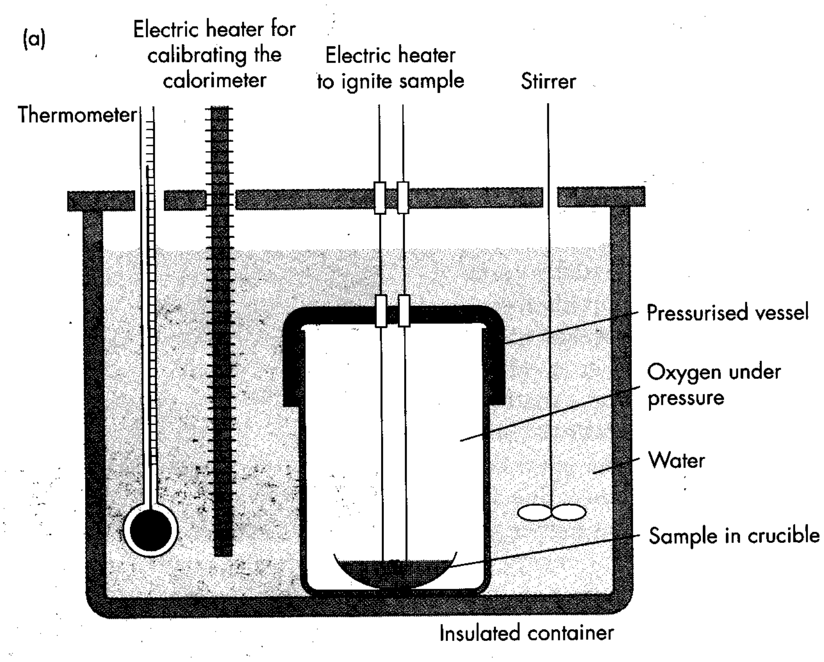
CALORIMETRY

As was mentioned earlier, carbohydrates, lipids and proteins are compounds found in our food that can be used as an energy source. A **bomb calorimeter** is an instrument that is used to determine the quantity of energy released from a burning sample of food. This energy is almost the same as the energy released by the food during cellular respiration. The energy released by a particular quantity of food is known as the food's **energy content.**

HOW DOES A BOMB CALORIMETER WORK?

A cross-section of a bomb calorimeter is shown below:



The instrument must first be **calibrated** by delivering an amount of electricity with known voltage and current to the heater over a specific period of time. The number of joules of electrical energy delivered can be calculated by applying the formula:

Energy = Voltage × Current × Time

OR

E = V × I × t

The relevant units are:

Volts (V) for **voltage**
Joules (J) for **energy**
Amps (A) for **current**
Seconds (S) for **time**

The heater converts this electrical energy directly into thermal energy, which causes a rise in the temperature of the water. The energy required to raise the temperature of the calorimeter and its contents (mainly water) by 1 ^{0}C can be determined. This is known as the **calibration factor** of the calorimeter.

$$\textbf{Calibration factor (J }^0\textbf{C}^{-1}\textbf{)} = \frac{\textbf{Energy released in calorimeter (J)}}{\textbf{Change in temperature}}$$

OR

$$\textbf{CF} = \frac{\textbf{E}}{\boldsymbol{\Delta}\textbf{T}}$$

Once the calorimeter has been calibrated, the resultant temperature rise from a burning sample of food can be measured and used to calculate the energy release that caused this temperature change.

QUESTION 1

A breakfast food company claims that 1 g of its corn flakes provides the body with 10,000 J of energy. To test this claim, a food scientist wishes to use a bomb calorimeter to determine the energy released by a sample of corn flakes.

To calibrate the instrument, an electric current of 4.70 A at a potential difference of 9.50 V for 10.0 minutes is deposited into the calorimeter and causes the temperature to change from 24.50^{0}C to 26.45^{0}C.

A 10.0 g sample of cornflakes is oxidised in the combustion chamber and the temperature is observed to rise from 27.15^{0}C to 29.04^{0}C.

