Epazote-Infused Cassava–Sargassum Bioplastic as Active Packaging to Repel FlourBeetles

Background and research questions

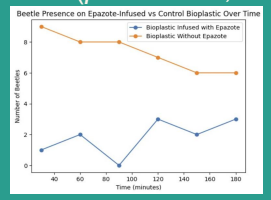
Flour beetles are common pantry pests that infest dried food products like flour, cereal, and pet food. While not harmful to humans, their presence contaminates food with dead insects, cast skins, and foul-smelling secretions, making the food unfit for consumption. By adding epazote, we could create a packaging material that protects against pest infestations. This allows us to create a product that is both safer for the environment and more effective at preserving and protecting food.

-Is the epazote-infused bioplastic effective in repelling flour beetles?

-Does the epazote-infused bioplastic affect the germination rates of different grades?

Data Analysis and Results

- Flour wrapped in epazote-infused bioplastic lost only 6.7% mass, while control lost 84.3%, showing reduced beetle feeding.
- Fewer beetles approached epazote-infused bioplastic over time compared to control.
- The repellency effect was statistically significant (p = 0.0016; Cohen's d = 2.54).

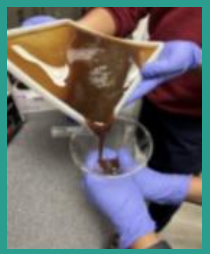


Statistical Test	Comparison	Test Statistic	p-value	Effect Size
Paired t-test	Epazote vs Control	t = −6.21	0.0016	Cohen's d = 2.54

The epazote-infused bioplastic showed a statistically significant repellency effect, with far fewer beetles present compared to the control bioplastic (paired t-test, p = 0.0016, Cohen's d = 2.54), indicating a strong and meaningful reduction in beetle attraction.

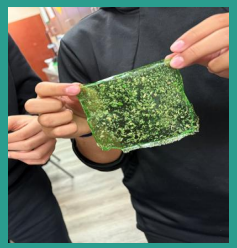
Methods

- Cassava starch and sargassum alginate were extracted separately.
- Bioplastic was formed by heating and mixing starch, alginate, agar, glycerin, vinegar, and water.
- Epazote extract was added to the mixture.
- Films were cast in molds and dried at 60 °C.



Discussion and Conclusion

Our experiments proved that epazote efficiently repelled beetles, outperforming the bioplastic without epazote significantly, which can be seen in our repellency tests. The epazote showed no difference when compared to the bioplastic without epazote, showing that it does not affect seed germination. This means that our bioplastic is safe to use.



Bugs Away! Epazote-Infused Cassava–Sargassum Bioplastic as Active Packaging to Repel Flour Beetles

Animal Science

All photos & graphs were taken/created by the students unless otherwise noted.

https://www.freepik.com/icon/bottle_5637300#fromView=keyword&page=1&position=1&uuid=742cf556-f41e-4035-9e7e-f715a72e1561

Plastics:
Their Impact on Earth

Current Situation

- Traditional Plastics contribute significantly to global emissions, accounting for about 3.4% of total greenhouse gases.

- Also, plastics are a major environmental pollutant, taking several years to decompose while contaminating ecosystems and affecting organisms.

https://www.4ocean.com/cdn/shop/articles/4oceanhowplasticpollutionhappens-1698172477985_82f59dc4-ed84-4fc1-a302-64a76d645cd1.jpg?crop=center&height=1200&v=1698173546&width=1200

However, biodegradable plastics offer a promising alternative, potentially reducing pollution.

