



# The Power of Poop

Methane production through anaerobic fermentation

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## Overview

This activity is designed to demonstrate anaerobic fermentation by having students build small-scale anaerobic digesters. The digester is made using a 2-liter plastic soda bottle. Students collect gas using a simple collection device and further design and perform controlled experiments using their digesters. The amount of gas produced will be a quantitative measurement of the effects of the variables.

## Biology and agriculture concepts

Methane production  
Anaerobic fermentation  
Environmentally safe agricultural waste treatment  
Decomposition  
Incorporation of new technology  
Alternative energy sources  
Carbon cycle

## The Teachable Moment

The biology teacher can best use this experiment when teaching topics such as the nitrogen and carbon cycles, microbiology, ecology or fermentation. This unit illustrates principles of decomposition very well. For the agriculture teacher, this experiment compliments the teaching of proper animal waste disposal and management as well as the digestion process itself. The experiment could also prompt discussion of the implementation of new technologies to existing farm practices.

## Background

Have you wondered why manure smells? What gases cause the odor and can those gases be utilized for something productive? The following experiment is designed to explore these questions and other related concepts. Through the process of anaerobic fermentation, students will process common local animal wastes—materials that have historically been considered a management problem—into useful products.

Anaerobic fermentation of organic matter is a three-stage chemical process. (See Fig. 1). The first stage involves the hydrolysis of cellulose and hemicellulose, major components of animal manure, by bacteria. The products of these chemical reactions are further transformed to the compounds acetate, propionate, and butyrate.

In the second stage, acetogenic bacteria act on these soluble organics to produce additional acetate. Accompanying this process is the co-reaction of the hydrogen ( $H_2$ ) reduction of carbon dioxide ( $CO_2$ ) to produce methane ( $CH_4$ ).

In the third stage, acetate is fermented by bacteria producing methane and carbon dioxide. Common examples of methanogenic bacteria are Methanobrevibacter ruminantium and Methanosarcina barkeri.

The products of anaerobic fermentation are useful in a variety of agricultural applications. High in nitrogen, the dry matter is a valuable fertilizer when applied as a soil amendment. The methane gas produced can be used as fuel for heat and electricity. Small-scale and large-scale anaerobic digesters are used around the world to manage waste and generate energy.

Concepts covered in this activity can foster discussion of the potential career opportunities for students in microbiology, agricultural engineering, biochemistry, ecology and agricultural extension.

There are two experimental options presented here. In option A, a student investigates gas production using one type of manure. Option B is a comparative study of the digestion of two different manures.

**Option A: Anaerobic Digester Activity**

After students have set up their anaerobic digester, they will record gas production in a table and then design a point graph. Because they are collecting data in a syringe with units of cc, they will have to convert this to ml.; simply 1cc = 1 ml.

**Option B: Anaerobic Digester Experiment**

You may have students design an experiment to test a hypothesis generated during class discussion. For example, students may want to use a different type of manure to determine which produces more methane. Students could record their information in a data table and then produce a bar graph.

**Teacher Management**

Preparation time	It takes about 30 minutes to build an anaerobic digester (you may want to glue tubing and cap a day in advance). Allow approximately 30 additional minutes to prepare for either option A or B.
Activity time	Allow approximately 45 minutes for teacher demonstration and student construction. Option A will take a total of two class periods. Depending on the design of the experiment, preparation time for option B will vary.
Materials	2-liter plastic bottles Plastic tubing Silicone rubber sealant Manure or another type organic matter (compost, mulched straw, etc.) Corn Syrup or glucose Lime (CaCO <sub>3</sub> ) -- Do not use the hydrated form as this will produce an exothermic reaction and deform the digester bottle. 30 ml syringe Velcro

### Sources of materials

Encourage students to bring in their own soda bottles and manure or organize a class field trip to gather these materials. Lime and dry manure can be purchased from your local lawn and garden store or farmer's coop.

### Tips and safety

Be sure that students achieve an air-tight seal between the rubber tubing and the bottle cap. Do this by using silicone sealant above and below the cap. As mentioned in the estimate of preparation time, you may want to seal the cap a day in advance.

If one uses dry manure, keep in mind that the manure will double in volume when water is added.

Try to obtain partially decomposed material. If fresh matter is used it will take longer for gas to be produced.

Invert digester at regular intervals to maintain a homogeneous mixture.

