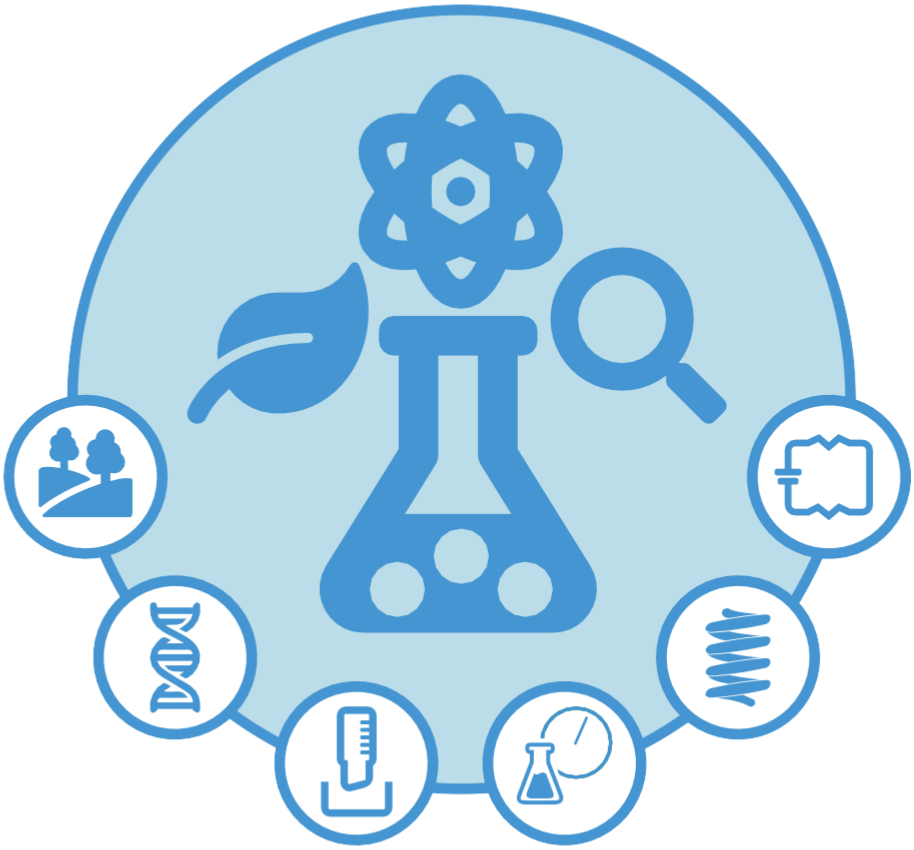
EXEMPLAR LESSON

CALORIMETRY: ENERGY IN FOOD



Acknowledgements

Ministry of Education

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CENDLOS, Ghana, for their collaboration and innovation in providing essential avenues for OpenSTEM Africa to reach learners and teachers.

Ghana Education Service, and the expert SHS science teachers, for their expertise in producing materials that are rooted in the Ghanaian school context, accessible and useful to learners and teachers.

For information on OpenSTEM Africa see:
www.open.edu/openlearncreate/OpenSTEM_Africa

OPITO for their generous support, which has made OpenSTEM Africa and the development of the Virtual Laboratory and these materials possible.

Contents

Exemplar lessons for the OpenSTEM Africa Virtual Laboratory applications

All the exemplar lessons are examples of lessons which could be used both individually and by whole classes of Senior High School (SHS) students in the elective sciences of Biology, Chemistry and Physics. Each of the lessons is linked specifically to one of the applications in the OpenSTEM Africa Virtual Laboratory. The exemplar lesson is created to give, both to SHS students and to SHS teachers, a clear example of the ways in which the applications can be used in the learning and teaching of practical science. There is a focus throughout the lesson on the student's development of the practical and experimental skills which, along with knowledge and understanding, are integral to the profile of learning, teaching and assessment in SHS sciences.

The 'you' in this lesson is 'you', the Senior High School student. Remember that you can repeat the experiments and activities in this lesson as often as you have time for in class. This freedom to repeat experiments and activities is also important if you are accessing the lesson outside the classroom, for example for homework. Every application in the OpenSTEM Africa Virtual Laboratory contains real data – the experiments are real experiments. This means you might make mistakes the first or second or third time you try an experiment or an activity – and that is exactly what often happens in the real world in the sciences. So, it is helpful for you as a student to share in some of the real-world trial and error of science as you develop your skills as a scientist.

