Energy Content of Foods

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The energy content of foods is investigated. The energy released by a number of food samples and absorbed by water is determined using technology. Inferences about the energy content of foods with high fat content and foods with high carbohydrate content are then made.

Hypothesis

Foods, depending on their carbohydrate/fat composition, have different energy content that can be determined by measuring the heat release from their combustion.

Primary Learning Outcomes

At the end of this lesson, students will be able to:

- Be familiarized with data collection using the Vernier LabPro and TI calculator
- Be familiarized with the use of the Vernier LabPro temperature probe
- Collect, graph, display and make inferences from data
- Determine the amount of heat released by a substance given the specific heat capacity (C_p) of water, the mass (m) of the food sample and the change in temperature (Δt)

Assessed GPS

<u>Characteristics of Science:</u>

Habits of Mind:

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

a. Follow correct procedures for use of scientific apparatus.
b. Demonstrate appropriate techniques in all laboratory situations.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.
c. Collect, organize and record appropriate data.
d. Graphically compare and analyze data points and/or summary statistics.
e. Develop reasonable conclusions based on data collected.
f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

a. Develop and use systematic procedures for recording and organizing information.
b. Use technology to produce tables and graphs.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

<u>Content:</u>

SC6. Students will understand the effects motion of atoms and molecules in chemical and physical processes.

b. Collect data and calculate the amount of heat given off or taken in by chemical or physical processes.

Duration
90 minutes

Materials and Equipment

- utility clamp
- 2 stirring rods
- ring stand and 10-cm (4-inch) ring
- 100-mL graduated cylinder
- small can
- cold water
- matches
- 2 food samples
- food holder
- wooden splint

Technology Connection

- Vernier LabPro interface
- TI Graphing Calculator
- Vernier DataMate program
- Vernier Temperature Probe

Procedures
Note: Students may be asked in advance to review Chemistry text Section 11.1 and have at least one news/informational article from any source ready to discuss in anticipation of this activity. Optionally, students may refer to Chemistry text Sections 27.2 and 27.4.

Step 1: Introduction/Motivation, 20 minutes
Break class up into groups for introductory discussion and subsequent activity.
Present two dishes: one dish of a food with a high carbohydrate content (such as marshmallows, breadsticks, etc) and another of a food with a high fat content (such as peanuts, butter, etc.). Lead a discussion of the way people gauge the nutritive quality of food. Elicit responses as to the kinds of things people look for when assessing the nutritive quality (thus, the desirability) of foods. Some examples may include: % of the recommended RDA allowance, Vitamins & Minerals, grams of fat, protein, sugar, calories, % calories from fat. When eliciting responses, elicit further information about the meaning of each of these criteria. After a brief discussion of the nutrition criteria given by students, begin focus on the concept of the calorie.

Why do marathon runners eat pasta the night before the marathon? What do we mean when we say "burning calories"?
All members of the animal kingdom, including humans, get the chemical energy needed for biological functions from ingested **proteins**, **carbohydrates** and **lipids**. Proteins are used by organisms as building blocks and for a large number of specific functions. Carbohydrates are used for energy storage and cell structure. Lipids, or fats as they are commonly referred to, play a number of roles, including that of high-energy storage. Fat storage of energy works a bit differently than that of sugar storage. One important difference is in their structure: all commonly eaten sugars contain mainly single bonds, while many commonly eaten fats have a number of double bonds. What is the effect of a molecule having a more **unsaturated** (i.e., presence of double bonds) character on the amount of storable energy compared to a molecule with a mainly **saturated** (i.e., mainly single bonds) character?

The purpose of this activity is to see if we can find out for ourselves what the energy content of common foods is and whether we can show that, gram-for-gram, fats have a different energy content than carbohydrates.