As the digestion progresses, the pH of the digester will decrease. For maximum methane production, the pH should be maintained around 8.5. If the experiment is not producing any gas, the pH may have dropped too low and you will need to add lime.

Temperature greatly influences the outcome of these experiments. Room temperature should be adequate for constant gas production.

Be sure **not** to position digester above the collection device. You will create a siphon.

To save on space and number of bottles needed for the experiment, one collection device can serve several digesters.

### Key Terms

**Anaerobic fermentation:** conversion of carbohydrates, in the absence of oxygen, to alcohol, lactic acid or similar compounds.

**Methane:**  $\text{CH}_4$ , a combustible gas, the end product of fermentation by methanogenic bacteria.

**Methanogenic bacteria:** bacteria that obtain their energy for growth from the oxidation of compounds such as hydrogen and the reduction of carbon dioxide to methane. They are strictly anaerobic.

## References

Hills, D. J. and D. W. Roberts. 1981. Anaerobic digestion of dairy manure and field crop residues. Agricultural Wastes vol. 3:179-189.

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Pfeffer, J. T. 1979. Anaerobic digestion processes. Anaerobic Digestion. Edited by D. A. Stafford and B. I. Wheatley. Applied Science Publishers, Ltd. London.

Zeeman, G., K. Sutter, T. Vens, M. Koster, and A. Wellinger. 1988. Psychrophilic digestion of dairy cattle and pig manure: start-up procedures of batch, fed-batch and CSTR-type digesters. Biological Wastes vol. 26:15-31.

# The Power of Poop

## Gas production through anaerobic fermentation

### Introduction

Have you ever wondered why manure smells so badly? What gases cause that odor and can those gases be utilized for something productive? The following experiment is designed to explore these questions and other related concepts.

Through the process of anaerobic fermentation, common local animal wastes—materials that have historically been considered a management problem—are processed into useful products. The purpose of this experiment is to design and observe a small scale anaerobic digester capable of processing wastes. What applications could this process have in your local community?

### Materials

Two plastic soda bottles (either 16 oz, 1-liter or 2-liter depending on the size of digester you want to make)  
Plastic tubing  
Silicone rubber sealant  
Manure or some other type of liquefied organic matter  
Corn syrup or glucose  
Lime ( $\text{CaCO}_3$ )  
Large syringe  
Velcro

