plastic problem. Bioplastics, which are made from natural materials like sugarcane or cornflour, could be the answer. These materials are becoming more popular in packaging and single-use items because they could cut down on the use of fossil fuels and lessen the damage that plastics do to the earth (Azeredo et al., 2017). There are still problems with how they can be scaled up, how much they cost, and how to handle their end-of-life.

Plastics have become an important part of modern life because they are useful in many fields, from healthcare to packaging. But the widespread use of plastics has also caused a big problem for the earth. Plastics come from fossil fuels, and the methods used to make them use a lot of energy and release greenhouse gases into the air. The problems with plastics in the environment come from the fact that they last a long time and don't break down easily. Because of this, plastic trash builds up in landfills, litters the landscape, and pollutes oceans and rivers, putting ecosystems and wildlife in great danger.

It is very important to have a full knowledge of how plastics affect the environment. According to a report by Geyer et al. (2017), about 8.3 billion metric tonnes of plastic have been made since the middle of the 20th century, but only 9% of that plastic has been recycled. Most plastic trash ends up in landfills, where it can stay

for hundreds of years and release harmful chemicals and tiny pieces of plastic into the environment. Also, plastic trash in marine environments is becoming a bigger problem. Studies show that plastics can hurt marine life by getting stuck in their bodies or eating them (Wright et al., 2013). Microplastics, which are very small pieces of plastic less than 5 millimetres long, are a major source of pollution that makes environmental problems even worse.

Some things that are being done to help the environment with plastics are recycling programmes, bans on single-use plastics, and the creation of compostable plastics. But these plans have a lot of problems, like the fact that some plastics are hard to recycle and biodegradable alternatives have negative effects on the earth. Also, because plastic is made and used all over the world, it needs organised international action and new ideas to cut down on waste and the damage it does to the environment.

2.1.2 Biodegradation of Plastics

Plastics are an important part of daily existence. They're flexible, light, and not expensive. Synthetic plastics like polyethylene (PE), polystyrene (PS), polypropylene (PP), and others are now essential to almost every part of our lives. The production of plastic trash and the following uncontrolled plastic pollution is one of the biggest environmental problems that governments and countries are facing today (Urbanek et al., 2020; Danso et al., 2018). The breakdown of plastic is a complicated process that releases large amounts of carbon dioxide and other harmful chemicals. A lot of the time, biodegradation and bioplastics are used to mean the same thing.

Not every type of bioplastic can be broken down by nature. Any polymer that is "bio-based" is made from renewable biological materials and organic waste. A material is "biodegradable" if it can break down naturally into natural chemicals like

biomass, water, and carbon dioxide when microorganisms break it down. So, bioplastics can be broken down into two groups: bio-based plastic and organic plastic. Greenhouse gas emissions are lower with biodegradable plastics because they can be made from materials that can be used again and again. Bioplastic breakdown doesn't release a lot of carbon dioxide, which shows how important it is to make biodegradable plastic every day.

Plastics and microplastics, which are also called polymers and polymeric materials, are getting a lot of attention these days. Plastics are hard to break down, are dumped in large amounts, and build up in ecosystems (Amaral-Zettler et al. 2020; Danso et al. 2019; Gu 2020). Recently, biodegradation of plastics has gotten more attention because of these problems, but there hasn't been much progress or new ideas in the research that has been published so far (Gu 2003, 2017).

This stubbornness causes a lot of issues. Plastics are broken down into smaller pieces, which are called microplastics and end up all over environments on land and in water. Microplastics can absorb and concentrate toxic substances, so many different animals eat them. They then get into the food chain and become a threat to wildlife and maybe even human health (Rochman et al., 2016). Greenhouse gas emissions are also greatly increased by the making of plastics. According to research done by Geyer et al. in 2017, the whole process of making plastics, from getting the raw materials to throwing them away, releases a lot of greenhouse gases that make climate change worse.

Biodegradable options and recycling programmes have grown out of efforts to lessen the damage that plastics do. Bioplastics, which are made from plant starches and cellulose that can be used again and again, are a hopeful option. Azeredo et al. (2017)

show that these materials could help us use less fossil fuels and make plastics less harmful to the environment.

Recently, biodegradation study has also looked into using engineered enzymes, like PETases, that can break down polyethylene terephthalate (PET), a common plastic used in water bottles (Joo et al., 2018). These enzymes have shown promise in speeding up the breakdown of PET, which could be a way to stop the buildup of plastic trash. But there are still problems with making biodegradation processes bigger so they can be used in real life.

These problems include controlling the rate and speed of degradation, making sure the environment is safe, and thinking about whether the process is even possible from a financial point of view (Geyer et al., 2017). More research is needed to find the best biodegradation strategies and figure out how they will affect the environment in the long run.

2.1.3 Rice Beetles (*Sitophilus oryzae*) as Biodegraders

The rice beetles, is in the family Curculionidae. Its main biological function is to infest stored grains, but new study suggests it might also be able to break down plastics. Studies have shown that some bug species, including rice beetles, have the enzymes they need to break down plastics when they eat them.

A study by Yang et al. (2015) showed that the mealworm beetle (*Tenebrio molitor*), which is related to rice beetles, can break down polystyrene (PS), a popular type of plastic, with the help of its gut bacteria. This research showed that insects might be able to break down plastic, and it made it possible to look into similar species like them in more depth.

The exact enzymes and methods that rice beetles uses to break down plastic are still being studied, but these results show that these insects might be able to help break down some types of plastic. Nevertheless, it is important to keep in mind that the usefulness and ability to use them for big-scale plastic breakdown have not yet been fully studied and understood. More research needs to be done to fully understand how these insects break down plastic and what uses they might have in the future.

2.2 Polyethylene Terephthalate (PET)

Polyethylene terephthalate (PET) is a flexible polyester that is partly crystalline (Levchik, S.V.; Weil, E.D. 2004). Table 1 shows that it is made by several different companies with different brand names. PET is strong and long-lasting, stable at both high and low temperatures, doesn't let gases through easily, and is simple to work with (Awaja, F.; Pavel, D. 2005). Because of these qualities, PET is a material that is useful in many situations and a big part of the plastic that is used around the world. 6.5% of Europe's plastic needs are met by PET, which is more than 3,000 tonnes. More than half of all synthetic fibres made in the world are made of PET, and more than \$17 billion worth of PET is used every year (Sinha, V.; Patel 2010).

