Renewable packing peanuts lab activity

Overview

During this lab activity, students will learn what a renewable and non- renewable material is. Additionally, the different options to produce packaging materials for many applications. This activity will teach students how industrial packing peanuts are made from polystyrene and will create awareness regarding the accumulation of plastics in landfills. Students will produce a more environmentally friendly option to replace the polystyrene peanuts using starch to produce starch-based packaging peanuts. Students will produce starch-based packaging peanuts and will compare its performance to polystyrene-based packaging peanuts

Objectives

Students will

1. Learn the difference between renewable and non-renewable materials
2. Learn how to make a sustainable packaging material
3. Explain the chemistry and interactions of making starch-based packaging peanuts
4. Test the performance of two types of packaging
5. Develop knowledge and awareness about sustainable options to reduce the plastic consumption for packaging materials

Content Standards

This lesson is appropriate for earth/environmental science, biology, physical science, and chemistry students, and it addresses the following standards:

North Carolina Essential Standards

Earth/Environmental	EEn.2.2.1, EEn.2.6.3, EEn.2.8.1, EEn.2.8.4
Biology	Bio.2.1.1, Bio.2.2.1, Bio.2.2.2
Physical Science	PSc.2.1.1, PSc.2.1.2, PSc.2.1.3, PSc.2.2.5
Chemistry	Chm.2.1.1, Chm.2.2.2

Next Generation Science Standards

Grades 9-12, Science and Engineering Practices and Cross-cutting Concepts:

Science and Engineering Practices	Asking Questions and Defining Problems; Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data; Using Mathematical and Computational Thinking; Constructing Explanations and Designing Solutions

Cross-Cutting Concepts	Patterns, Cause & Effect: Mechanism and Predictions; Scale, Proportion, and Quantity; Structure and Function

Time Requirements
The following are estimated times

- Preparation time by instructor 15 minutes
- Lab activity experiments 30 minutes
- Class discussion 15 minutes

Materials
Included in the kit:

- 3x16 oz boxes of corn starch
- Baking powder
- 10 oz glycerol
- 8 fl oz bottle of iodine
- Paper cups, 3oz not line with wax. (not sure whether this can be included)

Needed but nor supplied

- 3oz paper cups not line with wax
- Tap water
- Measuring spoons
- Microwave

Safety
Ensure that students understand and adhere to safe laboratory practices when performing any activity in the classroom or lab. Demonstrate the protocol for correctly using the instruments and materials necessary to complete the activities, and emphasize the importance of proper usage. Use personal protective equipment such as safety glasses or goggles, gloves, and aprons when appropriate. Model proper laboratory safety practices for your students and require them to adhere to all laboratory safety rules.

Background Information
The demand for packaging materials is exponentially increasing due to the e-commerce market. There are three different types of packaging. Primary packaging has the shape of the actual product, secondary packaging are those of small groups of primary packaging, and the tertiary level is for bulk handling (e.g., corrugated cardboard packing, bubble wrap and packaging peanuts). Packing peanuts are used to occupy the free spaces between a product and its shipping container to protect during transportation. The most common material used for the production of packaging peanuts is polystyrene. Figure 1. presents the chemical structure. Polystyrene is widely used for packaging applications (i.e., food containers, packing peanuts). However, polystyrene is a non-renewable material produced from petroleum, and it can take more than hundreds of years to decompose.

