Calorimetry: Measuring the Energy in Foods

A Carolina Essentials™ Investigation

Overview

During this investigation, students will determine the calories—or heat content—of 3 different foods. From the experiment setup and data collected, students will have the evidence necessary to construct a model of heat transferred through the reaction of food with oxygen. Students will then apply their model to cellular respiration.

Life Science
Grade: 9–12

Phenomenon

As a teacher demonstration, place a marshmallow on a paperclip and burn it until only ash remains. Ask students what has changed and why.

Essential Question

How are bonds of food molecules broken and new compounds formed, resulting in a net transfer of energy?

Allow students to discuss their ideas about the burning marshmallow. Guide them to remember that a marshmallow is very high in sugar. As the sugar burns, carbon ash is produced and heat or thermal energy is released. Some students may recognize that the thermal energy is responsible for melting the inner layers of the marshmallow while the outside burns.

Investigation Objective

1. Use a calorimeter to determine the number of calories in 3 samples of food.
2. Construct a model to illustrate the flow of energy through a calorimetry experiment and relate the model to what happens in cells.

Next Generation Science Standards* (NGSS)

PE HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.C: Organization for Matter and Energy Flow in Organisms** • As a result of chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.	**Energy and Matter** • Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

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TIME REQUIREMENTS

PREP	ACTIVITY
30 min	45-60 min

Teacher Prep: 20–30 min
Student Activity: 45–60 min

SAFETY REQUIREMENTS

MATERIALS (PER GROUP)

Soda can (empty with tab still attached)

Stirring rod

Support stand and 2 rings

Thermometer

Graduated cylinder, 100 mL

2 large paper clips

3 food samples with nutrition labels (2 to 3 g each of samples such as nuts, marshmallows, dry crackers, or chips)

Water

Matches

Aluminum foil (10 cm × 10 cm)

Electronic balance

Cork stopper (optional)

HELPFUL LINKS

Carolina ChemKits®: It's Not the Heat, It's Thermochemistry

REFERENCE KITS

Carolina BioKits®: Food Nutrient Analysis

CAROLINA®
www.carolina.com

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Safety Procedures and Precautions

Use safety glasses or goggles and be cautious with the matches and burning food samples. Check for food allergies before using food samples. Sensitive individuals should not participate in any activities that may result in exposure. Never eat or drink in lab.

Teacher Preparation and Disposal

To reduce student setup time, put 2 rings on each support stand. Place a smaller ring (to suspend the thermometer) above a larger ring from which to suspend the soda can. Remind students to dump the water out of the can before recycling it. All food, ash, and scraps can be rolled up in the aluminum foil and disposed of in the trash.

Student Procedure

1. Using the graduated cylinder, obtain 50 mL of water and carefully pour it into the soda can.
2. Determine the mass of water and the can. Record the mass of water in the data table (hint: density of water = 1 g/mL).
3. Hold the paper clip horizontally and bend the outer end upwards until it reaches a 90° angle to the rest of the paper clip.
4. Obtain a food sample that weighs 2 or 3 g—Sample #1.
5. Place the food sample on the end of the paper clip that extends upward. The sample should be freestanding, supported by the bottom of the paper clip (see Figure 1). Determine the initial mass of the food sample and paper clip, and record your findings in the data table.
6. Place a small piece of aluminum foil underneath the paper clip in a space that has been cleared of all flammables.
7. Insert the stirring rod through the soda can tab and position the can in the ring stand so the stirring rod supports it (see Figure 2).
8. Adjust the ring stand until the can is approximately 4 cm above the food sample.
9. Suspend the thermometer inside the can. The thermometer bulb should be in the water but not touching the bottom of the can. Unfold the second paper clip and use it as a hook to suspend the thermometer from the top ring.
10. Determine the initial temperature of the water in the can and record this value in the data table.
11. Carefully light a match and use it to light the food sample.
12. Allow the lit sample to heat the water in the can. Gently stir the water periodically with the thermometer (see Figure 3).
13. Monitor the temperature change of the water and record the highest observed temperature in the data table.
14. Once the food sample has burned, find the mass of the remaining food sample and paper clip. Record this value in the data table.
15. Repeat steps 1 through 14 for each of the remaining food samples.