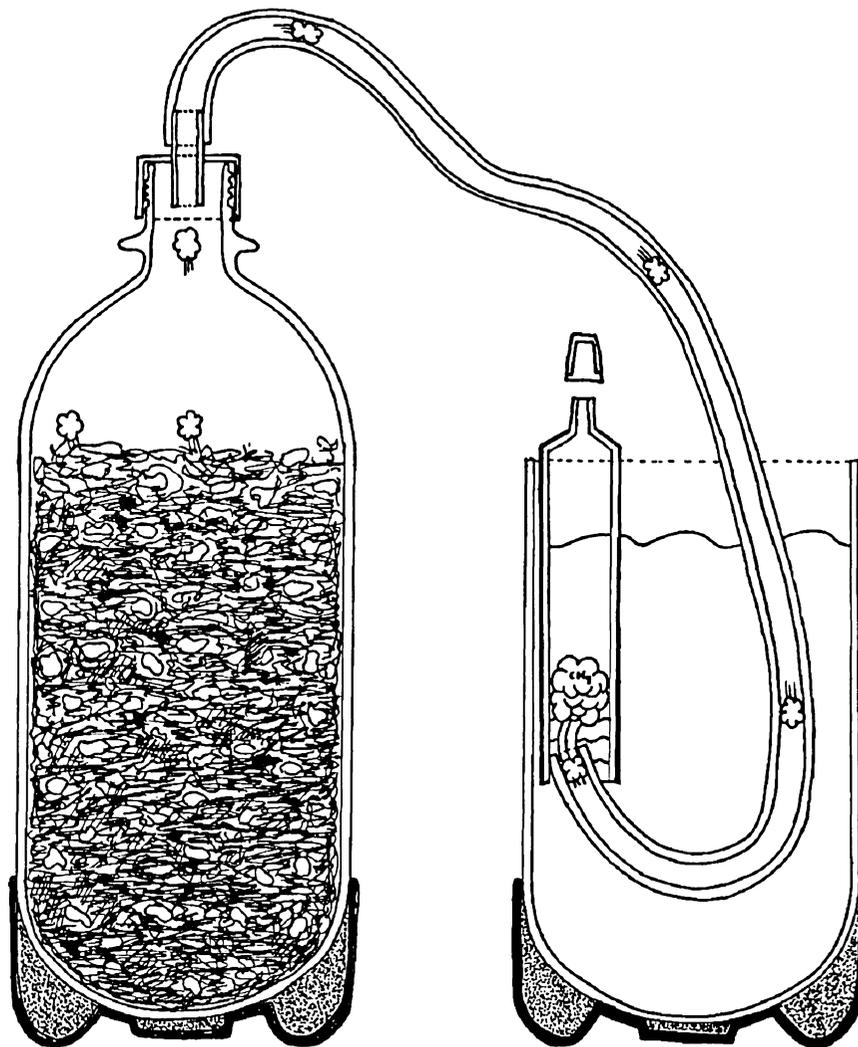
### Procedure

Constructing your digester: (See diagram)

1. Punch a hole slightly smaller than the diameter of the plastic tubing in the cap a soda bottle.
2. Using silicon sealer, seal around the plastic tubing on both sides of the cap.
3. Remove the labels from your soda bottle.
4. Prepare a manure slurry by mixing a 1:1 ratio of water and dry manure together. Use discretion for varying degrees of organic matter.
5. Pour a manure slurry into the bottle.
6. Add 50 mls of corn syrup and 4 tablespoons lime.

### Constructing the collection device:

1. Remove label and cut bottle about 2 inches below shoulder.
2. Attach velcro to syringe and rim of bottle.
3. Fill base with water up to velcro.
4. Attach inverted syringe full of water.
5. Insert tube under syringe.



Digester

Collection device

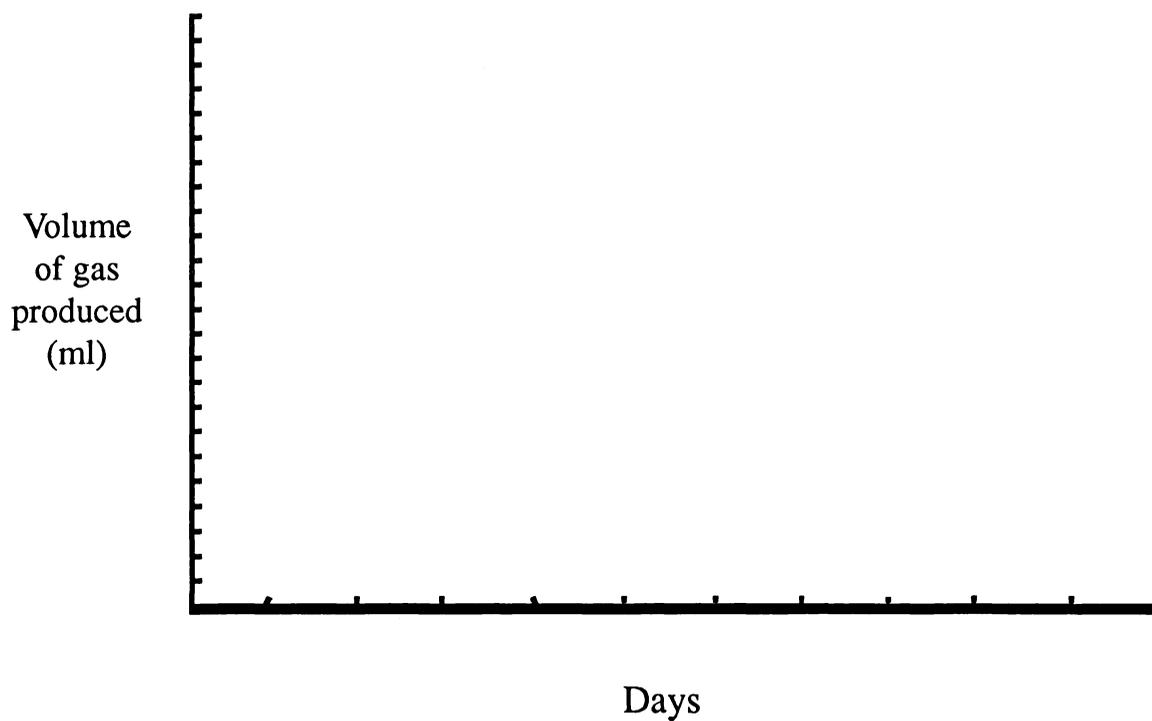
## Data Sheets for Option A: Anaerobic digester activity