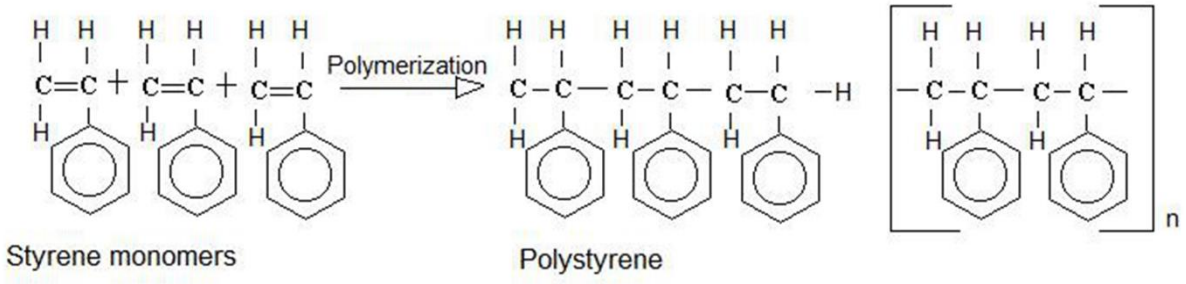


Figure 1. Chemical structure of polystyrene

In 2017, containers and packaging materials represented a large portion of the municipal solid waste (MSW), accounting for 30% (~80.1 million tons) (EPA, 2017). Since polystyrene can not degrade, one solution to reduce the dependance of polyestyrene packaging peanuts is to replace it for a renewable material such as starch.

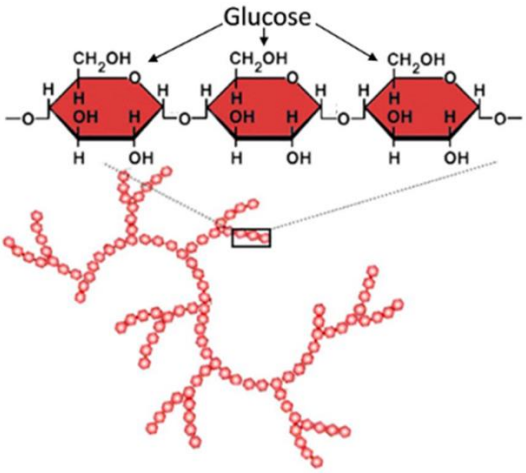


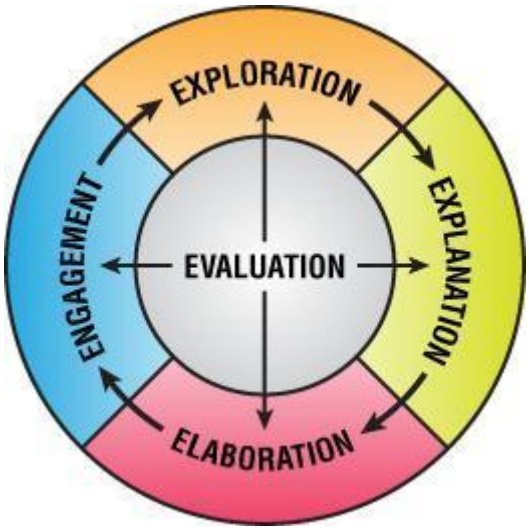
Figure 2. Starch structure

Starch is a natural polymer composed of many units of glucose, it is found in biomass (e.g., rice, corn, wheat, tapioca, and potato), it is renewable since you can plant crops and harvest many types, and depending on the season, every year (Le Corre et al. 2010)**.** The primary sources of starch are maize (82%), wheat (8%, potatoes (5%), and cassava (5%). Packing peanuts can be produced from starch, and it is biodegradable, which means that it can be reduced or degrade using microorganisms such as bacteria and fungi into water (Gadhave et al. 2018).

Preparation

1. To have ready all the materials as well as equipment such as microondas, water, egg (for performance test), Ziploc bag, small container boxes nearby.
2. The teacher can divide students into teams, and each team can develop each activity separately.

Guiding the lesson using the 5E Learning Cycle



Engage 10min

Before the activity, the teacher should review whether all materials are available. Discuss the many types of packaging materials used and present the content below.

1. Examples of the different packaging materials
2. Video about packaging peanuts
    - https://www.youtube.com/watch?v=k1LjKOdOpdM
3. Show how starch-packaging peanuts are made industrially.
    - https://www.youtube.com/watch?v=WR9h1fzfTeY
4. Show video of how starch-packaging peanuts degrade in water
    - https://www.youtube.com/watch?v=wdWRx05P4I0

Explore (15 min)

Set up students in groups of two or three and develop the following activities.