Manufacturer	Commercial name
DSM Engineering Plastics	Aritel®
Du Pont De Nemours & Co., Inc.	Mylar®
Du Pont De Nemours & Co., Inc.	Rynite®
Eastman Chemical Company	Eastapac®
ENKA-Glazstoff	Diolen®
Farbwerke Hoescht AG	Hostadur®
Imperial Chemical Industries Ltd.	Melinex®

Figure 2.1 Manufacturers and commercial names of polyethylene terephthalate (PET)

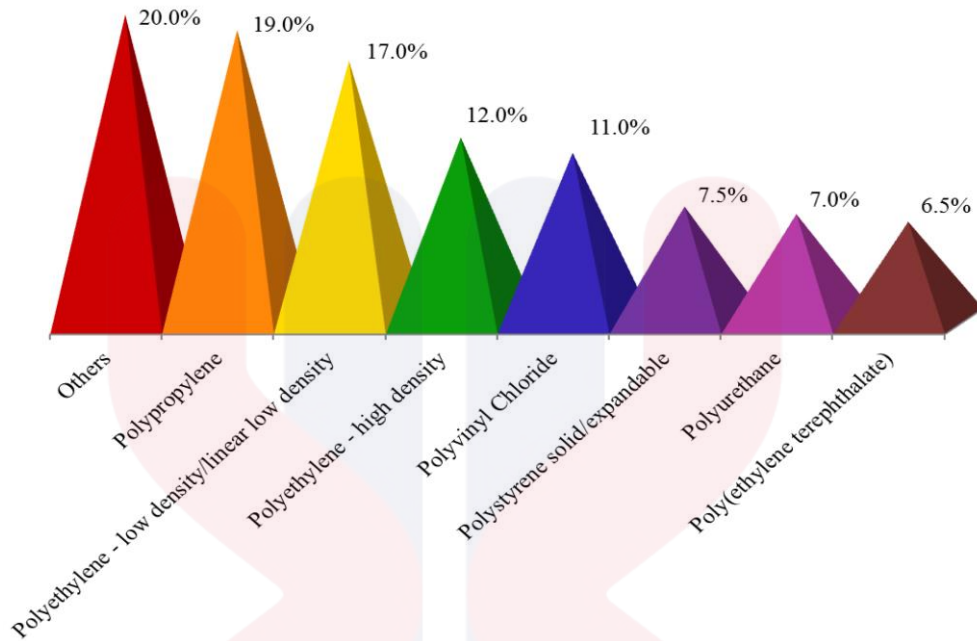


Figure 2.2 European plastic demand by resin type for the year 2011 (Webb., et al. (2012))

Polyethylene terephthalate, or PET, is a thermoplastic polymer that is used a lot in the packaging business, mostly to make fibres, bottles, and containers. People like it because it is clear, strong, and can hold fizzy drinks without breaking. On the other hand, PET is known for not breaking down naturally, which is a big problem for the environment because it stays in dumps and ecosystems for a long time.

Insects have been studied as a possible way for PET to break down in recent years. This is something that has been talked about a lot with the wax moth (*Galleria mellonella*). Studies have shown that wax moth larvae can biodegrade PET because they have enzymes that can break it down into its molecules (Yang et al., 2015; Bombelli et al., 2017). Researchers think that enzymes made by wax moth larvae, such as cutinase and lipase, can break down PET bonds and cause this biodegradation process (Danso et al., 2018).

Scientists have also looked into the rice beetles (*Sitophilus oryzae*) to see if it can break down plastic. There isn't as much study on rice beetles' ability to break down PET as there is on wax moths, but these beetles have been shown to be able to break down other types of plastics, like low-density polyethylene (LDPE) (Yang et al., 2015). Research shows that rice beetles may break down plastic by damaging it mechanically and using microbes in their guts to break it down.

2.3 Rice Beetles and Plastic Degradation

The fact that rice beetles (*Sitophilus oryzae*) can chew through plastic packaging and possibly help break down plastic is an interesting and not very well studied topic. There isn't a lot of information on this subject, but it's important to think about the different things that might affect the rice beetle's role in breaking down plastic. The process is very complicated, which makes it hard to study how rice weevils affect the breakdown of plastic. Plastics break down in a number of ways, such as through photooxidation, chemical weathering, mechanical wear, and more. The way rice beetles chew through plastic can be thought of as a form of mechanical wear because it breaks the plastic into smaller pieces. Getting these pieces apart is an important part of breaking down plastics because it makes other processes easier.

In a study done by Ojo et al. in 2017, they looked at how well rice weevils could chew through polyethylene and polypropylene plastic wrapping. According to this study, rice beetle might be able to help break up plastic. It is important to keep in mind, though, that this study is just one part of the vision. More research is needed to figure out how much of an effect they have on the formation of microplastics.

In conclusion, the fact that rice beetle can chew through plastic packaging is interesting, but more study is needed to fully understand their role in the breakdown of

plastic, especially when it comes to the creation of microplastics. Such studies can help us learn more about the complicated processes that break down plastic and come up with ways to lessen its effect on the world.

2.3.1 Comparative Analysis with Other Insects

For a more complete understanding of the rice beetle's ability to break down plastic, it is helpful to make comparisons with other insects that have been studied in the same way. One interesting example of this group of insects is the greater wax moth (*Galleria mellonella*), which has been studied in great detail for its ability to break down polyethylene, a common type of plastic. More recent studies have shown that greater wax moth larvae can not only eat polyethylene but also break it down naturally, eventually turning it into smaller pieces (Yang et al., 2018). This interesting finding shows that insects might play a part in breaking down plastic, and it makes mankind wonder if the rice beetle has similar abilities in this area.

There aren't many direct head-to-head comparisons between the rice beetle and the greater wax moth in the scientific literature right now. However, both of these insects chew on plastic, which suggests that they may both be contributing to the breakdown of plastic materials in similar ways. Researchers and environmental scientists are both interested in this common trait because it suggests that different insect species may be able to help clean up plastic pollution as part of a larger ecological process.