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Data Table 1: Daily gas production of anaerobic fermentation

	Day									
	1	2	3	4	5	6	7	8	9	10
Volume of gas produced (ml)										

Graph 1: Daily gas production of anaerobic fermentation



Observations: \_\_\_\_\_  
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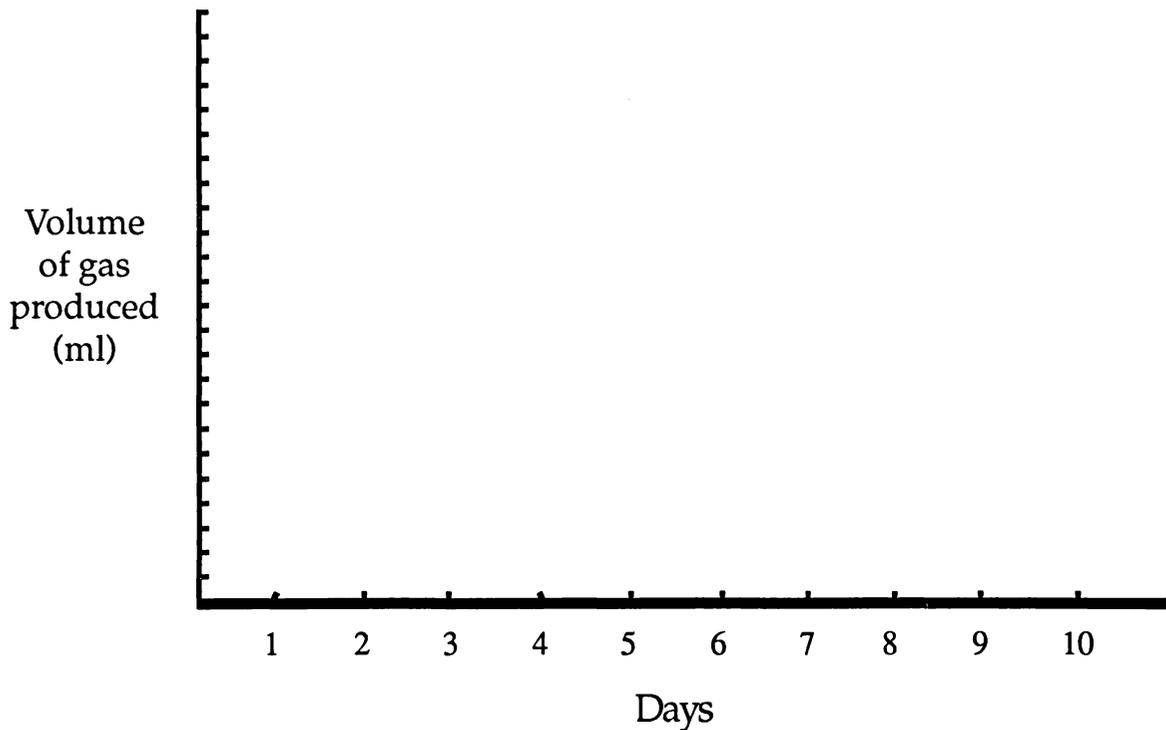
## Data Sheets for Option B: Anaerobic digester experiment

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Data Table 1: Daily gas production of anaerobic fermentation

Volume of gas produced (ml)	Day									
	1	2	3	4	5	6	7	8	9	10
Control										
Experimental										

Graph 1: Daily gas production of anaerobic fermentation



Observations and description of control and experimental conditions : \_\_\_\_\_

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## **Student Worksheet for Option B: Anaerobic digester experiment**

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1. State your hypothesis.
2. What was the variable in your experiment?
3. Compare the amount of gas produced in the experimental with the control.
4. What other differences can be observed between the control and the experimental?
5. Was your hypothesis supported? Explain.
6. How can this process be used to address present waste disposal problems?
7. How can this process be used to address present energy problems?

## Results and discussion

- Did your results support your hypothesis?
- Were there any problems with your experiment?
- Are there ways you might change your experiment next time?

## Extensions

If you enjoyed these experiments, you may want to continue further. The following are questions you might explore.

- Would varying the temperature of the digester have an effect on gas production?
- Would varying the pH level of the digester effect gas production?
- Would varying the amount of agitation you give the digester effect gas production?
- Would different manures produce different amounts of gas?
- How could you test for the presence of methane? of carbon dioxide?
- Could you use the product of the digester for fertilizer?