BIOFUELS AND BIOPRODUCTS (MS)

Bioplastics design challenge

Focus question	Can plant-based materials be used to engineer a biodegradable plastic?
Learning target	Students will understand how plant materials can be used to engineer biodegradable plastics, and will explore the properties, processes, and environmental benefits of creating sustainable alternatives to traditional plastics.
Vocabulary	Renewable resource, nonrenewable resource, synthetic, persistent organic pollutant (POPs), nonpersistent pollutant, biodegradable

MS-ESS3: Earth and Human Activity
MS-ETSI: Engineering Design

Performance expectation MS-ESS3-3	**Classroom connection:** Students investigate persistent organic pollutants (POPs) and nonpersistent pollutants and their ability to be broken down naturally.
Performance expectation MS-ETS1-1	Students design plant-based plastic prototypes and test these prototypes for strength and elasticity.

Science and engineering practices

Asking Questions and Defining Problems	**Classroom connection:** Students research the human impact of petroleum and plant-based plastics on the environment.
Constructing Explanations and Designing Solutions	**Classroom connection:** Students investigate potential solutions by creating and testing plant-based plastic prototypes.

Disciplinary core ideas

ESS3.C: Human Impacts on Earth Systems	**Classroom connection:** Students describe how the use of persistent plastics have integrated into the global food web and impacted natural ecosystems.
ETS1.A: Defining and Delimiting an Engineering Problem	**Classroom connection:** Students specify the constraints of the design challenge in creating plant-based plastics.

Cross-cutting concepts

Cause and Effect	**Classroom connection:** Students investigate the use of traditional plastics and their effect on the global food web.
Influence of Science, Engineering, and Technology on Society and the Natural World	**Classroom connection:** Students identify the limitations of the use of technologies employed in the generation of plant-based plastics and discuss how these technologies are driven by human needs and values.

Background

The first fully synthetic plastic, Bakelite, was invented in 1907 by Leo Baekeland. Its popularity grew significantly after WWII due to its low production cost and versatility of use. Currently, 99% of the plastic produced worldwide is considered to be a synthetic material. Plastic most often originates from petrochemicals like crude oil.

Petroleum can also be combined with other substances that make them persistent, or 'forever' materials, unable to easily degrade and break down naturally. It can take plastic anywhere from 20–500 years to decompose, but really it is only breaking apart into smaller and smaller particles. These smaller plastic particles enter the ecosystem to become a part of the global food web which leads to heterotrophic consumption. On average, humans consume 50,000 plastic particles a year.

Prior knowledge

In order to successfully complete this activity, students should understand the steps of the engineering design process and the vocabulary associated with it. They should be competent in the use of digital scales, graduated cylinders, serological pipettes, and microwave ovens.

Students should also have an understanding of food webs and the presence of persistent pollutants such as plastics in the food web.

This lesson is best implemented after students have completed lessons that address the law of conservation of matter and chemical vs. physical changes.

Suggested timing

50–100 minutes

Materials

- Cornstarch
- Soy flour
- Sorghum flour
- Water
- Glycerin
- White vinegar
- Paper cups or bowls
- Microwave
- Spoons or mixing stick
- 5- or 10-ml serological pipets
- Pipette pump
- Safety goggles
- Wax paper
- Digital scale
- 50-ml graduated cylinder
- Force meter
- Magnifying glass
- Washers or hook weights
- Ruler

Teacher preparation

1. Pass around different pieces of plastic for student groups to observe. These plastics should be composed of different materials and structures and perform various purposes. Ask students to brainstorm the properties and uses of these traditional plastics, considering both their benefits for human use and their environmental impact. Explain that most plastics are composed of nonrenewable materials such as petroleum and are persistent in our environment; whereas plant-based plastics are a more sustainable alternative that are composed of renewable crops such as corn, sorghum, and soybeans.
2. Students will design and test nonpersistent alternatives to petroleum-based plastics using corn, sorghum, soybeans, and glycerin. Provide the student groups with the student worksheet and the materials needed to create the three plant-based plastics. Once created, have the students label each plastic and allow them to dry overnight before testing.
3. On day 2, students will test each plant-based plastic and evaluate the results to determine which material produces the best plastic, comparing their properties and environmental impact to the more abundant petroleum-based plastics. Explain that students will test plant-based plastics for clarity, durability, flexibility, and strength to determine how each material performs. Define each criterion with examples:
    - Clarity: How transparent or opaque the plastic is
    - Durability: How well it holds up over time or under stress
    - Flexibility: How bendable or pliable it is without breaking
    - Strength: How much weight it can bear without tearing
4. Students will record observations and results for each test on their handouts, noting any significant differences between materials. Compare findings from each test. Discuss how each base material performed and theorize why certain materials might be more suited for specific uses. Students should record items and make notes about each of their plant-based plastics. Do a gallery walk or share out about each group's plant-based plastics.
5. Ask students to compare their plant-based plastics with traditional plastic, focusing on properties like flexibility, durability, and potential uses.
    - *Note: Consistency:* Soy meal plastic may have a more textured, opaque appearance due to protein content.
    - *Note: Flexibility:* Increasing glycerin helps improve flexibility, but the final product may still be less elastic than cornstarch-based plastics.
    - *Note: Consistency:* Sorghum-based plastic will have a more opaque, matte finish and may feel slightly firmer compared to cornstarch plastic due to the texture of sorghum meal.