Define the equation for the calculation of the heat released/absorbed of a substance given the mass of the substance and the specific heat of that substance:

$q = C_p \times m \times \Delta t$

where C_p is the **specific heat**, or the heat needed to raise the temperature of 1 g by 1 K,

m is the **mass** of the substance

Δt = final temperature – initial temperature

In this activity, we will burn various foods, but instead of measuring the heat released by the burning food, we will measure the heat absorbed by a sample of water that will be heated by the burning food. In this way, we can use the mass of the food sample, but use the C_p (which we know) and Δt (which we can measure) of the water. C_p of water is given as 4.18 J/g˚C. We will burn both fat-rich and sugar-rich food samples, calculate the energy content of those samples, and see whether we can see similarities and/or differences in their energy storage.

Step 2: Activity, 50 minutes

Students will break up into groups and conduct activity "Energy Content of Foods" as outlined in student activity handout.

Recommendations:

- A large paper clip may be shaped to be able to hold a food sample. Partially straighten one end of the paper clip, then loop the end. The loop will hold the sample. The other end of the paper clip may be shaped into a V shape to serve as the base. For added sturdiness, and to catch burnt material, the base could be glued onto the underside of a small jar lid such as a baby-food jar lid. Small soup cans or aluminum cans may be used to hold the water.
- Students are recommended to use 100-mL volumes of water for high fat foods such as nuts, as these foods will release more heat.
- Water initial temperature is recommended to be 15-18˚C for best results.

Step 3: Review, 20 minutes

Gather students as a class and discuss results, answers to the review questions given at the end of the student handout, and any problems or questions with the procedure. Unused food material may be made available to the class during review.

Assessment

Completed student worksheets will be collected and graded.
Student understanding of activity components may be assessed by unit examination.
Student affect and work ethic may be assessed by affect/ethic rubric.

References

Holmquist, D.D., Randall, J. & Volz, D. (2000). Chemistry with Calculators. pp. 1-1 – 1-T3. Vernier Software & Technology: Beaverton, Oregon.

Wilbraham, A.C., Staley, D.D., Matta, M.S., Waterman, E.L. (2002). Chemistry: Addison-Wesley. Prentice Hall: Needham, Massachusetts

Energy Content of Foods

All human activity requires "burning" food for energy. In this experiment, you will determine the energy released (in kJ/g) as various foods, such as cashews, marshmallows, peanuts, and popcorn, burn. You will look for patterns in the amounts of energy released during burning of the different foods.

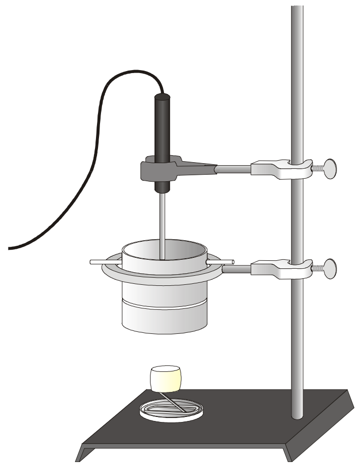

Figure 1

MATERIALS

LabPro or CBL 2 interface	utility clamp
TI Graphing Calculator	2 stirring rods
DataMate program	ring stand and 10-cm (4-inch) ring
Temperature Probe	100-mL graduated cylinder
2 food samples	small can
food holder	cold water
wooden splint	matches

PROCEDURE

1. Obtain and wear goggles.
2. Plug the Temperature Probe into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
3. Turn on the calculator and start the DATAMATE program. Press CLEAR to reset the program.
4. Set up the calculator and interface for the Temperature Probe.
   a. Select SETUP from the main screen.
   b. If the calculator displays a Temperature Probe in CH 1, proceed directly to Step 5. If it does not, continue with this step to set up your sensor manually.
   c. Press ENTER to select CH 1.
   d. Select TEMPERATURE from the SELECT SENSOR menu.
   e. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
5. Set up the data-collection mode.

a. To select MODE, press ▲ once and press ENTER.
b. Select TIME GRAPH from the SELECT MODE menu.
c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
d. Enter “6” as the time between samples in seconds.
e. Enter “100” as the number of samples. The length of the data collection will be 10 minutes.
f. Select OK to return to the setup screen.
g. Select OK again to return to the main screen.