Plastic biodegradation has come a long way recently, but there is still a lot we don't know about the exact part that insects, like rice beetles (*Sitophilus oryzae*), play in breaking down different kinds of plastics. Some research has looked into how insects can break down plastic (Yang et al., 2015), but not much is known about the types of

plastics that rice beetles like and how these likes might affect the rate of biodegradation. To fill this gap, the main goals of this work are twofold.

First, the study wants to find out if plastics can be broken down by insects, specifically by looking into the part that rice bugs (*Sitophilus oryzae*) play in this process. The second part of the study aims to compare the types of plastics that rice beetles like and how quickly they break down. This will help scientists figure out which plastics these bugs like and how to use that information to cut down on plastic waste.

2.3.2 The Feeding Habits and Adaptations of Rice Beetles Larvae: Beyond Rice Consumption

A interesting area of entomology is the study of how the rice beetle (*Sitophilus oryzae*) larvae eat. These small, reddish-brown bugs are known to consume preserved grains, especially rice. They have four stages in their life cycle: egg, larva, pupa, and adult. The larval stage is very important for rice weevil development; it's mostly about eating and growing.

Larvae of the rice beetle have special mouth parts that help them eat. They have mandibulate mouthparts, which means they can chew or grind food. These jaws are strong and good at breaking down the tough top layers of grains like corn, wheat, or rice. As the larvae eat the endosperm, which is the healthy part inside the grain, they make holes in the grains. Not only does this feeding behavior keep the larvae growing, but it can also do a lot of damage to stored grains, which costs farmers and grain storage facilities money.

People often think that rice weevils only eat rice, but they actually eat other grains as well. Even though rice is one of their favorite foods, rice weevil larvae can also infest other cereal grains like wheat, corn, barley, and oats (Phillips, 2016). In

addition, they can get into other retained foods, like nuts, beans, and even pasta. They are very bad for farming because they can handle different kinds of grain and eat a lot of it.

Overall, when rice beetles are larvae, they feed by using their mandibulate mouthparts to eat the endosperm of different cereal grains. The most common host is rice, but they can also infest other grains and saved foods, which is a big problem for farming and food storage. This flexibility shows how important it is to use good pest control methods to stop and lessen rice weevil infestations in food storage facilities around the world (Hagstrum et al., 2013).

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

The assessment on the potential of plastics biodegradation by rice beetles (*Sitophilus oryzae*) using the following materials and equipment:

Table 3.1 Materials and Equipment

Laboratory materials and apparatus	<ul style="list-style-type: none">- Aquarium glass- 5 grams of rice beetles- Polyethylene (PE)- Polypropylene (PP)- Polyethylene Terephthalate (PET)- Polystyrene (PS)- Polyvinyl Chloride (PVC)- 5 Glass petri dishes- Analytical balances for measuring plastic weights- Scissors- Forceps- Biodegradable gloves- Aluminium foil- Grinder- Plastic blender
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3.2 Method

3.2.1 Collection and rearing of rice beetles

Rice beetles were carefully collected from old rice piles using forceps to ensure precision and avoid any damage to the insects. After collection, the beetles were placed in a glass container to prevent any potential contamination from plastic materials. The rearing environment was meticulously controlled, maintaining a consistent room temperature of 28-32°C and ensuring darkness to mimic their natural habitat. These conditions were critical for maintaining the health and viability of the beetles throughout the experimental period, providing a stable environment similar to their natural habitat.

3.2.2 Evaluating the Biodegradation Potential of Rice Beetles on Five Common Plastics

The selection of these five plastic types for the experiment was based on their prevalence in everyday life and their diverse chemical compositions, making them relevant to plastic pollution scenarios. These plastics represented a range of chemical structures, from simpler to more complex, to assess the biodegradability potential of rice beetles:

1. **Polyethylene (PE):** Widely used in plastic bags, packaging materials, and agricultural films. Composed primarily of carbon and hydrogen atoms, PE's relatively simple chemical structure made it suitable for biodegradation studies (Bhardwaj et al., 2020).
2. **Polypropylene (PP):** Commonly found in packaging, textiles, and automotive components. Like PE, it consists mainly of carbon and hydrogen, warranting investigation into its biodegradability due to its extensive use (Sivan, 2011).

3. **Polyethylene Terephthalate (PET):** Frequently used in beverage bottles and food packaging. Containing carbon, hydrogen, and oxygen, PET's resistance to degradation necessitated an evaluation of its biodegradation potential (Zheng et al., 2020).
4. **Polyvinyl Chloride (PVC):** Known for its durability, used in pipes, cables, and construction materials. Its chlorine content poses environmental challenges, making it important to evaluate its potential biodegradation (Mukherjee et al., 2020).
5. **Polystyrene (PS):** Prevalent in packaging and food service industries. Composed of carbon and hydrogen, PS is notorious for its slow decomposition, highlighting the need for biodegradation research (Liu et al., 2020).

Standardized plastic samples, each weighing 100 grams, were meticulously prepared. These samples were finely cut until they resembled dust, providing a uniform and accessible form for the rice beetles. To achieve this fineness, a grinding process using a plastic blender from the sustainability science laboratory was employed. This ensured that each plastic sample was reduced to a consistent particle size, facilitating interaction between the rice beetles and the plastic samples in the experiment.

