Burning Calories: How Much Energy is Stored in Different Types of Food?

https://www.sciencebuddies.org/science-fair-projects/project-ideas/FoodSci_p012/cooking-food-science/food-calorimeter

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Procedure PDF date: 2019-10-23

Experimental Procedure

Safety Note: Adult supervision is required! As with any project involving open flame, there is a fire hazard with this project. Make sure you work on a non-flammable surface. Keep long hair tied back. Be careful handling the items used in this experiment as they may be hot! Wear safety glasses.

Assembling Your Calorimeter

Use the diagram shown in Figure 1, to guide you through building your calorimeter.

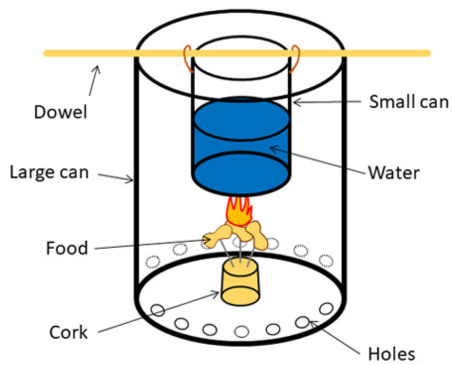

Figure 1. Diagram of homemade calorimeter.

1. *Note:*If you are not using the kit, you will need to select two cans that nest inside one another. The smaller can needs to sit high enough so that you can place the cork, needle, and food item beneath it. Use a can opener to remove the bottom from the *larger* can, so that you have a cylinder that is open on both ends. If this cylinder is not aluminum on the inside, cover its inside with aluminum foil. Folding the edge of the aluminum foil over the edge of the cylinder will keep it in place. Then, make holes around one edge of that cylinder. Space the holes about 4–5 cm apart. The holes are there to allow air to come in and sustain the flame. You will also need to punch holes on opposite sides of the smaller can, about 1–4 cm from the top (open end) (see Figure 2). These holes will be used to attach the support.
2. Pick up the small can. Locate the holes, these holes will be used to attach the support. Depending on the relative height of the cans, you can choose to punch bigger holes and to put the support through them, or use the smaller holes and attach the support on top of the can with metal wire as shown in Figure 1 and 2. Put the supporting rod in place and attach it firmly. *Note*: It is not a good idea to use glue, as the glue might melt when the calorimeter gets hot.

Figure 2. The rod can be attached on top of the small can with metal wire as shown here, or threaded through the holes.

3. Grasp the three needles and push the blunt ends into the cork, as shown in Figure 3. You will impale the food to be tested on the sharp ends of the needles. If needed, you can cut the cork lengthwise and let it rest on the cut side to reduce its height.

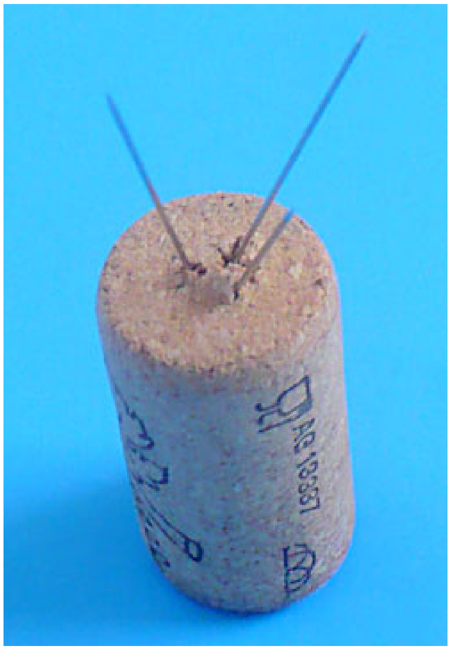

Figure 3. A cork with needles will hold the food items to be burned.

4. To construct the calorimeter:
    a. Place the aluminum pie pan on a heat resistant surface.
    b. Put the cork with needles sticking up in the middle of the pan.
    c. Place the larger can over the cork on the aluminum pie pan.
    d. Hang the smaller can inside the big cylinder.

The final result is shown in Figure 4.

Figure 4. Top-down view of the assembled calorimeter.

5. The smaller can will hold the water to be heated by burning the food samples. Use the graduated cylinder to measure how much water fills the can about half-full. Note this value (expressed in milliliters) in your lab notebook.

Taking Measurements

1. Copy the following table in your lab notebook. It will help you take notes as you perform your trials. Note that the mass of the water used in your calorimeter is not listed in the table. We advise you keep it the same for all your trials.

