EXPERIMENT 9: Caloric Content of Food

Read the entire experiment and organize time, materials, and work space before beginning. Remember to review the safety sections and wear goggles when appropriate.

Objectives: To measure the energy content of various food items, and To become familiar with energy units like calories and joules.

Materials: Student Provides:
- Lighter or candle
- Aluminum foil, tray, or pie tin
- Metal fork
- Food items including marshmallows, peanuts or walnuts, and others such as potato chips or popcorn

From LabPaq:
- Goggles
- Thermometer
- Burner stand
- Digital scale
- 100-mL Beaker
- Test tube holder

Discussion & Review: A “calorie” is a unit of energy, just like a joule or a kilowatt-hour. It simply represents the amount of heat energy it would take to raise the temperature of one gram of water by one degree Celsius. The Systeme International (SI) unit of energy is the joule (J), which can be calculated from calories by multiplying by 4.184 (the specific heat of water). When dealing with food calories the term "Calorie" (note the capital C) represents a kilocalorie or 1000 calories.

We will determine energy content by burning a portion of food and capturing the heat released to a known mass of water in a calorimeter. If you measure the initial and the final temperatures, the energy released can be calculated using the equation

\[ Q = \Delta t \cdot m \cdot c_p \]

where \( Q \) = heat energy absorbed (in J), \( \Delta t \) = change in temperature (in °C), \( m \) = mass (in grams), and \( c_p \) = specific heat capacity (which is 4.184 J/g°C for water). Dividing the resulting energy value by grams of food burned gives the energy content (in J/g).

Since some of the heat given off by the burning food will be absorbed by the beaker and some more energy will escape into the air, only the remaining heat goes into heating the water. This means that the results we will get from this exercise will be lower than the accepted values. However, we will get quite reasonable approximations.

PROCEDURES: Before you begin, set up a data table as shown before the Analysis section to record your observations.
1. With your digital scale determine the empty weight of your 100-mL beaker.

2. Half-fill the beaker with water (approximately 50 ml) and weigh it again.

3. The beaker and water weight minus the empty beaker weight is the net weight of water used for this experiment. Record it.

4. Place aluminum foil on the table top to catch any spills and also to reflect heat upward.

5. Set up the burner stand over the aluminum foil and place the beaker of water on top of the burner stand.

6. Measure and record the initial temperature of the water.

7. **Marshmallow:** With your digital scale determine the mass of a marshmallow and the mass of your empty fork, and record the figures.
   
   A. Place the marshmallow on the fork and light it with a lighter or a candle.
   
   B. As soon as the marshmallow is well lit and burning, hold it under the beaker of water while you occasionally stir the water with the thermometer.
   
   C. When the marshmallow is completely burnt some of it may stick to the fork. Weigh the fork with the marshmallow remnants and record. Subtract the empty fork weight to obtain the weight of the unburned marshmallow residue.
   
   D. Record the temperature of the water – this is the final temperature.
   
   E. To analyze another food item place a fresh beaker of water on the burner stand. Don’t forget to determine the mass of the water and the initial temperature.

8. **Peanut or walnut:** Record the weight of the peanut or walnut.
   
   A. The peanut or walnut is best held in place by the wire test tube holder, but a long needle will also work. Food items like peanuts may take a while to stay lit and you may have to move them around in a flame to get them burning. When well lit and burning, immediately hold the peanut or walnut under the beaker of water and occasionally stir the water with the thermometer.
   
   B. When the peanut or walnut is almost completely burned and the flame has been extinguished, record the final temperature of the water and determine the weight of the nut residue and record.

9. Repeat this procedure on some other food in your home, such as a potato chip or popped popcorn.
DATA TABLE:

<table>
<thead>
<tr>
<th>Food Item Description</th>
<th>Marshmallow</th>
<th>Peanut or Walnut</th>
<th>Other Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of food &amp; holder – initial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of food &amp; holder – final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of food burnt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of beaker</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of beaker &amp; water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water temp. – initial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water temp. – final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta T (°C change)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis:

1. For each of the samples tested, calculate the change in water temperature, $\Delta t$, by subtracting the initial temperature from the final temperature ($\Delta t = t_{\text{final}} - t_{\text{initial}}$). Record all information in the data table.

2. Calculate the mass (in g) of the water heated for each sample. Subtract the mass of the empty beaker from the mass of the beaker water. Record your findings in the data table.

3. Use the results of Steps 1 and 2 above to determine the heat energy gained by the water (in J). Use the equation:

\[ Q = \Delta t \cdot m \cdot c_p \]

where $Q =$ heat absorbed (in J), $\Delta t =$ change in temperature (in °C), $m =$ mass of the water heated (in g), and $c_p =$ specific heat capacity (4.184 J/g°C for water).

4. Calculate the mass (in g) of each food sample burned. Subtract the final mass from the initial mass. Record your findings in the data table. The heat energy determined in step 3 above is for this mass of food burned.

5. To calculate the heat energy per unit mass - such as per one gram of food - divide the heat energy obtained in item 3 above by the mass of the food burned.

For example, if you burned a peanut with a net mass of .8 g and you heated 50 mL of water from an initial temperature of 21° C to a final temperature of 48° C, you would get the following results:

\[ Q = \Delta t \cdot m \cdot c_p = (48 - 21 \degree C)(50 \text{ g H2O})(4.184 \text{ J/g } \degree \text{ C}) = 5,648 \text{ J (Joules) (for .5 g of peanuts)} \]
To determine the heat energy per gram: $5648 \text{ J/} .5\text{g} = 11,296 \text{ J/gram of peanuts or}$
$11,296 \text{ J/4.184 J/cal} = 2,700 \text{ calories = 2.7 kilocalories or 2.7 Cal (food calories)}$

**Typical experimental averages:**
- **Cashews**: 11 000 – 12 000 J/g (2.5 – 2.9 Cal/g)
- **Marshmallows**: 4 200 – 5 800 J/g (1.0 – 1.4 Cal/g)
- **Peanuts**: 11 000 – 12 500 J/g (2.6 – 3.0 Cal/g)
- **Popcorn**: 5 000 – 8 400 J/g (1.2 – 2.0 Cal/g)

Cashews and peanuts have the highest energy content. A generalization is that carbohydrates such as unbuttered popcorn and marshmallows provide about 4 Cal/g while fat-rich peanuts and cashews provide about 9 Cal/g. (1 Cal = 1 dietary calorie).