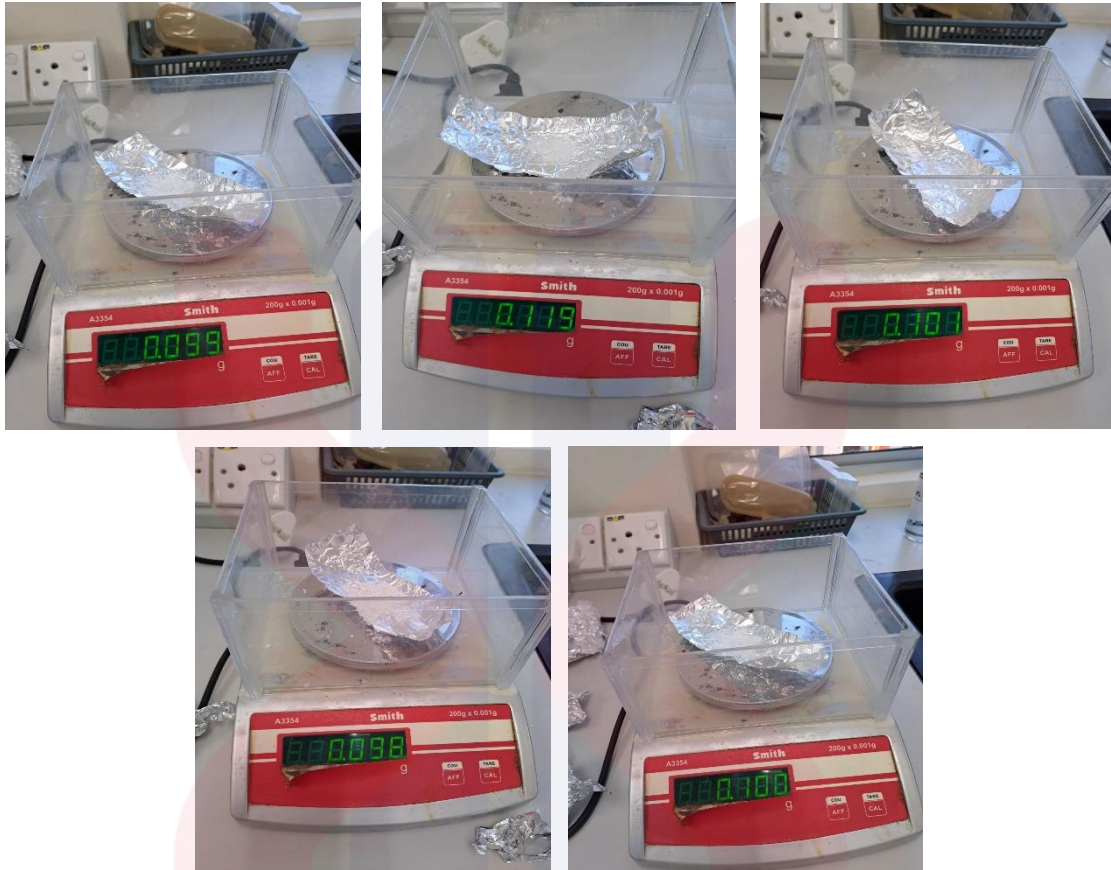


Figure 3.1 Five types of plastic weighed on an analytical balance

3.2.3 Test optimisation

A single glass aquarium was prepared, housing five glass petri dishes suitable for containing immature rice beetles and plastic samples. These dishes were designed to provide an environment where the beetles could interact with the plastic under specified conditions. Each petri dish contained 100 grams of a specific plastic type (PE, PP, PET, PVC, or PS) along with the rice beetles, ensuring controlled exposure to the plastic substrate. The isolated setups within the aquarium minimized external disturbances, ensuring a controlled environment and reducing stress on the beetles.



Figure 3.2 Preparation before placing rice beetles in five types of plastic in an aquarium

By observing the behavior of the rice beetles towards the plastics, valuable insights were gained into their preferences and potential for plastic biodegradation. In this experiment, the rice beetles collectively weighed 0.5 grams. The estimated duration for this experiment was at least 5 days.

Observation

Initial Observation (Day 1): On the first day, the interactions of rice beetles with each plastic type were observed and recorded. The focus was on the frequency and duration of interactions, with a hypothesis that PE and PS would attract more interaction due to their simpler chemical compositions.

Subsequent Observations (Days 2-5): Daily observations were conducted to monitor the preferences of rice beetles among the plastic types. It was anticipated that by day 2, PE and PS would be preferred, while PET, PVC, and PP would see less frequent interaction, potentially requiring 5-7 days to observe significant behavior changes.

Data Recording: All observations were meticulously recorded, including the type of interaction (drilling, climbing, avoidance), duration of interaction, and any physical changes to the plastic samples over time.

3.2.4 Monitoring and data collection

To assess plastic interaction and potential consumption, the reduction in plastic mass over time for each experimental group was meticulously measured. Consistent environmental conditions were maintained, including a temperature within the range of 28-32°C, to ensure reliable results. Visual observations were conducted to monitor and document any noticeable changes to the plastic samples that could indicate biodegradation or physical alteration by the rice beetles. Specifically, these observations focused on:

- **Surface Degradation:** Any visible changes to the surface of the plastic dust, such as discoloration, erosion, or the formation of pits or grooves, which might suggest that the beetles' activities or biological processes were affecting the plastic's integrity.
- **Changes in Mass:** Regular measurements of the plastic samples to detect any decrease in mass over time. A reduction in mass could be an indicator of biodegradation, as it might suggest that the plastic is being broken down into smaller components or consumed by the beetles.
- **Physical Damage:** Observations of any physical damage to the plastic substrate, such as holes, scratches, or other forms of structural damage. This could result from the beetles' drilling or feeding activities and would provide insights into the potential of rice beetles to physically alter or degrade plastic materials.

These visual observations were crucial for assessing the impact of rice beetles on the different types of plastics and for understanding the mechanisms through which these insects might contribute to the breakdown of plastic waste in natural environments.

