Using Calorimetry as an Experimental Means to Compare the Energy Content of Two Foods

Emily Morales

Providence Extension Program – Mason Campus

Author Note

The data included in this laboratory is the result of the very hard and careful work of Mrs. Emily Morales. Our lab team conducted the experiment, but due to the constraints of time and laboratory space, our results were not as robust as we desired.

Using Calorimetry as an Experimental Means to Compare the Energy Content of Two Foods

*Calorimetry* is an effective means by which the energy content (measured in joules or calories) of food or other fuels can be ascertained in the laboratory. In a calorimetric set-up, the food or fuel under investigation is burned, and all the heat coming from the substances combustion is assumed to be transferred to a known mass of water. Theoretically, if we can then calculate the amount of heat transferred to the known mass of water, then we can calculate how much heat or energy was contained in the food (Wilbraham, Staley, Matta, & Waterman, 2002).

Using the heat equation (*q = mC∆T*) - where “*q*” is the heat transferred to the water, “*m*” is the mass of the water absorbing the heat from the burned food (or fuel), “*C*” is the specific heat capacity for water (4.184 J/ g), and *“∆T*” is the temperature change in the water after it has absorbed the heat - we can calculate the energy content of the food (or fuel) that was burned, if we assume that all of the heat was completely transferred to the water, and none was lost to the surroundings. Bomb calorimeters are set up precisely so that as much heat as possible is transferred directly to the water; we did not use such a calorimeter for our own investigation, however.

For the purposes of our experiment, we set up a calorimetry apparatus to determine the energy content of two foods, a crouton and a peanut. While we were not surprised to empirically determine that the energy content of the peanut per gram (21,524.19 J) was greater than that of the crouton (3,856.37 J), we were disappointed at just how much. Theoretically, the peanut should have only been slightly higher in energy density than the crouton, not on the magnitude as our results demonstrated (5.6 times greater). When we compared theoretically-derived values for the energy content of croutons to that which we empirically determined, we calculated a percent error as high as 81.57%. Our percent error for the peanut was merely 12.81%. Perhaps these results suggest that our calorimetry apparatus and experimental conditions were effective for determining the energy content of peanuts, but not for croutons.

# **Methods**

Our experimental protocol required the use of the *Eisco Calorimetry Laboratory Kit*, along with a few other components as listed below.

**Materials**

**** Erlenmeyer flask (125 mL capacity)

Cylindrical metal stand

Metal suspension plate

Cork-and-nail sample holding assembly

Rubber stopper

Matches or a lighter

Thermometer or temperature probe

*Figure 1*. Calorimeter Assembly. Image from *Eisco Labs Calorimeter Instruction Booklet.*

Triple-beam balance (0.01 g resolution)

Two food samples (peanut, crouton)

**Procedure**

With goggles on and the workspace protected from being burned, we obtained the initial mass of the cork-and-clip food holder and the crouton, and recorded in Table 1(b), to the nearest 0.01 grams. We then recorded the mass of the empty Erlenmeyer flask (d). After pouring in 125 mL of room-temperature water we reweighed the flask and entered its mass in (e).

**Setting up the apparatus**. We inserted the thermometer into the rubber stopper, and placed it on the top of the flask, making sure the probe was submerged into the water, but not touching the glass. We set up the apparatus according to Figure 1; by inserting the flask through the metal plate, turning it by 90 degrees so the metal clamp on the flask rested on the plate, and then placed the plate on top of the aluminum tube. We then affixed the food sample to the cork-and-nail holder securely.

**Running the experiment.** Before burning any food, we obtained the initial temperature of the water and recorded it in Table 1(f). Using a match, we then set the crouton on fire and slipped it under the flask, fanning the opening of the aluminum tube in order to provide enough oxygen for the burn. We carefully monitored the temperature increase and once the crouton was burned out completely, we waited to see if the temperature would rise any further, then recorded the highest temperature in Table 1(g).

We then weighed the burnt crouton and holder, in order to determine the actual mass of food burned, and recorded this in Table 1(c).

After we repeated this entire protocol with a peanut using a new sample of water, and recording the data in Table 1, we performed our analysis.

**Analysis and calculation of energy content**. In order to determine the change in temperature *(∆T)* for each sample, we subtracted the initial temperature from the final temperature *(∆T = Tfinal – Tinitial)*, or g-f, and recorded this value in Table 1. To calculate the mass of water (*m*) heated for each food sample, we subtracted the mass of the empty beaker from the mass of the flask plus water (e – d) and recorded in Table 1. Knowing that the specific heat capacity for water is 4.184 J/ g ▪ ˚C, we inserted the other values into the heat equation, and calculated the energy content of each food. To determine the energy content per gram we divided the number of joules by the mass of food that was actually burned (b – c in Table 1) and recorded this value.

