Measuring Calories
Energy Content of Food

Introduction

All human activity requires "burning" food for energy. How much energy is released when food burns in the body? How is the calorie content of food determined? Let's investigate the calorie content of different snack foods, such as popcorn, peanuts, marshmallows, and cheese puffs.

Concepts

- Combustion reaction
- Calorimetry
- Nutritional Calorie
- Calorie content of foods

Background

What does it mean to say that we burn food in our bodies? The digestion and metabolism of food converts the chemical constituents of food to carbon dioxide and water. This is the same overall reaction that occurs when organic molecules—such as carbohydrates, proteins, and fats—are burned in the presence of oxygen. The reaction of an organic compound with oxygen to produce carbon dioxide, water, and heat is called a *combustion reaction*. The chemical equation for the most important reaction in our metabolism, the combustion of glucose, is shown in Equation 1.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{heat} \qquad \textit{Equation 1}$$

Within our bodies, the energy released by the combustion of food molecules is converted to heat energy (to maintain our constant body temperature), mechanical energy (to move our muscles), and electrical energy (for nerve transmission). The total amount of energy released by the digestion and metabolism of a particular food is referred to as its *calorie content* and is expressed in units of nutritional Calories (note the uppercase C). A *nutritional Calorie,* abbreviated Cal, is equivalent to a unit of energy called a kilocalorie, or 1000 calories (note the lower case c). One calorie is defined as the amount of heat required to raise the temperature of 1 gram of water by 1 °C. (This is also the definition of the specific heat of water.) The calorie content of most prepared foods is listed on their nutritional information labels.

Nutritionists and food scientists measure the calorie content of food by burning the food in a special device called a calorimeter. *Calorimetry* is the measurement of the amount of heat energy produced in a reaction. Calorimetry experiments are carried out by measuring the temperature change in water that is in contact with or surrounds the reactants and products. (The reactants and products together are referred to as the system, the water as the surroundings.)

In a typical calorimetry experiment, the reaction of a known mass of reactant(s) is carried out either directly in or surrounded by a known quantity of water and the temperature increase or decrease in the water surroundings is measured. The temperature change (ΔT) produced in the water is related to the amount of heat energy (q) absorbed or released by the reaction system according to the following equation:

$$q = m \times s \times \Delta T \qquad \textit{Equation 2}$$

where m is the mass of water, s is the specific heat of water, and ΔT is the observed temperature change. As mentioned above, the specific heat of water—defined as the amount of heat required to increase the temperature of one gram of water by 1 °C—is equal to 1 cal/g·°C.

Experiment Overview

The purpose of this experiment is to determine the amount of heat energy released when different snack foods burn and identify patterns in the calorie or energy content of snack foods.

Pre-Lab Questions

1. A candy bar has a total mass of 2.5 ounces. In a calorimetry experiment, a 1.0-g sample of this candy bar was burned in a calorimeter surrounded by 1000. g of water. The temperature of the water in contact with the burning candy bar was measured and found to increase from an initial temperature of 21.2 °C to a final temperature of 24.3 °C.

   (a) Calculate the amount of heat in *calories* released when the 1.0-g sample burned.

   (b) Convert the heat in calories to nutritional Calories and divide by the mass of the burned sample in grams to obtain the *energy content* (also called fuel value) in units of Calories per gram.

   (c) Multiply this value by the total number of grams in the candy bar to calculate the total *calorie content* of the candy bar in Calories. *Hint:* Convert the mass in ounces to grams.

2. Consult the nutritional labels on two of your favorite snack foods: Report their total calorie content (total Calories) and calculate their fuel value (Calories per gram).