Activity 1. Fluff starch peanut (5 min)

a. Mix 1 tablespoon of corn starch to a paper cup.
b. Add 1 tablespoon of tap water to the same paper cup.
c. Stir this mixture until all the hard clumps are gone, and it becomes watery.
d. Microwave the paper cup for 30 seconds. (Note: pay attention to time, it could vary with different microwaves. Add a napkin below the paper cup just in case it overflows)
e. Take the paper cup out of the microwave and let cool.
f. Once the cup has cooled down enough to hold, peel the paper cup off the starch.
g. Record your observations of the resulting starch peanut.

Activity 2. Fluffier starch peanut (5 min)

a. Mix 1 tablespoon of corn starch and ¼ teaspoon of baking powder to a paper cup.
b. Add 1 tablespoon of tap water to the same paper cup.
c. Stir this mixture until all the hard clumps are gone, and it becomes watery.

d. Microwave the paper cup for 30 seconds. (Note: pay attention to time, it could vary with different microwaves. Add a napkin below the paper cup just in case it overflows)
e. Take the paper cup out of the microwave and let cool.
f. Once the cup has cooled down enough to hold, peel the paper cup off the starch.

Record your observations of the resulting starch peanut.

Activity 3. Even more flexible and fluffier starch peanut (5 min)

a. Mix 1 tablespoon of corn starch and ¼ teaspoon of baking powder to a paper cup.
b. Add 1 teaspoon of glycerol and 2 teaspoons of tap water to the same paper cup.
c. Stir this mixture until all the hard clumps are gone, and it becomes watery.
d. Microwave the paper cup for 40 seconds. (Note: pay attention to time, it could vary with different microwaves. Add a napkin below the paper cup just in case it overflows).
e. Take the paper cup out of the microwave and let cool.
f. Once the cup has cooled down enough to hold, peel the paper cup off the starch.
g. Record your observations of the resulting starch peanut.

Explain (10 min)

- Make sure students understand what is happening in each packaging peanut activity, the addition of every component produces interactions and hydrogen bonds that increases and changes the height of the peanuts into a fluffier and flexible one.
- The teacher and class discuss the chemical reactions occurring.
  a) When water and baking powder mix produces, it produces carboxylic acid that eventually releases dioxide. $HCO_3^-(aq) + H^+(aq) \rightarrow H_2O(l) + CO_2(g)$ This carbon dioxide produces bubbles through the mixture, and it gives fluffiness to the packaging peanut.
  b) The addition of glycerol is to increase the performance of the packaging peanut. Glycerol is a type of plasticizer which can make the resultant packaging peanut more durable and flexible.

Elaborate (15 min)

- Develop a performance test to simulate that packaging peanuts can protect an item as they would industrially protect equipments. To achieve this:
  a. Add an egg in a Ziploc bag insert, and in a small container, box add a few starch-based packaging peanuts (note: enough o protect the egg on the sides and bottom).
  b. Drop the box and test different heights until the egg breaks. Measure height and time.
  c. Calculate speed and discuss what speed is required to break the egg.

$$v = \frac{height\ (ft)}{time\ (seconds)}$$

- Do the packaging peanut dissolve in water? To test this, follow the next procedure.
    a. Add a few starch-based packaging peanuts in blender with enough water. (take notes about the findings)
    b. Add a few polystyrene packaging peanuts in a blender. (take notes about the findings)

Evaluate (20 min)

- Ask the questions and discuss with students
- Discuss awareness of reducing the use of non-renewable resources

Differentiated Learning and Extension Activity ideas

Students could make some changes to the lab activities.

a) Change of components ratio to see if there is any different when increasing or reducing amounts of glycerol
b) Students can change the time and see how this affects the structure of the packaging peanut
c) Students can try to use a different container instead of paper cups

Answers to Questions in the Student Guide

1. Do you notice a difference in the three types of packaging peanuts?
   Each peanut packing starts to get fluffier and more flexible

2. What happens when baking powder is added to the mix?
   The packaging peanut increases in height and flexibility

3. What happens when glycerol is added to the mix?
   Glycerol is a plasticizer, and it makes the packaging peanuts even more flexible

4. What chemical interaction occurs between the components in the mix?
   The interactions between the components water, baking powder, and glycerol forms hydrogen bonds

5. What speed does it take for the egg brake? Report height and time.
   I have measure up to 7 ft height, and it did not brake.
   $$v = \frac{height\ (ft)}{time\ (seconds)}\ units\ of\ the\ speed: \frac{ft}{s}$$

6. Why yes/not does the starch dissolves in water?
   Yes, it dissolves in water because starch is polar, and water is polar as well. Rule of thumb, equal dissolves equal

7. Why yes/not does the polystyrene dissolve in water?

It does not dissolve, because polystyrene is non-polar and can not be dissolved in water.