Food Item	Trial #	Food: M_i (g)	Food: M_f (g)	Water: T_i (°C)	Water: T_f (°C)	Q_{water} (Cal)	Q_{water} for 1 g food (Cal/g)	Average Q_{water} for 1 g food (Cal/g)
Food item 1	1							
	2							
	3							
Food item 2	1							
	2							
	3							
Food item 3	1							
	2							
	3							

Table 1. Table in which to record measured and calculated values.

2. Decide on the food items you would like to study. For each item on your list, you will perform three measurements (trials). It is a good idea to repeat measurements to ensure consistent results. For each trial, you will impale a few pieces of each type of food; using a few items (and not just one) will allow you to burn a larger mass.
3. For each trial, you will:
    a. Start with your calorimeter disassembled.
    b. Weigh the food items to be burned and record the mass in the column "Food: M_i".
    c. Impale the food items on the needles. Make sure all items touch, as shown in Figure 5. This will allow the flame to go from one item to the next.
    d. Stir the water in the small can and measure the initial temperature (T_i). Record this temperature in the column "Water: T_i".
        i. *Note*: After you have used your calorimeter, the water and can might still be cooling. Wait until the water reaches the same temperature as the environment or measure just before you put the can on top of your burning food. Remember to note the temperature in your table.
    e. Have your calorimeter pieces close at hand, and ready for use.
    f. Place the cork with food already impaled in the middle of the aluminum pie pan and light the food items with the long matches. Try the following if you have trouble igniting the food:
        i. A big flame on your match will help ignite the food. A slight breeze helps create bigger flames. If you cannot find a fire-safe place with a breeze, consider using a fan (at safe distance).
        ii. Be patient, some food items like nuts might take a while to catch fire.
        iii. Definitely use *long* matches. This will make it safer and easier to keep the food item in the flame for a longer period of time.
    g. When at least one food item catches fire, place the *large* can around the cork, then carefully place the smaller can in place above the flame.
    h. Allow the food item to burn itself out. Use smoke coming out of the top as an indicator to evaluate if the burning is still in process. Try the following if you have trouble keeping the fire alive in the calorimeter:
        i. Some food items might keep burning when they were put in the calorimeter just smoldering, but others will need a real flame to keep the burning active in the calorimeter. Experiment a bit with whether the food items burn better with a vibrant flame. Figure 6 might give you some ideas.
        ii. Enlarge the holes at the bottom of your cylinder to allow more air to pass through.

    If the food in your calorimeter burns well, you might opt to tent the calorimeter with aluminum foil so less heat is lost to the environment, leaving a small opening at the top to allow air circulation.

i. Shortly after the food stops burning, carefully stir the water and measure the final temperature (T_f). Make sure the thermometer has reached a steady level before recording the value.
j. When the burnt food item has cooled, carefully remove it from the needles and weigh the remains. Record your value in the column "Food: M_f". Ideally, all the food should have burned up. If it is not, you will correct for this during your analysis by subtracting the final mass from the initial mass.
k. This will complete one trial for this food item.

Figure 5. Food items held in place by needles are placed so they touch each other.

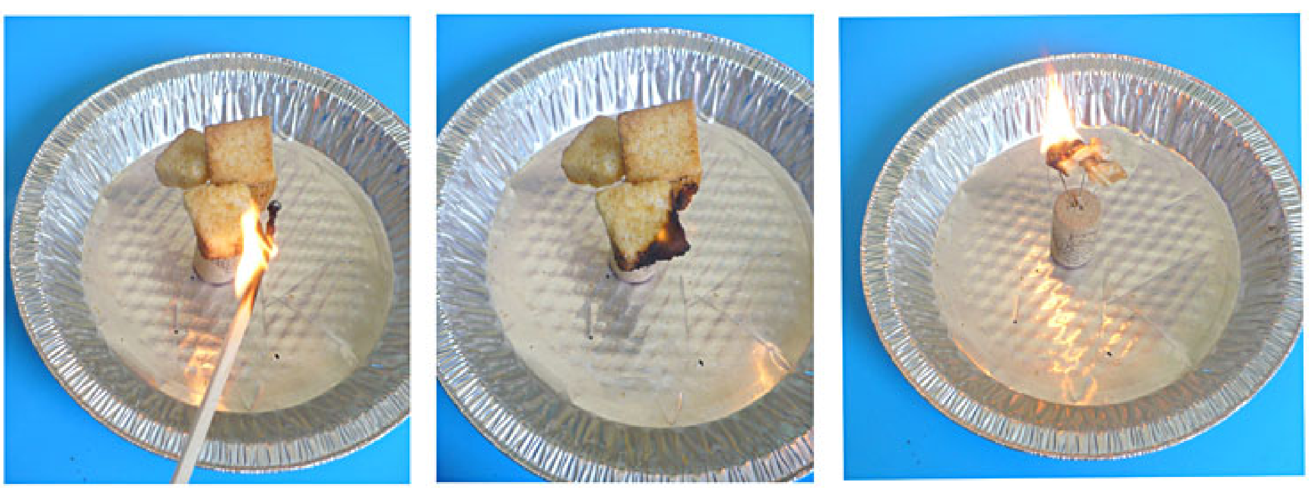

Figure 6. Some food items will need to be in flames before being put under the calorimeter.

