Fermentation in a Bag

Overview

In this simple experiment, students investigate the process of fermentation in resealable bags with bakers yeast, warm water and various sources of plant sugar. Students observe and measure evidence of the chemical changes associated with fermentation: bag inflation (CO_2) and indicators of ethanol production. Younger students can observe fermentation in a single bag, while older students can create multiple set-ups to compare how yeast ferments sugar, starch and cellulose-based biomass options. Students can measure and compare fermentation rates between feedstocks using a variety of methods including ethanol probes, breathalyzers or bag inflation. This activity works well in a variety of formal and nonformal educational settings. In the classroom setting, it can serve as an engaging activity to launch more in-depth investigations into biofuels.

Fermentation in a Bag – Recommended Procedure:

1. In a snack-size resealable zipper bag, combine 1 teaspoon of sugar (or another feedstock) and 1 teaspoon of yeast.
2. Add 50 mL (1/4 cup) of warm tap water (approx 40˚ C) and seal bag closed, removing as much air as possible.
3. Mix gently. Lay bag on a flat surface and watch for results – fastest results should be achieved in 15 minutes.**
4. Optional: Measure and compare ethanol and/or CO_2 production using ethanol probes, breathalyzers, rulers, etc. Discuss and interpret results.

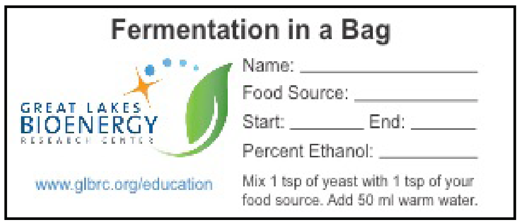
***Warning: As the yeast produce carbon dioxide, the bag will expand – it may even pop! Be sure to monitor the bag and release the gas if it becomes too inflated.*

The Investigation

Using table sugar (sucrose) as a feedstock will yield the most rapid results. Some alternate feedstocks include corn meal, ground corn stover, sawdust, finely ground grass clippings, dead leaves, composting materials, etc. Feedstocks with a starchy or fibrous composition will not ferment as well. For an inquiry version, have students bring in and choose their own feedstocks. Students can also develop their own methods to measure fermentation and extend the investigation by changing variables to increase fermentation rates.

Labels

Bag labels formatted for Avery Template 5163 are included in this package. Below is a sample label:



Master Materials List

Required:

- Dry active yeast (one 4 oz. jar contains approximately 36 teaspoons of yeast, which will make 36 bags)
- Warm water source
- Small graduated cylinders (100mL)
- Measuring spoons (one teaspoon for each feedstock source and the yeast to avoid cross-contamination)
- Feedstock(s): sugar, cornmeal, corn stover, sawdust, etc.
- Resealable zipper bags (“snack” size) with fill-in labels (see Supplementary Materials for label template).

Recommended:

- Rulers to measure bag inflation. See Supplementary Materials for instructions.
- Classroom-grade ethanol probe (Vernier or PASCO) or breathalyzer for detecting ethanol levels. See Supplementary Materials for instructions.
- 2-4 liter thermos (with spout) for dispensing warm tap water
- Paper towels

Suggestions for Running the Activity in the Classroom

We suggest using Fermentation in a Bag as an engaging activity to launch a discussion and investigation into two overarching questions:

1. Why are researchers investigating how to make fuels from plants?
2. How can we make fuels from plants?

To address question #1, we provide suggestions and materials for introducing how biofuels, which are being developed by GLBRC researchers, can help with the climate change problem. To address question #2, we suggest using this activity to introduce fermentation and how the process is used to make ethanol biofuel from plants. By comparing the fermentation of sugar to inedible, fibrous plant parts (cellulosic biomass), this activity can serve an launching point to discuss the methods GLBRC researchers are using to convert inedible, waste plant parts to fuels and its potential benefits.

We encourage using this activity to launch a more in-depth investigation into the sustainable production of biofuels. More detailed suggestions for running this activity and follow-up lessons are described below.

