Fermentation in a Bag Measurement Method: Bag Height

Overview

Fermentation produces ethanol and carbon dioxide. As the fermentation reaction occurs, the plastic bag will inflate with gas indicating the extent of the reaction. Students can use rulers to measure bag height as a measure of fermentation rates between samples. Taking bag height measurements can be used as an inexpensive, low technology alternative to finding percent ethanol or BAC measurements. Bag height readings can also supplement ethanol readings, allowing students to compare results using different measurement techniques and analyze and explain relationships between bag inflation and ethanol production.

During fermentation, yeast consume glucose and produce ethanol and carbon dioxide as byproducts:

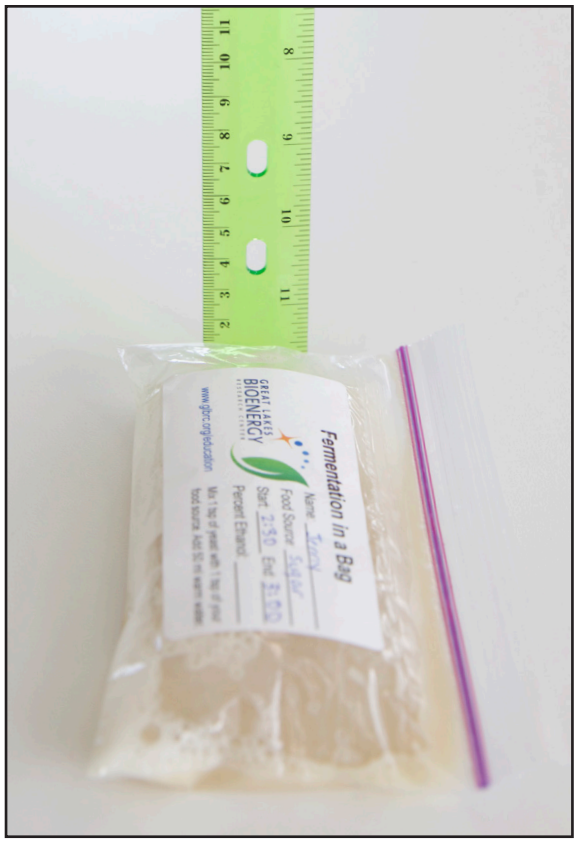
$$C_6H_{12}O_6 \text{ —> } 2CH_3CH_2OH + 2CO_2$$

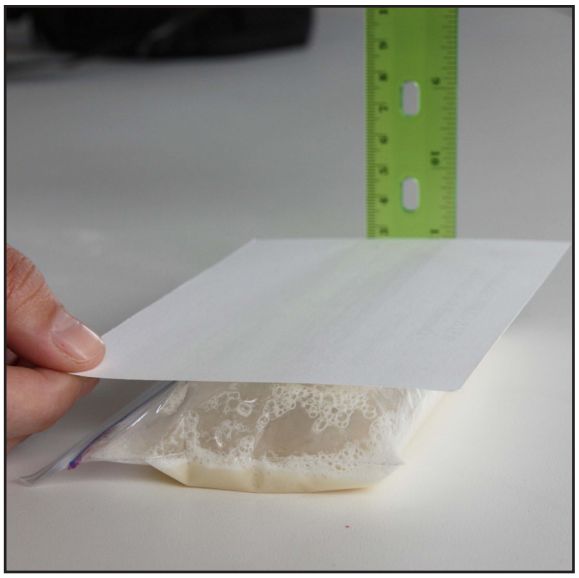
glucose —> ethanol + carbon dioxide

The CO_2 generated during fermentation causes the bag to inflate. Because CO_2 and ethanol are generated in the same proportions in the reaction, measuring CO_2 production can indicate how much ethanol is produced.

Supplemental Materials

- Ruler or tape measure
- Rigid paper (index card), cardboard, or other flat object (optional)





Left: Lay the fermenting bag flat on a table or other stable surface. Hold a ruler perpendicular to the table, eye the highest point of the inflated bag and record the height of the bag.
Above: For more accurate measurments, place a flat object (like a notecard) on top of the bag, parallel to the table and record where the paper intersects the ruler.

Protocol

Follow the basic recipe and protocol for Fermentation in a Bag. Ensure that students remove as much air as possible before sealing their bags. To take a measurement, have students measure the height of their bag by placing a ruler perpendicular to the table and measuring to the top of the bag. For more precise measurements, students can place a rigid, flat object (like an index card or piece of cardboard) on top of their bag and record where the paper intersects their ruler.

Students can take height measurements every 5 minutes and plot height versus time. After 20-30 minutes, bags with sugar will approach their max height. For this reason, we recommend taking final height readings after ~20 minutes.

Compare final bag heights for different feedstocks and/or fermentation rates. Fermentation rates can be calculated by plotting height vs time, fitting a line to the points and then calculating the slope of the line. The slope of the line is the reaction rate (mm of inflation per minute).

See sample data and graphs below for expected bag height and ethanol results. By comparing bag height to ethanol, students can collect evidence to discover the basic fermentation reaction equation.