4. Repeat step 3 for two additional trials of this food item.
5. Repeat steps 2 and 3 for the other food items you have on your list.

Analyzing Your Data

1. To analyze your data, you will first calculate the energy captured by the water for each trial. As explained in the Introduction (#background), the energy captured by the water (Q_{water}) can be calculated from the mass of the water in your calorimeter (m_{water}), the change in temperature of the water (T_f - T_i) and c, the *specific heat capacity* of water, which is 1 cal/(g °C) or 1/1,000 Cal/(g °C) using this equation:

$$Q_{water} = m_{water}\, c\, (T_f - T_i)$$

   Use the data in your data table to calculate the heat captured by the water for each trial and record your result in the column labeled Q_{water}. Following example where you burn 1.1 g of almonds and start out with 150 milliliters (mL) of water in the calorimeter might make the equation clear. Since 1 mL of water has a mass of exactly 1 g, this water has a mass of 150 g (m_{water} = 150 g). If initially the temperature of the water is 20.0°C, and after burning the nuts in the calorimeter we measure a water temperature of 33.3°C, then the change in temperature of the water (T_f - T_i) equals 13.3°C, and the heat captured by the calorimeter Q_{water} is (150 g × 0.001 Cal/(g °C) × 13.3°C) or 2.0 Cal.

2. The energy you just calculated (Q_{water}) reflects energy released by the total amount of food burned, or (M_f - M_i) grams of food burned. Calculate how much Q_{water} would be if 1 g of food was burned by dividing Q_{water} by the amount of food burned (M_f - M_i). We call this the energy per unit weight, and it is expressed in Cal/g.

$$Q_{water for 1 g food} = \frac{Q_{water}}{(M_i - M_f)}$$

   In the above example, Q_{Almond}, 1 g of food equals 2.0 Cal/1.1 g, or 1.81 Cal/g. Do the calculation and write your number down in the column "Q_{water} for 1 g food".

3. Average the energy per unit weight released per individual food item over all three trials and write your value in the last column of your data table.
4. Since in a homemade calorimeter, *only part* of the energy contained in the food and released during burning transfers into energy stored in the water, the measured values only reflect a fraction of the chemical energy contained in the food. Some of the energy will get lost to, for example, heating up the surrounding air. Still, you can learn a lot from your obtained values. Below are some ideas to get you started:
   a. Order your food items from more caloric to less caloric.
   b. Create a graph, listing the food items on the x-axis and the caloric content of 1 g of food on the y-axis. Remember to label your axes, and add the units and a title to the graph.
   c. *Normalize* the caloric content of food items to the caloric content of one food item. To do this, choose one food item from your list (e.g. Cheerios) and fill in the values, as directed by the equations in Table 2.

Food Item	Average Q for 1 g of Food (Cal/g)	Average Caloric Content Normalized to the Caloric Content of Cheerios
Cheerios	$Q_{Cheerios}$	1
Food item 1	$Q_{item\ 1}$	$Q_{item\ 1}$ / $Q_{Cheerios}$
Food item 2	$Q_{item\ 2}$	$Q_{item\ 2}$ / $Q_{Cheerios}$

Table 2. Table containing the average caloric values as measured for all food items and the normalized caloric content relative to the caloric content of Cheerios.

   These relative values show you how much more or less caloric food items are with respect to the item chosen (here Cheerios). For example, if the normalized caloric content for nuts would be 2, it would inform you that these nuts contain double as many calories per gram of food than Cheerios do.

   d. Create a graph listing the food items on the x-axis and the normalized caloric content on the y-axis. Remember to label your axes, and add the units and a title to the graph.
   e. Do you think the amount of Calories you measured is likely to be higher or lower than the true value for each food item? Why? If you can, look up the caloric content of your food items *per gram of food*. Does this confirm your hypothesis?
5. The Introduction (#background) states that, unfortunately, in homemade calorimeters, part of the energy stored in the food does not make it to the water. Can you suggest areas for improvement?