Before the Experiment - Introduction to Biofuels, Fossil Fuels and the Climate Change Problem (Part 1):

- See the slides and student handouts in the activity package that accompany this activity. Depending on student background knowledge and objectives, you can shorten the introduction.
- After a short discussion on “What is a fuel?” (Slides 2-3), give students the short reading on fossil fuels, biofuels and climate change. Have students answer the follow-up questions and discuss answers in small groups.
- Pool student responses to questions 1-3 comparing fossil fuels and biofuels. Students can use the accompanying worksheet to organize their ideas. Key ideas: Both fuels come from plants and the energy in plants comes from sunlight. However, fossil fuels are made from ancient plants and biofuels are made from recently living plants.
- Use slides 5-7 to review the process of making fossil fuels and biofuels. For this activity, don’t worry about the details. The focus is on where the trapped carbon (from CO_2) in the plant biomass is going in the two scenarios.
- After small group discussion, have students share ideas about how biofuels might help with the climate change problem. Project slide 9 and have students use the diagram to support their explanations. Ask students to try to identify what processes (i.e. photosynthesis or combustion) are associated with each arrow. The goal is to introduce the idea of recycling recent carbon vs releasing fossil carbon. It’s OK if students have trouble with this. See suggestions below for follow-up activities to investigate this question in depth.
- Introduce the biofuel ethanol. See what students have heard about it, and share some characteristics and uses (Slide 10). If possible, give students some ethanol to observe and then demonstrate how ethanol burns.

Fermentation in a Bag Experiment (Part 2):

- Introduce the problem, “How can we make fuels from plants?” Elicit student ideas (Slide 2) and introduce fermentation (Slide 3).
- Discuss the questions to be investigated: 1) “What chemical changes happen during fermentation?” and 2) “How well can yeast ferment different sources of plant sugar?” (Slides 4-10).

- Review the experimental protocol and biomass options. Have students make initial predictions and explanations for expected results. Use accompanying worksheet and Slides 11-14. Having students work in pairs helps promote debate.
- Have students set up their fermentation in a bag trials and make observations over 10-30 minutes. See supplementary instructions and videos for measurement options for fermentation (% ethanol with probes, BAC with breathalyzers and/or bag height with rulers).
- Have students summarize what changes they observed in small groups and then as a class using the worksheet and Slide 15. During discussion, guide students to identify evidence to support their claims about the substances in the bag before and after the experiment. Depending on the level of students, you can synthesize class results in a simple equation. For example, sugar + yeast $\rightarrow$ ethanol + gas + leftover yeast. To develop a detailed understanding of the chemical changes at the molecular level, follow-up this activity with the Biofuels vs Fossil Fuels Unit.
- Synthesize class results and compare plant sugar sources. Use Slide 16 or a similar data table to pool class results. See sample data below for an idea of what to expect and an explanation. See if the class can come to a consensus conclusion about which option fermented better based on the data. Explore possible explanations.

Follow-up discussion - Comparing Ethanol Production Pathways (Part 3):

- Have students compare the processes by which ethanol is produced from sugar, starch and cellulosic sources. Use Slides 3-5 as handouts for students to examine in small groups and to help build their explanations for why the differences were observed in the fermentation of the different biomass options.
- As a class, discuss why most ethanol today is made from sugar cane and corn and why we are trying to develop more efficient ways to make ethanol from cellullosic sources (Slides 6-8).

Extensions & Variations

1. Read and discuss a research story about Dr. Donna Bates, GLBRC scientist currently investigating fermentation in A Modern Scientist-Engineer in the World of Fermentation.
2. Use this activity as a warm-up for the GLBRC Fermentation Challenge investigation in which students test how changing different variables such as pH, temperature or yeast strain can affect fermentation rates.
3. Extend the learning with the Data Dive: Boosting Yeast's Appetite for Sugars by having students learn about how scientists are using directed evolution techniques to create mutant yeast strains than can ferment all of the sugars in plant biomass, not just the glucose.
4. Students can investigate the process of making ethanol from cellulosic sources such as corn stover or sawdust using the GLBRC CB2E: Cellulosic Biomass to Ethanol lab.
5. For a thorough investigation into the production and use of biofuels vs. fossil fuels, the processes of combustion, photosynthesis and fermentation, and how fuels impact the carbon cycle see the Biofuels vs. Fossil Fuels Unit.
6. Fermentation in a Bag can be adapted to use a variety of feedstocks and different instructional approaches.