The Unseen Risks

Beyond pollution: Public health risks

- While plastics pose an environmental threat, their limitations in packaging also create risks to food supply.
- Pests, such as the flour beetle, can compromise food safety.
- This poses both economic risks and potential health hazards from contaminated food.

https://www.texasstandard.org/wp-content/uploads/2024/10/Tribolium_castaneum.jpg

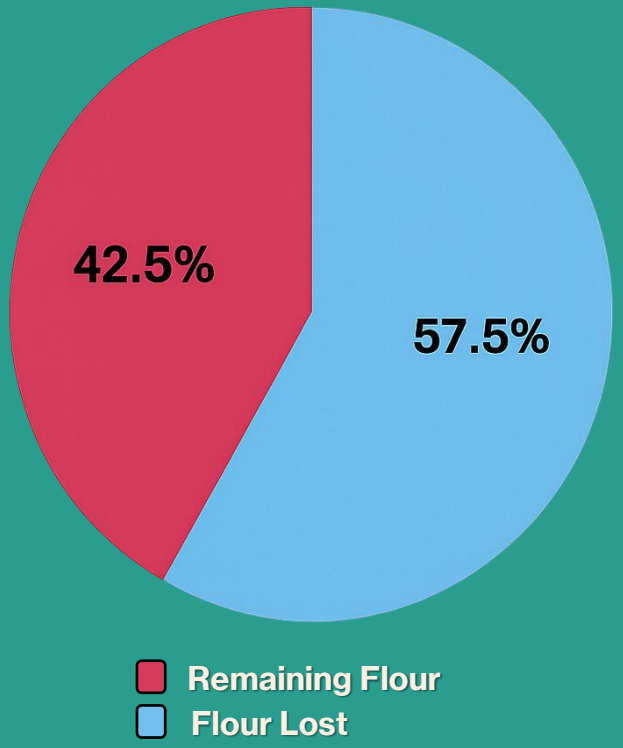
Our goal

This project aims to create and assess an epazote-infused antimicrobial bioplastic to address pest risks, offering an environmentally friendly material that protects against pest hazards.

Inside the Pantry: The Hidden Impact of Flour Beetles

Flour beetles are common pantry pests that infest dried food products like flour, cereal, and pet food. While not harmful to humans, their presence contaminates food with dead insects, cast skins, and foul-smelling secretions, making the food unfit for consumption.

https://en.wikipedia.org/wiki/Flour_beetle



According to a study published in the Directory of Open Access Journals, Flour Beetles infestations can cause up to 42.5% weight loss in stored wheat flour within 8 months.

A Solution From Our Culture

Addressing both problems

- Our bioplastic will be made from renewable resources, reducing dependence on fossil fuels and lowering greenhouse gas emissions.
- By adding epazote, we could create a packaging material that protects against pest infestations.
- This allows us to create a product that is both safer for the environment and more effective at preserving and protecting food.

https://www.keeo.com.au/cdn/shop/articles/Eco_Friendly_packaging_1000x.jpg?v=1615548149

Our Focus: Protecting Flour From Pests

- Our epazote-infused bioplastic offers a solution for common problems in stored food products.
- It provides a natural, effective barrier against pests, safeguarding food quality and reducing waste.

https://m.media-amazon.com/images/I/71PcpoAyqjL._AC_UF894,1000_QL80_.jpg

Statement of the Problem

General Problem:

This project aims to create a bioplastic that repels flour beetles, using epazote as a natural repellant, and cassava and sargassum as our key components of our bioplastic.

Hypothesis

If a cassava starch–sargassum alginate bioplastic is infused with epazote, **then** flour beetles will show greater avoidance of the bioplastic compared to a non-infused bioplastic, **because** epazote releases volatile compounds that interfere with the beetles' ability to detect and locate food sources.

Specific Questions:

- Is the epazote-infused bioplastic effective in repelling flour beetles?
- Does the epazote-infused bioplastic affect the germination rates of different grades?