3.3 Research Flow

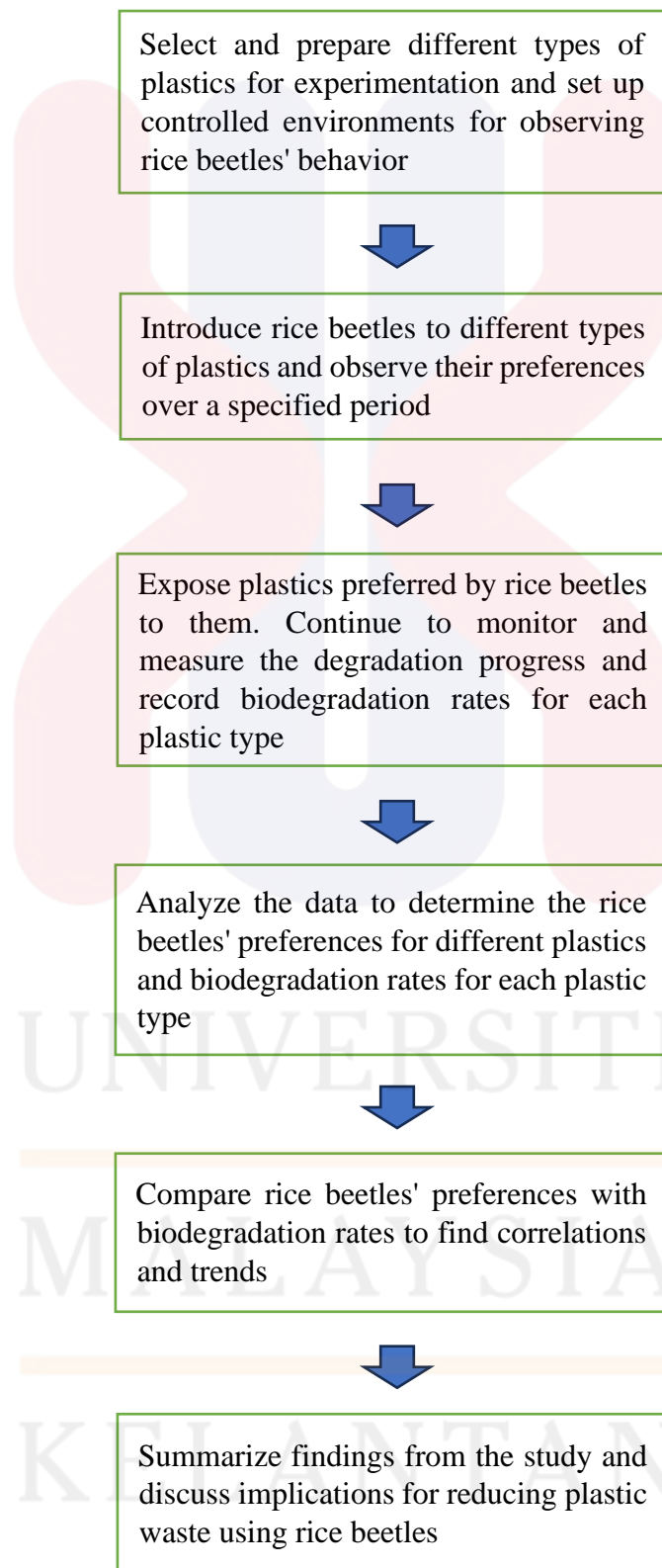


Figure 3.3 Research flow chart for the assessment on the potential of plastic biodegradation by rice beetles

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Initial Observations and Plastic Interaction

The focus of this experiment was to investigate the ability of rice beetles (*Sitophilus oryzae*) to consume or break down various types of plastics. The plastics used in the experiment were polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC).

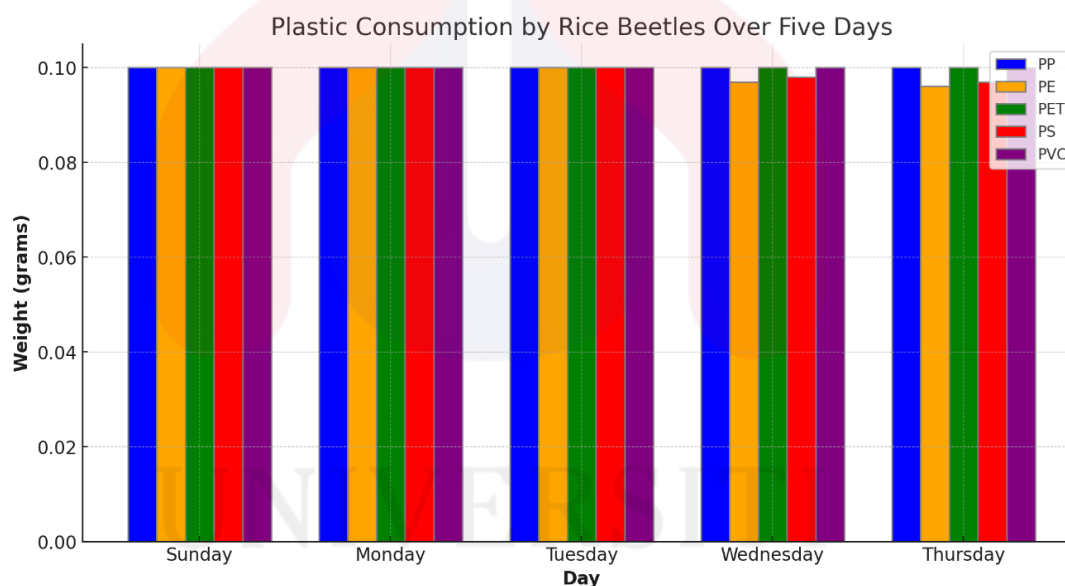


Figure 4.1 Bar chart showing the weight of plastic consumed by rice beetles over five days

On the first day of the experiment, all five types of plastic were weighed and placed in glass petri dishes, each containing 100 grams of plastic. According to the results and the bar and pie charts, nearly half of the plastic remained untouched and was not preferred by the rice beetles. The results indicated that plastics such as polyethylene (PE) and polystyrene (PS) showed significant reduction.

Despite these findings, the behavior of the rice beetles suggested that their preference for certain plastics might not be due to consumption but rather their drilling activity. Rice beetles have snouts, which make them more likely to drill into materials rather than consume them. The snout, a prominent feature, is used for drilling into food sources and was observed to be actively used in their interaction with the plastic pieces, particularly PE and PS. This behavior was particularly evident with the plastics that showed a reduction in weight.

4.2 Factors Influencing Plastic Weight Reduction

The observed reduction in plastic weight might also be attributed to plastic fragments sticking to the beetles' legs and bodies. Specifically, PE and PS were often observed to stick to the beetles' legs and body, potentially contributing to the measurable reductions in plastic mass or being carried away by the wind. These factors could have contributed to the apparent decrease in plastic weight without actual consumption by the beetles.

Throughout the experiment, detailed observations were made on the interactions between the rice beetles and the plastic samples. The significant reduction in PE and PS suggests that these types of plastics are either more attractive to the beetles for drilling or more prone to disintegration due to beetle activity. Interestingly, the rice beetles seemed to prefer smooth, non-rigid, and soft plastics. This preference might be influenced by the beetles' sense of smell and their specific odor preferences. The chemicals and odors emitted by these plastics could play a significant role in attracting the beetles.