See the example inquiry version described in "Supporting Materials" in which students bring in their own feedstocks and develop different methods to measure fermentation.

Running the Activities at Science Fair Outreach Events

Prep time: 30-60 minutes, depending on event/group size

Activity time: 5-minute bag set-up, observe for 10-30 minutes.

Fermentation in a Bag is a fun, engaging activity for learners of all ages at family-oriented "science fair" events. We have used this activity at numerous tabletop "exploration stations" where visitors can set up their own fermentation experiment by choosing from feedstock options, adding yeast and water to pre-labeled bags and watching the reaction. After setting up the experiment, the participants return in 10-30 mintutes to make final observations, take ethanol readings and compare and discuss results. Participants can add their data to a public data table and discuss patterns in a "crowdsourced" experiment. Props such as biomass samples (corn stalks, switchgrass, corn grain), a jar of ethanol, and the Grassoline poster in this package are useful for discussions about where biofuels come from.

In a fun variation, we have also developed a "Fermentation on a Necklace" version of this activity in which participants attach the bag to string around their neck so they can make and share observations on the road. In this version, use a single hole punch to create two small holes on the top of both sides of each bag. Then, use an elastic neck cord (such as from a necklace-style name tag) or other string to create a loop. The fermenting bag can now be worn as a necklace.

Supplemental Materials

- Extra bags, feedstock, yeast and other dispensable goods
- Props such as biomass samples (corn stalks, switchgrass, corn grain), a jar of ethanol, and the

Sample Results

Sample ethanol probe data: The following ethanol readings were measured after 20 minutes using a Vernier ethanol probe.** Data was measured in percent ethanol.

	SUGAR	CORNMEAL	CORN STOVER
	0.77	0.40	0.16
	3.18	0.35	0.11
	2.61	0.29	0.14
	2.95	0.27	0.20
	2.72	0.29	0.16
	2.91	0.32	0.21
	2.98	0.25	0.17
	1.72	0.29	0.18
	2.66	0.21	0.24
	3.21	0.24	0.18
	2.86	0.26	0.25
	2.52	0.22	0.19
Average:	2.59	0.28	0.18

Interpreting results: Yeast only has the ability to "eat" simple sugars such as glucose, fructose and sucrose. This explains why table sugar (sucrose) produced the highest ethanol yields. Cornmeal is primarily starch, a polymer (long chain) of glucose. Yeast does have the enzymes required to break down starch into glucose, but this happens slowly so we see less fermentation. Corn stover - ground up corn stalks - is primarily made up of cellulose. Cellulose is also a polymer of glucose molecules, but it is wrapped up inside the plant cell wall and very difficult to break down. There are virtually no sugars available for yeast in corn stover and yeast cannot produce the enzymes needed to break cellulose down into glucose. Yeast are able to produce small amounts of ethanol in corn stover because there is a little bit of sugar in the dry yeast mixture. This is similar to the amount of ethanol that would be produced from combining yeast and water.

**See Supplemental Materials for instructions and sample data taken using bag height measurements with a ruler and BAC readings with a breathalyzer.

Standards

Next Generation Science Standards (2013)

Performance Expectations

Elementary School:

- **K-LS1-1.** Use observations to describe patterns of what plants and animals (including humans) need to survive.

High School:

- **HS-LS2-3.** Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

Scientific and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and carrying out investigations Analyzing and interpreting data Engaging in argument from evidence	**LS1:** From Molecules to Organisms: Structures and processes **LS2:** Ecosystems: Interactions, energy, and dynamics	Patterns Cause and effect: Mechanism and explanation Energy and matter: Flows, cycles and conservation