Sample Data

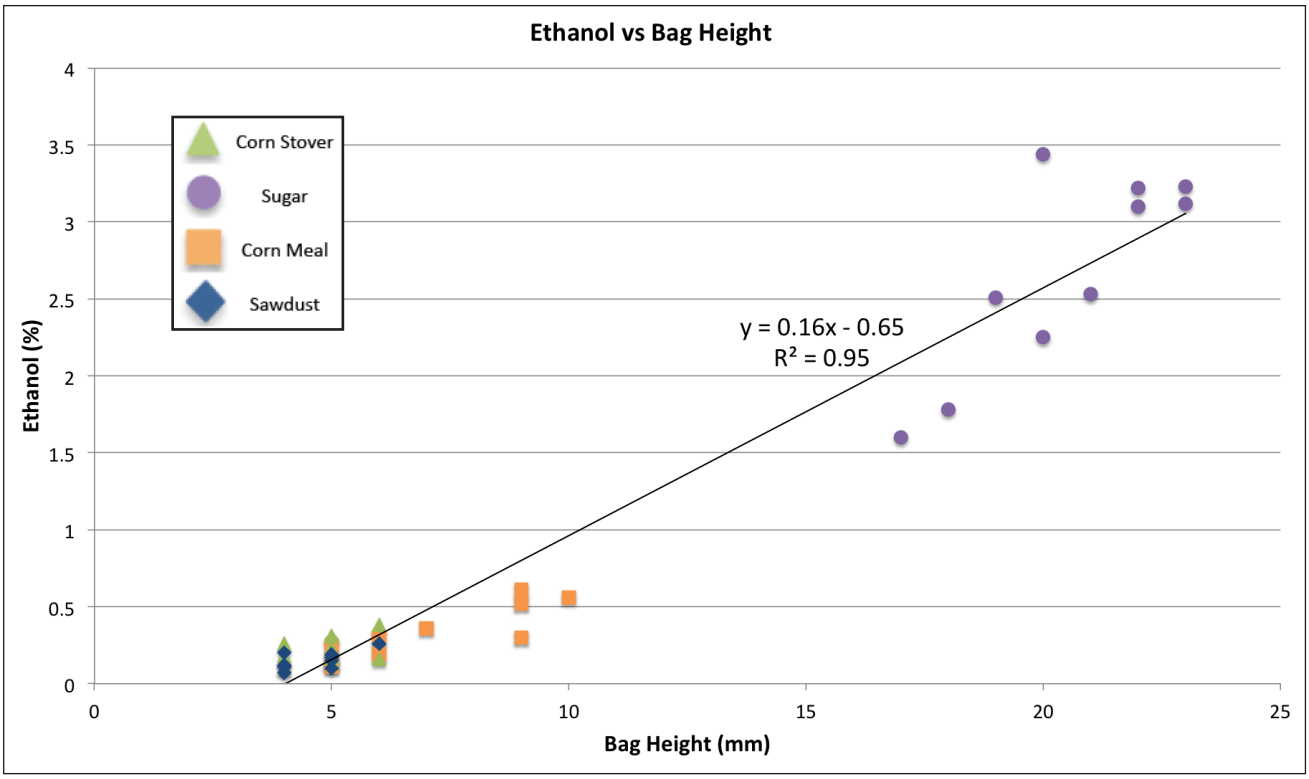
See data below for bag height (in millimeters) and percent ethanol for different feedstocks after 25 minutes. Height was measured with a ruler and percent ethanol was measured with a classroom-grade ethanol probe (Vernier or PASCO). The results indicate that bag height is a reasonably accurate measure of fermentation rate.

Replicate	Sugar height (mm)	Sugar ethanol (%)	Cornmeal height (mm)	Cornmeal ethanol (%)	Corn stover height (mm)	Corn stover ethanol (%)	Sawdust height (mm)	Sawdust ethanol (%)
1	23	3.12	10	0.56	5	0.29	4	0.07
2	19	2.51	9	0.30	4	0.18	4	0.12
3	22	3.10	9	0.52	5	0.14	5	0.17
4	23	3.23	5	0.14	5	0.31	4	0.20
5	20	3.44	5	0.24	6	0.38	5	0.10
6	22	3.22	6	0.30	4	0.26	5	0.15
7	17	1.60	6	0.19	5	0.17	5	0.19
8	18	1.78	7	0.36	4	0.10	4	0.12
9	20	2.25	9	0.61	5	0.23	6	0.26
10	21	2.53	5	0.11	6	0.16	4	0.11
Average:	**20.5**	**2.678**	**7.1**	**0.333**	**4.9**	**0.222**	**4.6**	**0.149**
Standard error:	**0.654**	**0.204**	**0.623**	**0.059**	**0.233**	**0.028**	**0.221**	**0.018**

Sample Graphs

Ethanol vs Bag Height

Plotting the above data (percent ethanol vs bag height) reveals a strong correlation between bag height (CO_2 production) and ethanol production ($R^2 = 0.95$). Classes who do not have access to ethanol probes can use the linear regression model and this plot to reasonably estimate percent ethanol based upon bag height readings.



Bag Height vs Time

Fermentation rates can be calculated by plotting height vs time, fitting a line to the points and then calculating the slope of the line. The slope of the line is the fermentation rate (mm of inflation per minute). In the sample graph below, the inflation rate is 0.55 mm/min.

Time (min)	Height (mm)
0	3
5	6
10	9
15	11
20	13
25	17
30	20