In order to compare the energy content between the two foods, we converted the energy expressed in J/g to Calories/g. Finally, we calculated our percent error by comparing our empirically derived values for energy, to that of food industry standards values.

**Results**

All measurements and the calculations derived from them, as included in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
| Table 1  *Data Recorded from Calorimetry Protocol* | | | |
|  |  | Sample 1 | Sample 2 |
| a. | Food Used | crouton | Peanut |
| b. | Mass of food and holder (initial) | 4.91 g | 4.59 g |
| c. | Mass of food and holder (final) | 4.28 g | 4.12 g |
|  | Mass of the food that was burned (c – b) | 0.63 g | 0.47 g |
| d. | Mass of empty flask | 96.03 g | 96.03 g |
| e. | Mass of flask plus water | 205.59 g | 210.08 g |
|  | Mass of water only (e – d) | 109.56 g | 114.05 g |
| f. | Initial water temperature | 19.9 ̊C | 20.1 ̊C |
| g. | Final water temperature | 25.2 ̊C | 41.03 ˚C |
|  | Temperature change (g – f) | 5.3 ̊C | 21.2 ̊C |
|  | Empirical\* energy content per gram (J/g) | 3,856.37 J/g | 21,524.19 J/g |
|  | Theoretical energy content per gram (J/g) | 20,920.00 J/g | 24,685.60 J/g |
|  | % error (empirical value/theoretical value x 100) | 81.57 % g | 12.81 % g |

\*Crouton: 5.00 kcal/ gram; Peanut: 5.9 kcal/ gram

**Comparison of Energies**

# From our data it was obvious the peanut had more energy as measured in joules per gram (21,524.19 J/g), than the crouton (3,856.37 J/g). While we were not surprised that the peanut had more energy density, we were surprised at just how much more when compared to the crouton. Theoretically, the peanut should have had 24,685.60 J/g, and the peanut 20,920.00 J/g. By these values then, theoretically, the energy content for the peanut should have only been 15.3% higher than that for the crouton, yet our results show the peanut to be 558% more energy-dense than the crouton.

**Percent Error**

We calculated the percent error of the peanut as follows:

And the percent error of the crouton accordingly:

Note that the percent error for the peanut (12.81%) demonstrates that our empirically-derived numbers were much more accurate when compared to theoretical values, than those for the crouton (81.57%). We have a few ideas as to why this is – for one thing, it required many attempts to light the crouton and simply get it to burn. In all those attempts, the crouton was more than likely losing mass and not contributing any energy to the flask of water.

# Experimentally, we determined that the energy content of the peanut was 21,524.19 J/g, and 3,856.37 J/g for the crouton. Theoretically, the energy content for the peanut should have only been 15.3% higher than that for the crouton, yet our results show the peanut to be 558% more energy-dense than the crouton.

# **Discussion**

The experimental design did in fact support our notion that the peanut should have been more calorie-dense than the crouton, yet the degree by which it was more dense certainly presents a problem. Since theoretically the peanut should have only been 15.3% more energy-dense than the crouton - and our results showed it to be 558% more dense - we can only conclude there was a problem with the experimental design. It was reported that the crouton required many attempts to actually ignite, so perhaps every time the crouton was lit, and re-lit, it lost mass (and chemical potential energy) without imparting any heat to the known mass of water in the Erlenmeyer flask. Looking back, it may have been a good idea to reweigh the crouton every time it required a re-ignition, and use the mass measurement at the point at which it started burning vigorously enough to actually impart heat to the water.

The very low percent error of the peanut in contrast to that of the crouton could be due to the fact that it did not require being lit and re-lit: once the peanut was ignited, it burned completely. By this it is a fair conclusion to state that the calorimeter apparatus was very effective at empirically determining the energy content of the peanut, but not of the crouton.

# **Citations and References**

My food diary. (2019). Retrieved from <https://www.myfooddiary.com/foods/search?q=croutons>

Food – peanuts. (n.d.). Retrieved from <https://www.nutritionix.com/food/peanuts/1-peanut>

Providence Extension Program/ General Chemistry course. (2018). Energy Content of Foods – Calorimetry. Loveland, OH: Self-publish.

Wilbraham, A.C., Staley, D.D., Matta, M.S., & Waterman, E.L. (2002). Chemistry. Upper Saddle River, NJ: Prentice Hall, Inc.