Independent Variable

Epazote Infused Bioplastic

Dependent Variable

Effectiveness of repelling against flour beetles

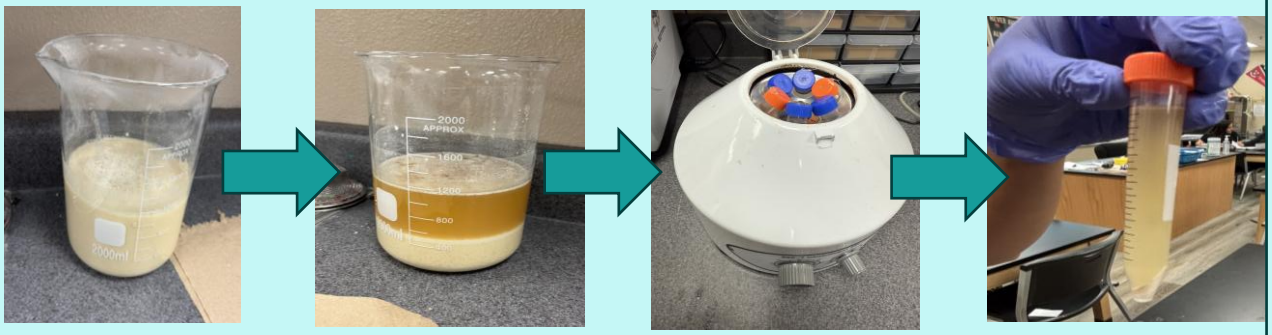
Constant Variable

Time, flour, and environment in where we maintain the flour in

Preparing the Cassava:

1.

2.



3.

The preparation of cassava starch involved several steps. Fresh cassava roots were first peeled and cut into small pieces, then dehydrated until completely dry. The dried cassava was ground into a fine powder. Water was added to the powder, and the mixture was allowed to settle so that the starch could separate and sink to the bottom. After settling, the mixture was carefully filtered to isolate the starch. The collected starch was dehydrated a second time to remove excess moisture and then stored for later use in bioplastic production.

Preparing the Sargassum:

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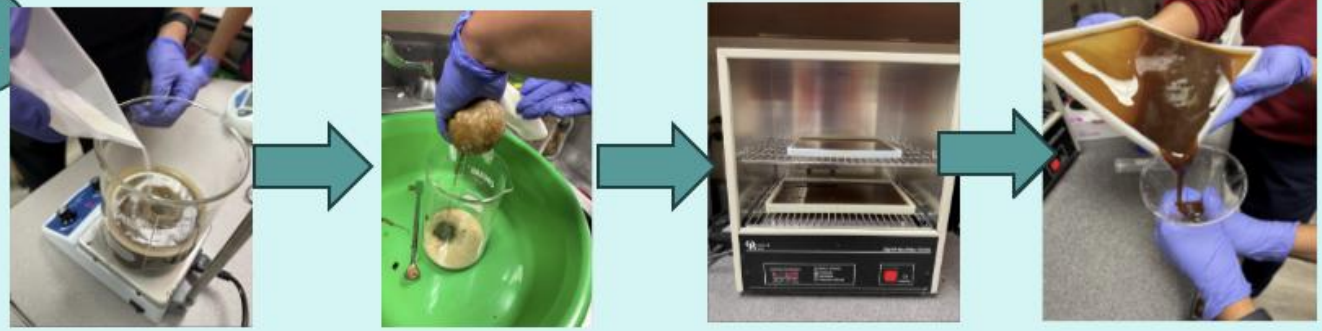


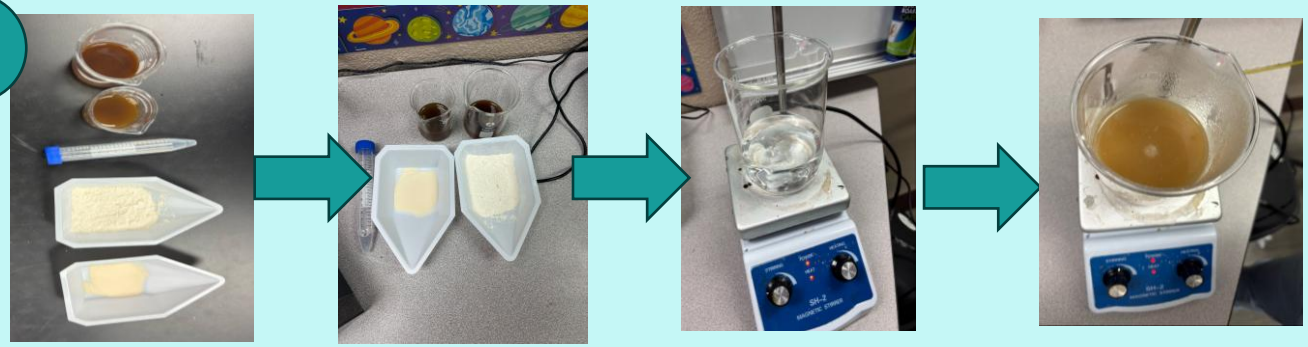
Dried Sargassum seaweed was first rinsed, chopped, and blended with water to create a slurry, as shown in the initial images. The mixture was then boiled and stirred on a hot plate, allowing alginate to be released from the seaweed cell walls. After boiling, the mixture was strained to remove solid seaweed residues, producing a dark brown alginate-rich solution.