4.3 Summary of Experimental Results

The data supporting these results are summarized in Table 4.3, which shows the daily and total consumption of each type of plastic by rice beetles over five days. The table highlights the consistent consumption of PE and PS and the lack of reduction in other types of plastics:

Plastic Type	Day 1 (gram)	Day 2 (gram)	Day 3 (gram)	Day 4 (gram)	Day 5 (gram)	Mass Reduction (gram)	Percentage Reduction (%)
PP	100	100	100	100	100	0.000	0.0
PE	100	100	100	0.097	0.096	0.007	1.4
PET	100	100	100	100	100	0.000	0.0
PS	100	100	100	0.098	0.097	0.005	1.0
PVS	100	100	100	100	100	0.000	0.0

As seen from the table, the total consumption and mass reduction of PE and PS plastics were more significant compared to PP, PET, and PVC. PE showed a mass reduction of 0.007 grams, equivalent to a 1.4% reduction, while PS showed a reduction of 0.005 grams, or 1.0%. The other types of plastics showed no measurable reduction, remaining at 0.0%.

While the rice beetles showed some interaction with the plastic samples, particularly PE and PS, the overall results suggest that their role in plastic decomposition might be limited. The reduction observed could be more related to physical displacement rather than actual biodegradation. This study highlights the importance of considering behavioral factors, such as texture and odor, and physical

interactions in evaluating the potential of organisms like rice beetles in mitigating plastic pollution.

4.4 Detailed Observations and Implications

4.4.1 Drilling Behavior and Plastic Interaction

Initial observations of rice beetles interacting with finely ground plastic revealed that the beetles do not consume the plastic materials. Instead, they exhibited a unique behavior of drilling holes and rolling around in piles of finely ground plastic, specifically PE and PS. This discovery led to further experimentation to confirm and better understand these behaviors. To test these observations, a small piece of polystyrene was introduced into an environment with rice beetles.

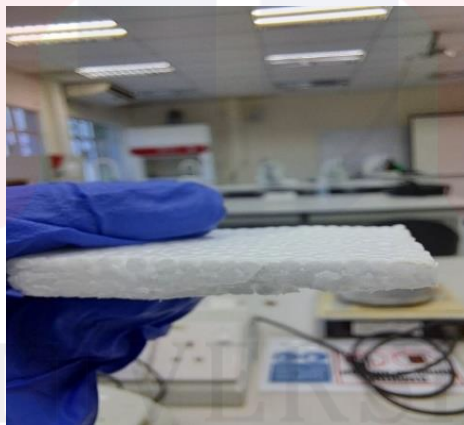


Figure 4.2 Polystyrene filled with holes caused by rice beetles drilling into it



Figure 4.3 A large number of rice beetles found in the polystyrene

The results were consistent with the initial observations. The rice beetles drilled numerous holes into the polystyrene and appeared to prefer staying within these drilled areas. They did not consume the plastic; instead, they utilized it for physical activities that might be akin to their natural behaviors in grain environments. This behavior can be likened to their natural tendency to burrow into grains for laying eggs and feeding. The plastic, while not a food source, seems to provide a similar texture and resistance, allowing the beetles to exhibit their natural drilling behaviors.

4.4.2 Rolling in Plastic

The preference for rolling in finely ground plastic is less understood but might be connected to the beetles' natural inclination to seek out environments that provide certain tactile feedback. In their natural grain habitats, they are surrounded by small particles and debris. The finely ground plastic could mimic this environment, providing a familiar and possibly comfortable setting for the beetles. Interestingly, the rice beetles seemed to prefer smooth, non-rigid, and soft plastics. This preference might be influenced by the beetles' sense of smell and their specific odor preferences. The chemicals and odors emitted by these plastics could play a significant role in attracting the beetles.

4.4.3 Differences Between Male and Female Rice Beetles

The morphometric measurements revealed distinct differences in the physical attributes of male and female rice beetles. Males are typically smaller with a less pronounced snout, while females are larger with a more robust snout structure. This physical distinction is reflected in their behavior, as females were observed to be more actively engaged in drilling and attempting to consume plastic pieces. This behavior is

presumably linked to their reproductive duties, such as laying eggs and preparing a suitable environment for their progeny. In contrast, males, though active, were less involved in drilling activities.

The beetles demonstrated a clear preference for interacting with polyethylene (PE) and polystyrene (PS) over other plastics like polypropylene (PP), polyethylene terephthalate (PET), and polyvinyl chloride (PVC). The preference for PE and PS could be attributed to their physical properties; these plastics are softer and more pliable, making them easier for the beetles to manipulate and attempt to ingest.

The softer texture of these plastics may also explain why they were more likely to become attached to the beetles' legs and bodies, resulting in extended contact and interaction.



Figure 4.4 Plastic fragments sticking to the bodies and legs of the rice beetles

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4.4.4 Chemical Emissions from Plastics and Their Influence on Rice Beetle Behavior

Plastics such as polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC) are widely used across various industries. When heated or degraded, these plastics emit different chemicals, many of which contribute to distinct odors. For instance, polypropylene emits aldehydes, ketones, and alcohols, resulting in a plastic-like or sweet smell (Raheem & Morad, 2016). Polyethylene releases hydrocarbons and aldehydes, producing a waxy or oily odor (Raheem & Morad, 2016). Polyethylene terephthalate primarily emits acetaldehyde and other aldehydes, which can have a slightly fruity smell (Raheem & Morad, 2016). Polystyrene releases styrene monomers and other hydrocarbons, resulting in a sweet, benzene-like odor (Raheem & Morad, 2016). In contrast, polyvinyl chloride, when heated or degraded, emits hydrochloric acid and other chlorinated compounds, producing a sharp, acrid smell (Raheem & Morad, 2016).

The determination that rice beetles exhibit a preference for boring into polyethylene and polystyrene over other plastics was drawn based on several observations and studies. The beetles' attraction to these plastics is influenced by factors such as odor and texture, which are conducive to their natural behaviors of feeding and laying eggs. Research has shown that polyethylene and polystyrene release volatile organic compounds (VOCs) that may mimic or resemble natural plant odors, triggering the beetles' olfactory system and guiding them towards these materials (Holcombe & Farrar, 1998). Additionally, the physical properties and texture of these plastics are more suitable for the beetles' boring behavior, allowing for easier penetration compared to other plastics like PP, PET, and PVC (Holcombe & Farrar, 1998). These findings suggest that the beetles have a preference for polyethylene and polystyrene, which is

likely driven by a combination of chemical attraction and the physical suitability of these materials for their boring activities.