6. Obtain a piece of one of the two foods assigned to you and a food holder like the one shown in Figure 1. Find and record the initial mass of the food sample and food holder. **CAUTION:** *Do not eat or drink in the laboratory.*

7. Determine and record the mass of an empty can. Add 50 mL of cold water to the can. Obtain the cold water from your teacher. Determine and record the mass of the can and water.

8. Set up the apparatus as shown in Figure 1. Use a ring and stirring rod to suspend the can about 2.5 cm (1 inch) above the food sample. Use a utility clamp to suspend the Temperature Probe in the water. The probe should not touch the bottom of the can. Remember: The Temperature Probe must be in the water for at least 30 seconds before you do Step 9.

9. Select START to begin collecting data. Record the initial temperature of the water, t_1, in your data table (round to the nearest 0.1°C). Note: You can monitor temperature in the upper-right corner of the real-time graph displayed on the calculator screen. Remove the food sample from under the can and use a wooden splint to light it. Quickly place the burning food sample directly under the center of the can. Allow the water to be heated until the food sample stops burning. **CAUTION:** *Keep hair and clothing away from open flames.*

10. Continue stirring the water until the temperature stops rising. Record this maximum temperature, t_2. Data collection will stop after 10 minutes (or press the STO▶ key to stop *before* 10 minutes has elapsed).

11. Determine and record the final mass of the food sample and food holder.

12. To confirm the initial (t_1) and final (t_2) values you recorded earlier, examine the data points along the curve on the displayed graph. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are displayed below the graph.

13. Press ENTER to return to the main screen. Select START to repeat the data collection for the second food sample. Use a new 50-mL portion of cold water. Repeat Steps 6-12.

14. When you are done, place burned food, used matches, and partially-burned wooden splints in the container provided by the teacher.

Name____
ENERGY CONTENT OF FOOD STUDENT WORKSHEET
When applicable, show your work!

PROCESSING THE DATA

1. Find the mass of water heated for each sample.

2. Find the change in temperature of the water, Δt, for each sample.

3. Calculate the heat absorbed by the water, *q*, using the equation

$$q = C_p \cdot m \cdot \Delta t$$

   where *q* is heat, C_p is the specific heat capacity, *m* is the mass of water, and Δt is the change in temperature. For water, C_p is 4.18 J/g°C. Change your final answer to kJ.

4. Find the mass (in g) of each food sample burned.

5. Use the results of Steps 3 and 4 to calculate the energy content (in kJ/g) of each food sample.

6. Record your results and the results of other groups in the Class Results Table. Which food had the highest energy content? The lowest energy content?

7. Food energy is often expressed in a unit called a Calorie. There are 4.18 kJ in one Calorie. Based on the class average for peanuts, calculate the number of Calories in a 50-g package of peanuts.

8. Two of the foods in the experiment have a high fat content (peanuts and cashews) and two have a high carbohydrate content (marshmallows and popcorn). From your results, what generalization can you make about the relative energy content of fats and carbohydrates?

Name____

DATA AND CALCULATIONS

Food type	____________	____________
Initial mass of food and holder	g	g
Final mass of food and holder	g	g
Mass of food burned	g	g
Mass of can and water	g	g
Mass of empty can	g	g
Mass of water heated	g	g
Final temperature, t_2	°C	°C
Initial temperature, t_1	°C	°C
Temperature change, Δt	°C	°C

Heat, q	kJ	kJ
Energy content in kJ/g	kJ/g	kJ/g

CLASS RESULTS TABLE

Marshmallows	Peanuts	Cashews	Popcorn
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g

Average for each food type

kJ/g	kJ/g	kJ/g	kJ/g