The filtered extract was chemically treated to convert the alginate into sodium alginate. Sodium hydroxide (NaOH) was added while heating to promote alginate extraction and solubilization. The solution was then adjusted using sodium carbonate to stabilize the alginate, followed by vinegar (acetic acid) to neutralize excess base and improve purification. Throughout the process, the solution was maintained at controlled temperatures using a hot plate, as shown in the images.

Finally, the sodium alginate solution was strained and filtered multiple times, then dehydrated for storage and later use in bioplastic film production.

Adding Epazote and Finishing Plastic:

1.



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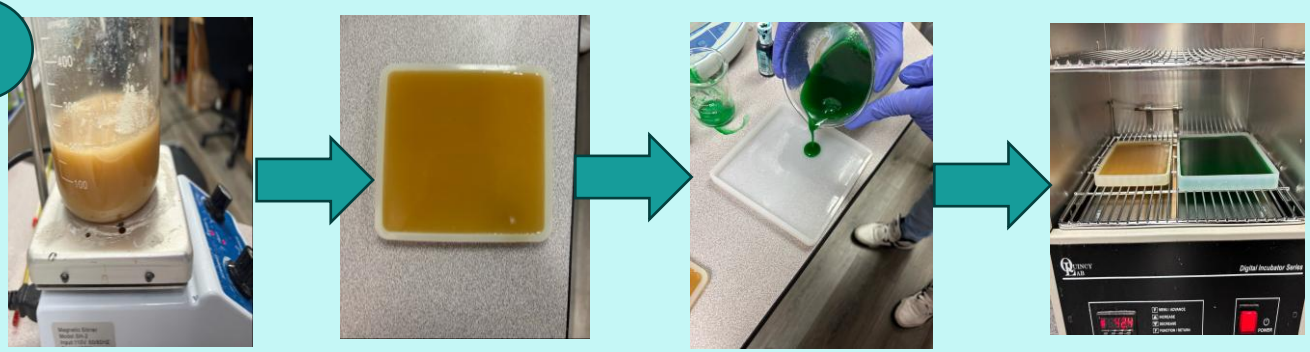
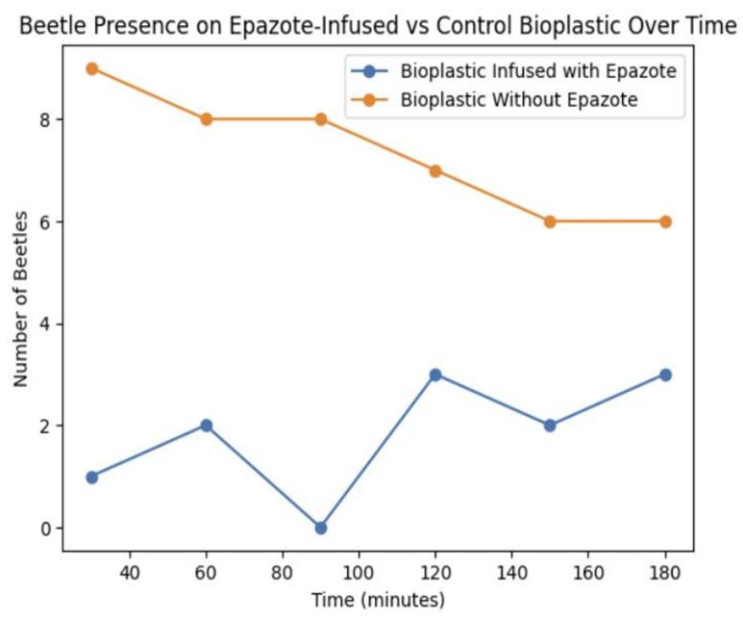