(a) Calculate the calibration factor of the calorimeter.

$$E = V \times I \times t$$
$$= 9.50 \times 4.70 \times 600 \ (10 \times 60)$$
$$= 26790 \text{ J}$$

$$CF = \frac{E}{\Delta T}$$

$$\Delta T = 26.45 - 24.50 = 1.95$$

$$CF = \frac{26790}{1.95} = 13738.462 = 1.37 \times 10^4 \text{ J }^0\text{C}^{-1}$$

OR BY PROPORTION:

A 1.95 ^{0}C temp change is caused by 26790 J of energy
A 1 ^{0}C temp change is caused by ***x* J**

$$\boldsymbol{x} = \frac{1}{1.95} \times 26790 = 1.37 \times 10^4 \text{ J }^0\text{C}^{-1}$$

(b) Calculate the energy released from the 10.0 g sample of corn flakes.

Temperature change caused by the burning 10.0 g sample: $\Delta T = 29.04 - 27.15 = 1.89$

Energy released by the burning 10.0 g sample:

$$\begin{aligned} E &= CF \times \Delta T \\ &= 13738.462 \times 1.89 \\ &= 25965.693 \text{ J} \\ &= 2.60 \times 10^4 \text{ J} \end{aligned}$$

OR BY PROPORTION:

A 1 ^{0}C temp change is caused by 13738.462 J of energy
A 1.89 ^{0}C temp change is caused by ***x* J**

$\boldsymbol{x} = \frac{1.89}{1} \times 13738.462 = 2.60 \times 10^4$ J

(c) Is the breakfast food company's claim correct?

Energy released from 1.00 g of corn flakes:

10.0 g $\rightarrow$ 25965.693 $\times 10^4$ J
1.0 g $\rightarrow$ x g

$x = 25965.693 \times \frac{1.0}{10.0} = 2{,}600$ J

No, the claim is not correct. 2,600 J is much less than 10,000 J

HEAT OF COMBUSTION

Heat of combustion is the energy released when a specified amount of a substance (Eg 1g, 1L, 1 mole etc.) of a substance burns completely in oxygen.

Note:

Many substances such as wood, kerosene, biscuits etc are not pure and so do not have a fixed formula such as CH_4, $C_6H_{12}O_6$ etc. Therefore, you cannot calculate the number of mole of these substances. So the heat of combustion for these substances is usually measured as energy released per gram or litre etc.

QUESTION 2
Calculate the heat of combustion in J g^{-1} of 0.750 g of a Tim Tam biscuit that burns in oxygen to produce 895 J of heat energy.

Solution

0.750 g of Tim Tam $\rightarrow$ 895 J
1.00 g of Tim Tam $\rightarrow$ $\boldsymbol{x}$ J

$$\boldsymbol{x} = 895 \times \frac{1.00}{0.750}$$

$$= 1193 \text{ J g}^{-1}$$

ENERGY IN FOODS

Energy content of carbohydrates, lipids and fats

Food group	Heat of combustion ($KJ\ g^{-1}$)	Available energy ($KJ\ g^{-1}$)
Carbohydrate	**17**	**17**
Lipid	**39**	**37**
Protein	**24**	**17**

What is the difference between the heat of combustion and available energy of a food group?

The heat of combustion of a food group refers to the energy released when 1 g of the food burns in a bomb calorimeter.

The available energy of the food is the energy released after the digestion of 1 g of the food in the human body.

Why is there a discrepancy between the heat of combustion and available energy values of some foods?

In a bomb calorimeter, every bit of the sample of food will burn provided that excess oxygen is used and the combustion process is given enough time to run to completion. In the human body the whole biological process involved in releasing energy from the food is less than 100% efficient. Not all of the food taken into the body will be digested and changed into molecules that can be used in the energy releasing process of cellular respiration. Some of it will pass out of the body with the faeces. A small proportion of the food will be converted into urea and discarded from the body as urine.

It should be noted that the available energy value in the table for carbohydrate is not valid if the carbohydrate in question is cellulose. 1 g of cellulose will completely combust in a bomb calorimeter to give a heat of combustion of 17 $KJ\ g^{-1}$. However, the human body is unable to digest cellulose so the available energy would be very close to 0.

METABOLISM

The word metabolism refers to all the chemical reactions occurring in the human body. The term basal metabolic rate refers to rate at which energy is used by the human body when it is at rest. It is just the energy required to stay alive when no muscular work is being done and no food ingested.

There are many factors that determine the basal metabolic rate for an individual. Some of them are:

- Sex
- Age
- Weight
- Level of pulmonary and cardiovascular fitness
- Hormonal state
- General health condition