The exemplar lesson also contains a set of teaching notes at the end of this document for 'you' the SHS science teacher, to suggest how you might want to set up this particular lesson with one of your classes. Hopefully it will also generate ideas for other lessons on the same topic, or other lessons which use the same OpenSTEM Africa Virtual Laboratory application.

Calorimetry: energy in food

Lesson objectives

By the end of the lesson, you will be able to:

- Identify main macronutrients and their contribution to the energy stored in food.
- Interpret food nutritional labelling.
- Determine the energy in food using calorimetry experiments.

The following practical and experimental skills will be developed:

- Taking measurements of mass and temperature
- Recording quantitative data
- Carrying out calculation of kilocalories
- Interpreting results
- Identifying sources of errors in a calorimetry experiment.

Background

Chemical substances in food

The body needs food for energy, movement, repair, growth and reproduction. The combination of foods regularly eaten by an individual or a population, referred to as their **diet**, has a major impact on health. To stay healthy, the body needs a diet that provides the right balance of six categories of **nutrients**, the chemical substances in food that provide the body with the nourishment it requires:

- carbohydrates
- fats
- proteins
- vitamins
- minerals
- water

Dietary carbohydrates, fats and proteins are collectively termed **macronutrients** because the body requires them in relatively large amounts. Carbohydrates and fats typically provide the body with most of its energy. Proteins can also provide energy, but more importantly they are required to provide the building blocks needed to build thousands of new proteins with essential roles in body processes and structures.

Vitamins and minerals are referred to as **micronutrients** because they are required by the body in very small amounts. They do not provide energy, but they are essential to build and maintain structures in the body

Which minerals are essential for the body?
Go to Appendix 3 for the answer.

As food passes through the **alimentary canal**, complex macronutrients are broken down into smaller components. This allows them to be absorbed by the cells lining the gut. The fate of these molecules we obtain from food depends on the needs and demands of our bodies. Some molecules, such as **glucose,** are used to provide energy. Other molecules, such as **amino acids**, are used to build and repair cellular structures and tissues.

Figure 1 summarises the main roles in the body of the six different categories of nutrients and reminds you of some of the foods that provide them.

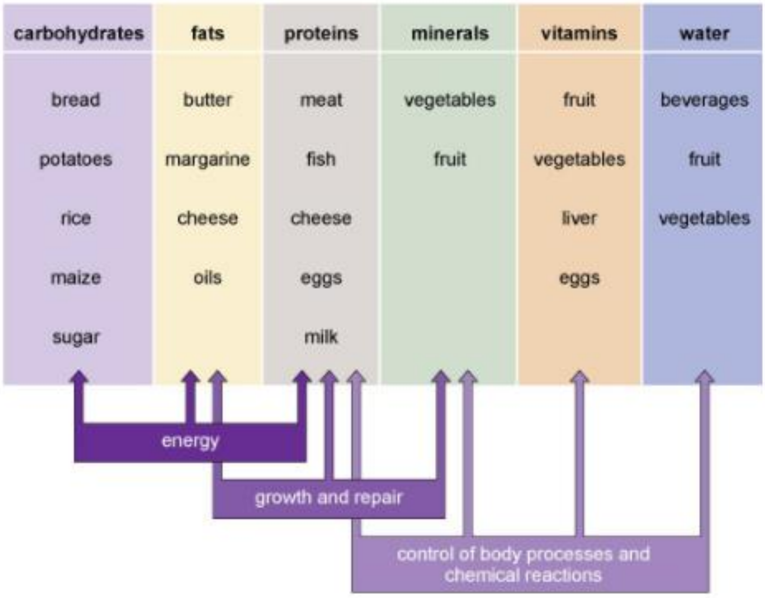


Figure 1. A summary of the six different categories of nutrients, their main roles in the body and some of the foods that provide them.