Once all materials were prepared, the bioplastic was fabricated by combining the components in a glass beaker. First, 100 mL of distilled water, 1 g of agar-agar powder, 10 g of cassava starch, 10 mL of sodium alginate solution, 2 mL of vinegar (acetic acid), and 2 mL of glycerin were measured and mixed. The mixture was heated and continuously stirred using a magnetic stirrer until a homogeneous solution was formed. After thorough mixing, 10 mL of epazote extract was added to the solution and stirred to ensure even distribution. The final bioplastic solution was then poured into silicone molds and placed in an incubator at 60 °C until fully dried, forming solid bioplastic films.

Results: Bug Repellency



Graph and table were created by the students using Jupyter notebook and excel, 2025

Statistical Test	Comparison	Test Statistic	p-value	Effect Size
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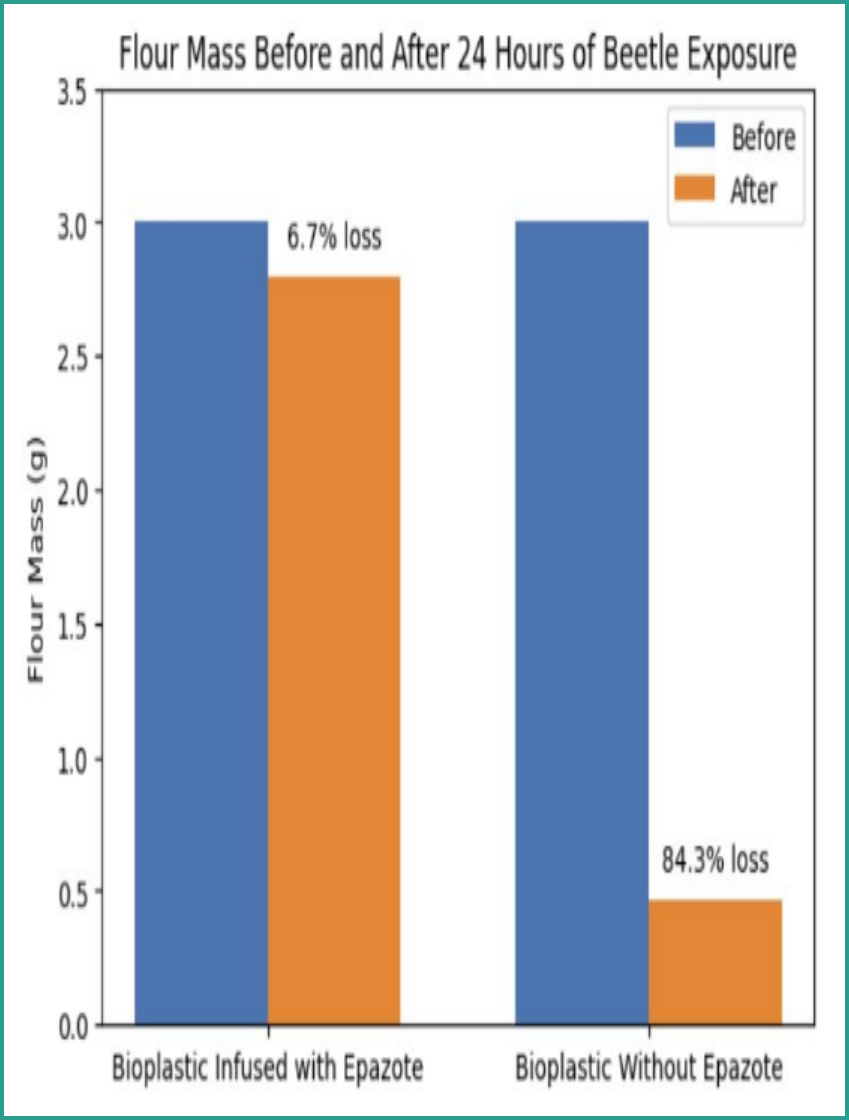
The epazote-infused bioplastic showed a statistically significant repellency effect, with far fewer beetles present compared to the control bioplastic (paired t-test, $p = 0.0016$, Cohen's $d = 2.54$), indicating a strong and meaningful reduction in beetle attraction.