Supplemental Resources

Never throw packing peanuts away
https://www.youtube.com/watch?v=k1LjKOdOpdM

Biodegradable packing peanuts
https://www.youtube.com/watch?v=bccGGusPFZA&t=24s

Eco-friendly Packing peanuts –Science experiment
https://www.youtube.com/watch?v=wdWRx05P4I0

EPA, 2017: Containers and Packaging: product-Specific data
https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/containers-and-packaging-product-specific-data

Le Corre, D., Bras, J., and Dufresne, A. (2010). "Starch nanoparticles: A review," *Biomacromolecules*, 11(5), 1139–1153. DOI: 10.1021/bm901428y

Gadhave, R. V., Das, A., Mahanwar, P. A., and Gadekar, P. T. (2018). "Starch Based Bio-Plastics: The Future of Sustainable Packaging," *Open Journal of Polymer Chemistry*, 08(02), 21–33. DOI: 10.4236/ojpchem.2018.82003

Name _____ **Student Guide**
Date _____

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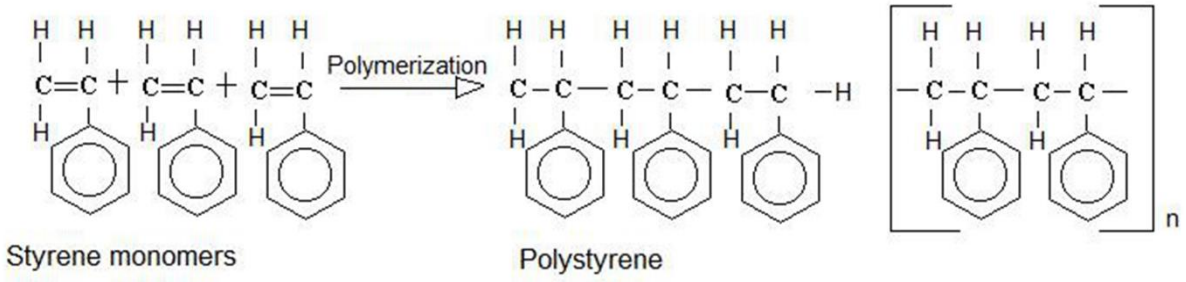

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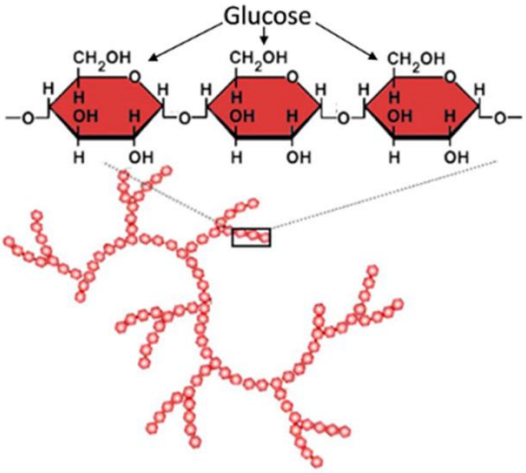

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Procedure

Manufacture of renewable packaging peanuts

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Performance testing

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Questions

1. Do you notice a difference in the three types of packaging peanuts?
2. What happens when baking powder is added to the mix?
3. What happens when glycerol is added to the mix?
4. What chemical interaction occurs between the components in the mix?
5. What speed does it take for the egg brake? Report height and time.
6. Why yes/not does the starch dissolves in water?
7. Why yes/not does the polystyrene dissolve in water?