Research indicates that polyethylene, polystyrene, and PET release VOCs that mimic the chemical signals of the beetles' natural food sources, such as grains. These VOCs likely act as olfactory cues, leading the beetles to perceive these plastics as potential food or suitable habitat (Hagstrum & Subramanyam, 2006). In contrast, plastics such as PVC and PP emit VOCs that do not attract rice beetles in the same way. The chemical composition of the VOCs from these plastics may either be neutral or even repellent to the beetles (Phillips & Throne, 2010). The surface texture and physical properties of the plastics also contribute to this differential attraction, as certain surfaces could be more conducive to the beetles' movement and exploration (White & Leesch, 1996).

The attraction of rice beetles to specific VOCs can be understood through chemical ecology. VOCs play a crucial role in insect behavior, particularly in food location and selection. Insects have highly sensitive olfactory systems capable of detecting minute concentrations of VOCs, enabling them to locate food sources from considerable distances (Blum, 1996). The VOCs emitted by polyethylene, polystyrene, and PET may contain compounds that mimic the odors of grains or other organic materials that rice beetles feed on, thereby attracting them. Behavioral assays, where rice beetles are exposed to these VOCs in controlled environments, can help determine the attractiveness of specific compounds. Understanding the chemical profiles of these plastics and their impact on rice beetle behavior can provide insights into pest management strategies.

The preference of rice beetles for certain plastics over others could also be influenced by the physical properties of the materials. For instance, the surface texture

and hardness of plastics might affect the beetles' ability to move and explore. Plastics with smoother surfaces may facilitate easier movement for the beetles, enhancing their exploration and attraction. Conversely, rough or uneven surfaces might deter beetle movement and reduce their attractiveness. The physical properties of plastics, combined with their chemical emissions, create a multifaceted environment that influences beetle behavior (White & Leesch, 1996).

The differential attraction to various plastics can be linked to the beetles' evolutionary adaptations. In their natural habitats, rice beetles have evolved to locate and exploit specific food sources, primarily grains. The ability to detect and respond to VOCs associated with these food sources is a critical survival trait. When certain plastics release VOCs that mimic these natural cues, the beetles are likely attracted due to their evolutionary predisposition. This phenomenon highlights the intricate relationship between insect behavior and environmental cues, shaped by millions of years of evolution (Blum, 1996).

By understanding the chemical and physical factors that attract rice beetles, researchers can develop materials that are less attractive to pests. This approach can help mitigate the risks associated with beetle infestations in stored products and other materials. For instance, modifying the chemical composition of plastics to alter their VOC emissions or changing their surface properties could reduce their attractiveness to rice beetles. Such innovations can enhance the durability and safety of materials used in various industries (Phillips & Throne, 2010).

4.4.5 Chemical Composition of Recycled Plastics

Recycled plastics are often composed of various additives and contaminants that are introduced during their manufacturing and recycling processes. These chemicals can include plasticizers, stabilizers, flame retardants, and heavy metals, which are added to enhance the properties of plastics. Studies have shown that these chemicals can leach out over time, impacting both the environment and biological organisms. Additives such as plasticizers and stabilizers are commonly used to improve the flexibility and durability of plastics, but they can leach out and pose risks to organisms.

For instance, plasticizers, which make plastics more flexible, can migrate out of the plastic matrix and contaminate the surrounding environment, potentially affecting the health and behavior of insects and other organisms. Studies have documented the presence of such additives in various plastic products and their potential to leach into the environment, impacting both terrestrial and aquatic ecosystems (Capolupo et al., 2019; Valavanidis et al., 2008).

Moreover, recycled plastics often contain heavy metals, especially in materials like PVC, which can leach out and be bioavailable, posing toxicity risks to aquatic organisms and potentially deterring pests. For example, a study by Boyle et al. (2020) highlighted that PVC fragments can release lead (Pb) additives into the environment, which are then bioavailable and can cause adverse effects in aquatic organisms such as zebrafish. This leaching of heavy metals from recycled plastics can create an environment that is inhospitable to many organisms, including pests like rice beetles, which may avoid such materials due to the toxic effects.

Volatile organic compounds (VOCs) are another class of chemicals commonly found in recycled plastics. These compounds are often emitted during the melting and recycling processes and contribute to the overall chemical profile of the recycled

material. VOCs can have various effects on insect behavior and survival, potentially making recycled plastics less attractive to pests. For instance, Tsai et al. (2009) and He et al. (2015) documented the emission of VOCs from plastic recycling facilities and their potential impacts on the environment and human health. These emissions include compounds such as toluene, ethylbenzene, and methyl methacrylate, which can have adverse effects on biological organisms, including insects.

4.4.6 Impact on Insects and Beetles

The chemical composition of recycled plastics can significantly impact insect behavior and survival. Various studies have explored how these additives and contaminants affect different insect species, including beetles. Behavioral and toxicological responses to these chemicals can vary widely among different insect species, but there is evidence to suggest that many insects, including beetles, may avoid recycled plastics due to the presence of harmful chemicals.

One of the primary behavioral responses observed in insects is avoidance. Rice beetles and other insects may avoid recycled plastics due to the presence of harmful chemicals. This avoidance behavior has been documented in other beetle species, where plastic additives led to avoidance and reduced penetration rates in packaging materials. For instance, Yar et al. (2017) conducted a study on the red flour beetle (*Tribolium castaneum*) and found that polyethylene packaging was more susceptible to damage by beetles compared to PP and PVC, suggesting that certain plastics may be less attractive or accessible due to their chemical composition. This avoidance behavior is likely driven by the detection of chemical cues that indicate the presence of harmful substances, prompting the insects to seek out safer environments.