Bug Repellency Test

- A bug repellency test was conducted to evaluate the insect-repellent properties of an engineered bioplastic infused with epazote using beetles as the test organism.
- Three grams (3 g) of flour were wrapped inside bioplastic samples with epazote and without epazote (control), placed in the same environment, and observed for a period of 3 hours.
- Beetle attraction was measured by the number of beetles approaching or remaining near each sample, while repellency was indicated by avoidance of the epazote-infused bioplastic.

Photo taken by the students, 2025

Results: Flour Mass



Graph was created by the students using Jupyter notebook and excel, 2025

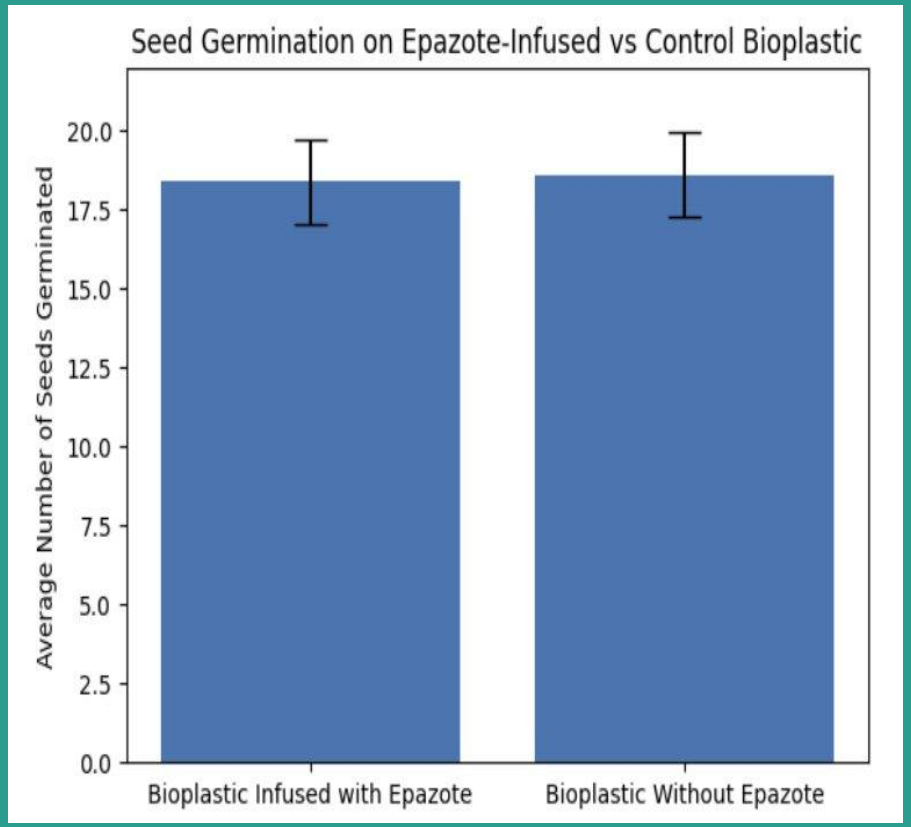
Flour Mass

- The flour wrapped in epazote-infused bioplastic showed only a 6.7% mass loss after beetle exposure, indicating minimal feeding activity.
- In contrast, the flour wrapped in bioplastic without epazote experienced an 84.3% mass loss, demonstrating high beetle attraction and feeding.
- These results provide strong evidence that epazote significantly reduces beetle feeding, supporting its effectiveness as a natural insect-repellent additive in bioplastics.

Photos taken by the students, 2025

Results: Seed Germination

The epazote did not interfere with seed germination, which can be seen on the data. Statistical analysis confirmed a strong and meaningful repellent effect with no negative impact on seed germination. Overall, the material is compatible with plant growth and stays environmentally safe.