Teacher Preparation and Tips

To save student time, prepare ring stands and food samples ahead of time.

For water, 1 g = 1 mL.

If the paper clip is unstable, student can insert the paper clip into a cork stopper or tape the base of the paper clip to the aluminum foil.

Triscuit and Cheez-It crackers work well. Dry nuts work well too, if no students have nut allergies. Foods advertised as "hot" may have jalapeno oil and produce a high, long-lasting flame that leaves a sticky residue.

Different foods produce different heights of flames. Circulate around the room to make sure the flame is not too far from the can. A large distance will increase error.

Remind students that the thermometer bulb should be in the water and not touching the bottom of the can.

Students should blow the match out and place it on the aluminum foil.

Remind students to read the thermometer at eye level with the thermometer bulb remaining in the water.

It is OK to brush off ashes before weighing.

Start with water that is close to the same temperature each time.

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Data and Observations

Student answers will vary in mass, and the final temperature of the water will vary with the type of food burned.

	Sample #1	Sample #2	Sample #3
Mass of Water	*50 g*	*49 g*	*50 g*
Initial Mass of Food Sample and Paper Clip	*4.2 g*	*3.7 g*	*3.2 g*
Initial Water Temperature (°C)	*18° C*	*18° C*	*19° C*
Final Water Temperature (°C)	*51° C*	*67° C*	*62° C*
Final Mass of Food Sample and Paper Clip After Burning	*2.7 g*	*1.7 g*	*1.6 g*

Analysis and Discussion

Using Sample 1 data

1. Determine the mass of food that actually burned. (Initial Mass of Food Sample and Paper Clip – Final Mass of Food Sample and Paper Clip After Burning) *1.5 g*

2. Determine the change in temperature of water, ΔT. *33 °C*

3. Calculate the energy (in calories) released by the burning food sample and absorbed by the water.

   $$Q = mCp\Delta T$$

   Q = heat absorbed by water, m = mass of water in grams, *Cp* = 1 cal/g °C, *ΔT* = change in temperature

   Q = *50 g X 1 cal/g °C X 33 °C = 1650 cal*

   Compare your calculated calories to the food nutrition label. Describe any differences. ***Student answer should be much higher because calories, NOT kilocalories, are calculated.***

4. Food calories, as read off a nutrition label, are actually kilocalories (often denoted as "calories" with a capital C). There are 1,000 calories in a kilocalorie, or food calorie. Determine the number of kilocalories (food calories) released by the burning food sample (1 kilocalorie, or calorie = 1,000 calories).

   1650 cal × 1 kilocal/1000 cal. = 1.65 kcal

5. Calculate the energy content of the food in kilocalories/gram.

   1.65 kcal/1.5 g = 1.1 kcal/g

6. Using information on the nutrition label of the food sample, calculate the food manufacturer's kilocalories/gram. (Divide calories per serving by the number of grams in a serving.)

   90 Cal/ 38 g = 2.37 kilocal/gram

7. Compare your experimentally determined energy content (in kilocalories/gram) to the calculated value from the nutrition label. Calculate the percent error for your experiment.

   (2.37 kcal/ gram – 1.1 kcal/gram) / 2.37 kcal/gram = 0.54 × 100 = 54%

   Sources of error may include heat lost to the can and to the air. Some of the heat was transferred to the can to warm it up, and some may have been transferred to the air between the food and can.

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Analysis and Discussion continued

8. Draw and label a model of energy transfers that take place during this activity. Be as detailed as possible. ***Student models can vary but should include these energy transfers: photosynthesis stored chemical energy in plant sugars ⟶ plant sugars burned/oxidized (chemical energy is changed to thermal energy as bonds are broken and then reformed in products) ⟶ thermal energy transferred to can and water in the can through convection.***
9. Explain how the calorimetry model compares to what happens in a cell. ***Cells "burn" or oxidize food on a smaller level during respiration. Food is broken down through digestion and sugar molecules are broken down into usable chemical energy and thermal energy. As bonds are broken in the sugar molecules and reformed in products, energy is released in the form of heat.***

TEACHER NOTES

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