Toxicity is another significant factor influencing insect behavior and survival in relation to recycled plastics. Chemicals leaching from recycled plastics can have toxic effects on insects, disrupting their biological processes and leading to mortality. Heavy metals, for example, can interfere with the normal functioning of insect physiology, leading to adverse outcomes. Boyle et al. (2020) highlighted that the presence of lead and other heavy metals in recycled plastics can pose significant toxicity risks to insects and other organisms. Additionally, Capolupo et al. (2019) documented the leaching of various organic and inorganic additives from plastics, which can have deleterious effects on aquatic organisms and potentially impact terrestrial insects as well.

4.4.7 Specific Studies on Beetles and Plastics

One notable study focused on the interaction between insects and plastic packaging. Yar et al. (2017) evaluated the susceptibility of different plastic packaging materials to damage by red flour beetles and found significant differences in the penetration and damage rates among various plastics. The study revealed that polyethylene packaging was more prone to damage and penetration by beetles compared to PP and PVC. This finding suggests that the chemical composition of the plastic materials plays a crucial role in determining their attractiveness and susceptibility to insect infestation. The presence of certain additives and contaminants in recycled plastics may make them less appealing to beetles, leading to reduced damage and penetration rates.

Another area of research has explored the microbial degradation and biodegradation of plastics by insects. Studies on mealworms (*Tenebrio molitor*) have shown that some beetle larvae can biodegrade plastics like polystyrene (PS) and low-density polyethylene (LDPE), but struggle with more crystalline plastics like PP and

PVC. This difficulty is likely due to the higher crystallinity and the presence of chemical additives in these plastics, which make them more resistant to degradation. Yang et al. (2020) and Zhong et al. (2021) documented the ability of mealworms to degrade certain types of plastics and highlighted the role of gut microbiomes in facilitating this process.

However, the degradation rates and efficiency were significantly lower for more crystalline plastics, indicating that the chemical composition and physical properties of the plastics play a critical role in determining their biodegradability and attractiveness to insects.

4.4.8 Environmental and Ecological Implications

The avoidance of recycled plastics by insects like rice beetles has broader ecological implications. Understanding these interactions can inform pest management strategies and the environmental impact of plastic waste. Effective pest management strategies can leverage the knowledge of insect behavior and chemical composition of recycled plastics to develop more resistant packaging materials and reduce the risk of infestation. From a pest management perspective, utilizing less attractive or more resistant plastic materials for food packaging can reduce infestation rates.

The findings from studies like those by Yar et al. (2017) suggest that modifying the chemical composition of plastics could make them less appealing to pests. For instance, incorporating certain additives or altering the physical properties of the plastic materials can create a less hospitable environment for pests, thereby reducing the likelihood of infestation and damage.

The environmental impact of recycled plastics extends beyond their interaction with pests. The chemical composition of recycled plastics not only affects pest behavior

but also has significant environmental repercussions. The leaching of harmful substances from recycled plastics can contaminate ecosystems, affecting a wide range of organisms. Studies have shown that the leaching of heavy metals, plasticizers, and other additives can have toxic effects on aquatic and terrestrial organisms, contributing to environmental pollution and ecological imbalances (Capolupo et al., 2019; Boyle et al., 2020). Addressing these environmental concerns requires a comprehensive understanding of the chemical composition of recycled plastics and their potential impacts on different ecosystems.



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The primary aim of this study was to explore the potential of rice beetles (*Sitophilus oryzae*) in contributing to the biodegradation of various types of plastic. By observing the beetles' interactions with polyethylene (PE), polystyrene (PS), polypropylene (PP), polyethylene terephthalate (PET), and polyvinyl chloride (PVC), we sought to understand whether these insects could play a role in mitigating plastic pollution. The findings of this study provide insights into the limited yet notable interactions between rice beetles and plastic materials.

On the first day of the experiment, all five types of plastic were weighed and placed in glass petri dishes, each containing 100 grams of plastic. Over five days, the weight of these plastic samples was monitored to detect any reductions. According to the results, nearly half of the plastic remained untouched, indicating a lack of preference by the rice beetles for certain plastics. However, PE and PS exhibited significant reductions of 1.4% and 1.0%, respectively, whereas PP, PET, and PVC showed no measurable reduction in mass.

The reduction in PE and PS can be attributed primarily to the rice beetles' physical interactions rather than actual consumption. Rice beetles have a prominent snout, or rostrum, used for drilling into grains, and this snout was observed to be actively used in their interaction with the plastic pieces, particularly PE and PS. The beetles' preference for these softer plastics is likely due to their texture, which provides a similar resistance to grains. This drilling behavior, combined with plastic fragments

sticking to the beetles' legs and bodies or being carried away by environmental factors such as wind, contributed to the reduction in mass observed in PE and PS.

Additionally, the beetles displayed a preference for rolling in finely ground plastic, which might be linked to their natural inclination to seek environments with specific tactile feedback. This behavior was observed more in females, who are larger and possess more robust snouts compared to males. Females were more active in drilling and interacting with the plastic pieces, likely due to their reproductive role.

The study also highlighted the influence of environmental factors such as wind and static electricity, which affected the lightweight plastic pieces, causing minor reductions in mass. These factors underscore the importance of controlled conditions in future studies to isolate the effects of rice beetles' behavior from environmental influences.

In summary, while rice beetles demonstrated some interaction with PE and PS plastics, the overall impact on plastic decomposition was minimal and primarily due to physical displacement rather than true biodegradation. The beetles' distinct behavioral and morphological characteristics, combined with environmental factors, played a significant role in the observed results.

These findings suggest that rice beetles, in their current capacity, are not a viable solution for mitigating plastic pollution on a large scale. However, this study provides a foundation for understanding the interactions between rice beetles and plastic materials, highlighting the need for further research to identify more effective biological agents for biodegradation. Future research should explore alternative biological agents with greater biodegradation capabilities and investigate the sensory preferences of rice beetles and the role of chemical emissions from plastics.

5.2 Recommendation

Future research on the potential of rice beetles for plastic biodegradation should concentrate on several critical areas. It is crucial to investigate the microbial community within the gut of these beetles to pinpoint specific bacteria or enzymes that may be responsible for plastic degradation. Analyzing the biochemical pathways involved and optimizing environmental conditions to improve degradation could provide more profound insights. Comparative studies with other insect species could also identify more effective biological agents for mitigating plastic pollution.

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