Statistical Test	Comparison	Test Statistic	p-value	Effect Size
Paired t-test	Epazote vs Control	t = −0.27	0.8	Cohen's d = 0.12

Discussion, Conclusion, and Future Directions

Discussion

- Is the epazote-infused bioplastic effective in repelling flour beetles?

Our experiments proved that epazote efficiently repelled beetles, outperforming the bioplastic without epazote significantly, which can be seen in our repellency tests.

- Does the epazote-infused bioplastic affect the germination rates of different grades?

According to our results, the epazote showed no difference when compared to the bioplastic without epazote, showing that it does not affect seed germination. This means that our bioplastic is safe to use.

Conclusion

The epazote-infused bioplastic was proven to be effective in repelling flour beetles while maintaining the same seed germination rates as bioplastic without epazote. This demonstrates that epazote can be successfully incorporated into bioplastic as a natural insect repellent without negatively affecting plant growth.

Significance

This study highlights the potential of epazote-infused bioplastic as an environmentally friendly alternative to synthetic insect repellents. By using a natural plant-based additive, this bioplastic may help reduce pest damage in agricultural settings while remaining safe for seeds and supporting sustainable farming practices.

Future Directions

Future research could explore the long-term effectiveness of epazote-infused bioplastic under real agricultural conditions. Additional studies may also test its effectiveness against other pest species, evaluate different concentrations of epazote, and assess the biodegradability and environmental impact of the bioplastic over time.

References

- Center for International Environmental Law. (2019). *The toxic impacts of plastic across its lifecycle*. https://www.ciel.org/the-toxic-impacts-of-plastic-across-its-lifecycle/
- European Bioplastics. (n.d.). *What are bioplastics?* https://www.european-bioplastics.org/bioplastics/
- *Frontiers in Sustainable Food Systems*. (2022). Management of stored-product insect pests in food systems: Challenges and opportunities. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2022.993341/full
- Green America. (2021). *Take the plastic challenge: 7 bioplastics benefits and pitfalls*. https://www.greenamerica.org/take-plastic-challenge/7-bioplastics-benefits-and-pitfalls
- MDPI. (2017). Bioplastics from organic waste. *Sustainability*, *9*(1), 529. https://doi.org/10.3390/su9010529
- MDPI. (2019). Antimicrobial food packaging. *International Journal of Molecular Sciences*, *22*(9), 11590. https://doi.org/10.3390/ijms220911590
- National Geographic. (2019). *Plastic pollution*. https://www.nationalgeographic.com/environment/article/plastic-pollution
- Nature. (2011). Bioplastics: Sustainable materials. 478, 21. https://doi.org/10.1038/478021a
- Phenolic Plastics. (2021). Top 6 benefits of antimicrobial additives in plastic products. https://phenolicplastics.com/top-6-benefits-antimicrobial-additives-plastic-products/
- PMC. (2014). Antimicrobial polymers. Microbiology and Biotechnology, 5(4), 6927. https://pmc.ncbi.nlm.nih.gov/articles/PMC546927/
- SciDirect. (2024). Stored flour losses caused by Tribolium beetles. https://www.sciencedirect.com/science/article/abs/pii/S0022474X24001541
- St Andrews University. (2023). Mapping the beetle's wiggle could help battle global food security. https://news.st-andrews.ac.uk/archive/mapping-beetles-wiggle-could-help-battle-global-food-security
- Stored Product Insects Resource. (2021). Economic losses from Tribolium castaneum infestations. https://storedproductinsects.com/biology/economic-losses-from-tribolium-castaneum-infestations
- United Nations Environment Programme. (2021). Plastic pollution. UNEP. https://www.unep.org/plastic-pollution
- U.S. Environmental Protection Agency. (2020). Impacts of plastic pollution. EPA. https://www.epa.gov/plastics/impacts-plastic-pollution
- Wikipedia. (2021). Biofilm prevention. In Wikipedia. https://en.wikipedia.org/wiki/Biofilm_prevention