Student handout

Reflection

1. What differences did you observe between plant-based plastics and petroleum plastic?

Plant-based plastic is thicker and may not be as long lasting. Petroleum plastic is durable and has a wide range of uses.

2. What did you notice about the plant-based plastic's properties?

Cornstarch is the most durable and has the greatest strength. Cornstarch turned into a very durable hard substance that could be molded into any shape before the drying process. The soy mixture was brittle and harder to spread onto the cutting board to dry. Sorghum was flexible but had no strength. It could barely hold 5 grams before pulling apart. The sorghum was more like a playdough than a hard plastic.

3. What challenges might scientists face in developing plant-based plastics?

Items that scientists might face are durability, consistency, cost, and scalability. Determining which factors consumers are looking for can vary many parts of the plant-based plastic's recipe. Using plant-based plastics on a larger scale could require new equipment and production techniques along with agricultural products.

4. Which plant-based plastic base showed the highest durability, clarity, flexibility, and strength? Why do you think that is?

Cornstarch showed the best qualities of all. Cornstarch is the most favorable material because of the properties within corn. Cornstarch is used for thickening mixtures during cooking and when turned into oobleck is very hard.

5. How might different applications (like packaging or single-use items) require different plant-based plastic properties?

Depending upon the final intended use, the plant-based plastic might change your base material. If you want a clear and strong plant-based plastic, you should choose cornstarch. If you want a more flexible and play dough-like consistency to be used as a barrier between materials, then a sorghum base would be more appropriate. For a seed coating in agriculture, you may use a soy base due to its ability to harden.

6. What are the environmental benefits of using plant-based plastics instead of traditional plastics?

Plant-based plastics have the potential to reduce dependence on fossil fuels and lower greenhouse gas emissions. Plant-based plastics are also nonpersistent and break down naturally in a much shorter time frame than petroleum plastics. Plant-based plastics are made from renewable resources like corn starch, sugarcane, potatoes, or other biomass.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** If there are nearby farms for any of the commodities that you will be using for the lesson, you could reach out to see if a farmer would be willing to come to your class to speak about the uses for their commodity and how they cultivate the product.
- **Students with special needs (auditory/visual/language/reading):** Students with special needs (auditory/visual/language/reading) will be placed in lab groups to work collaboratively with other students. If they struggle with reading, the group will work together. Stronger readers will be made the director of the group, who reads aloud the lab sheet to the rest. After which, there is discussion of how the group will proceed or what answers they will then put down on the paper. ESL students may need to utilize their translation devices with the group in order to fully communicate with their peers.
- **Extra Support:** The following resources may be provided to offer some additional support:
  - Plastics 101: National Geographic video: `live.myvrspot.com/iframe?v=fMmI3YmI5ZTgzYjMxY2JhZGUxZGMwNzAzM2EyZTE3Mzc`
  - PBS NewsHour: The Problem with Plastics video: `live.myvrspot.com/iframe?v=fNzhlNGY5NmJjMjIyMWU4NTFmN2NhNDZjNTVjNGVjNGY`
  - Plastech Products website: `plastechproducts.com`
- **Extensions:** Students can continue to explore the environmental impact of plastics through their own research and communicate these findings to the class. This could be done with a visual or as a presentation. You could also allow students to use their data to create their own recipe and retest the plant-based plastics.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Asking questions and defining problems for the human impact of plastics on natural ecosystems	Inconsistent or minimal contribution with group members.	Consistent contribution with group members to ask questions and define human impact of plastics on natural environments.	Leading contributor of group discussion to encourage questions and research human impact of plastics on natural environments.
Specifying constraints and designing solutions for plant-based plastics	Relies heavily on limited information provided by his/her own group only. Did not take into account the shared information of similarities and differences of solutions found from other lab groups.	Utilizes information from multiple engineering groups adequately. Takes into account the information of similarities and differences of the solutions from other lab groups.	Effectively incorporates information from all engineering groups to determine the best solution. Takes into account the information of similarities and differences of the solutions from other lab groups and applies all the information to develop and improve the final solution.
Determining the correlation between the influence of plastic technologies and human impact on the environment	Minimal understanding of petroleum and plant-based plastics in the environment and human impact due to plastic consumption.	Able to provide a good description of petroleum and plant-based plastics in the environment and human impact on plastic consumption.	Leading contributor to outline the impacts of petroleum and plant-based plastics in the environment and discuss potential solutions to human use for future impact.

Rubric for self-assessment

Skill	Yes	No	Unsure
I understand that traditional plastics are persistent organic pollutants and do not break down naturally.			
I actively contributed to the success of the engineering group.			
I was able to compare and contrast plant-based plastic materials effectively in order to modify our plant-based plastic bag.			
I understand that materials used in traditional plastic products have an impact on the environment and food web.			