Materials

Balance, centigram (0.01 g precision)
Calorimeter and lid*
Erlenmeyer flask with plastic spill-rim collar, 125-mL
Food holder (cork) and pin
Graduated cylinder, 50-mL
Matches
Snack foods (cheese puffs, peanuts, marshmallows, popcorn, etc.), 2 pieces
Stirring rod
Thermometer or temperature sensor
Water

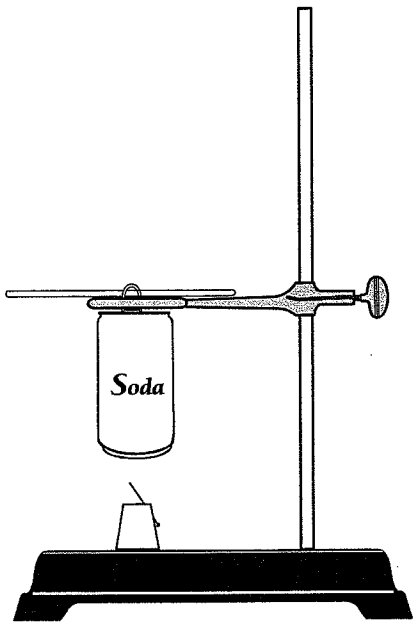
*Or "soda-can" calorimeter. See the *Alternative Procedure* section.

Safety Precautions

Wear safety goggles whenever working with chemicals, glassware, or heat in the laboratory. Exercise care when handling hot glassware and equipment. Allow the burned snack food sample to cool before handling it. The food-grade items that have been brought into the lab are considered laboratory chemicals and are for laboratory use only. Do not taste or ingest any materials in the chemistry laboratory. Wash hands thoroughly with soap and water before leaving the lab.

Alternative Procedure. A "Soda-Can" Calorimeter

1. Place a food sample on the food holder. Measure and record the combined mass of the food holder and sample. Place the food holder on a ring stand.
2. Obtain a clean, empty soda can. Measure and record its mass.
3. Add about 50 mL of tap water to the can and measure the combined mass of the can and water.
4. Bend the top tab on the can up and slide a stirring rod through the hole. Suspend the can on a ring stand using a metal ring. Adjust the height of the can so that it is about 2.5 cm above the food holder.
5. Insert a thermometer into the can. Measure and record the initial temperature of the water.
6. Light the food sample and center it under the soda can. Allow the water to be heated until the food sample stops burning. Record the maximum (final) temperature of the water in the can.
7. Measure and record the final mass of the food holder and sample.
8. Clean the bottom of the can and remove any food residue from the food holder. Repeat the procedure with a second food sample.



Name: _____

Class/Lab Period: _____

Measuring Calories

Data Table. *The Calorimetry Experiment*

Food Sample	Initial Mass (Food Sample and Holder), g	Final Mass (Food Sample and Holder), g	Initial Temperature (Water), °C	Final Temperature (Water), °C

Post-Lab Calculations and Analysis *(Use a separate sheet of paper to answer the following questions.)*

Construct a *Results Table* to enter all of the following information and summarize the results.

1. Determine the mass of water heated in the calorimeter for each food sample.
2. Calculate the change in temperature (ΔT) for each sample.
3. Use the heat equation (Equation 2) to calculate the heat (q) absorbed by the water in the calorimeter for each food sample. Report the results in *calories, kilocalories,* and *nutritional Calories.*
4. Subtract the final mass of the food sample and holder from the initial mass to determine the mass in grams of the food sample that burned in each experiment.
5. Use the results from Questions #3 and 4 to calculate the energy content (fuel value) of the food sample in units of *Calories per gram* (Cal/g).
6. Record your results for the energy content of foods along with those of other groups in the class on the overhead projector or the board. Be sure to record the identity of the food sample.
7. Copy all of the results and use the class data to calculate the *average energy content* in units of Cal/g for different types of snack foods. Construct a *Class Results Table* to summarize the results.
8. Rank the snack foods in order of their average energy content, from highest to lowest. Which snack food has the highest energy content? The lowest?
9. Based on your knowledge of the fat content of different snack foods (if necessary, consult their nutritional labels to obtain this information), make a general statement describing the relative energy content of high-fat versus low-fat snack foods.
10. Consider the major sources of error in this experiment. Do you think your results are off on the high side or the low side? Explain.