Carbohydrates

Carbohydrates are a group of organic molecules that occur in living organisms and include sugars, starch and cellulose. Most people obtain the majority of their food energy from starch-rich foods, such as flour, potatoes, rice, pasta and pulses (peas, beans and lentils).

The general formula for simple carbohydrates, which relates the relative proportions of different atoms found in the molecule, is $C_n(H_2O)_n$, where n is the number of carbon atoms.

Most common simple sugars have five or six carbon atoms. These carbohydrates are known as **monosaccharides** as they are made of one sugar unit. Glucose is an example of a simple sugar, and it is vital for human life as our primarily source of energy. It also plays an essential part in the metabolism of plants and is the main product of photosynthesis. Glucose has the formula $C_6H_{12}O_6$ and can adopt two distinct types of structure: a straight-chain form or a cyclic form (as shown in Figure 2).

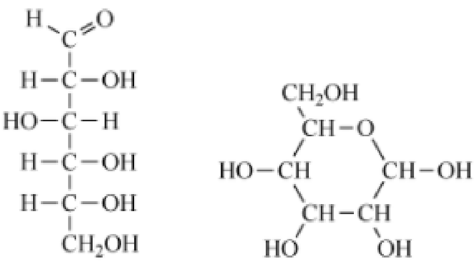


Figure 2. Structures of glucose: (a) straight chain for of glucose and (b) cyclic form of glucose.

Inside cells and organisms where glucose is dissolved in water, it adopts a cyclic form. The same structure is observed for other monosaccharides (such as fructose and galactose) when dissolved in water.

Which are the functional groups in the straight chain glucose?

Go to Appendix 3 for the answer.

Monosaccharides are the basic building blocks of all larger carbohydrates, which are built up by linking together two or more monosaccharide units by **covalent bonds**. Figure 3 shows a glucose molecule and a fructose molecule linking to form sucrose in a chemical reaction called a **condensation reaction**, because it releases a molecule of water.

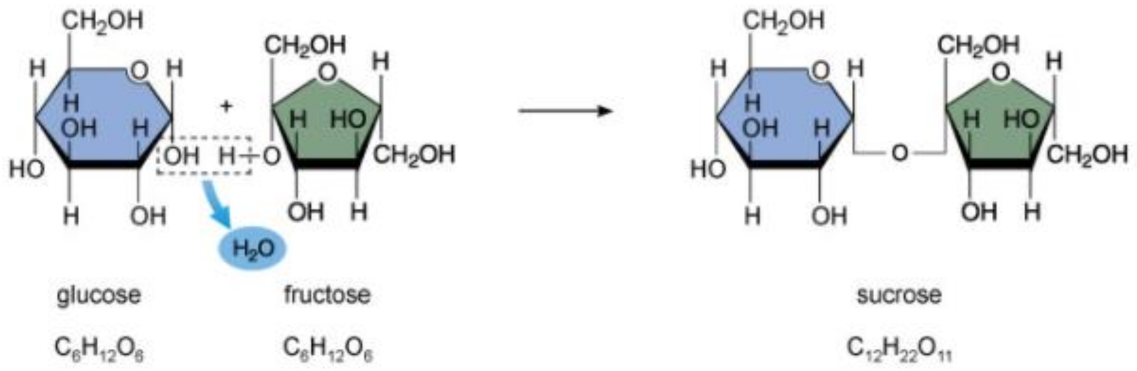


Figure 3. Glucose and fructose linking by covalent bonds to form sucrose (sweet table sugar). Monosaccharides are represented in a simplified way in which the ring structures are a hexagon (six-sided) shape for glucose and a pentagon (five-sided) shape for fructose.

Fats and oils

Fats and oils fit into a class of molecules collectively called **lipids**. These are organic compounds that have a slippery or greasy feel to the touch, and they are not soluble in water. Although sometimes dietary fats are regarded as unhealthy, in fact lipids perform many important roles in the body. Lipids provide a source of energy and a way of storing it, they help with the digestion and transport of substances that dissolve in fat, they insulate the body and they are important components of cell membranes.

Dietary fat is composed of molecules called **triacylglycerols** (you may also see them referred to by triglycerides). A triacylglycerol molecule is made up of three long molecules called **fatty acids**, attached to another molecule called glycerol (Figure 4).

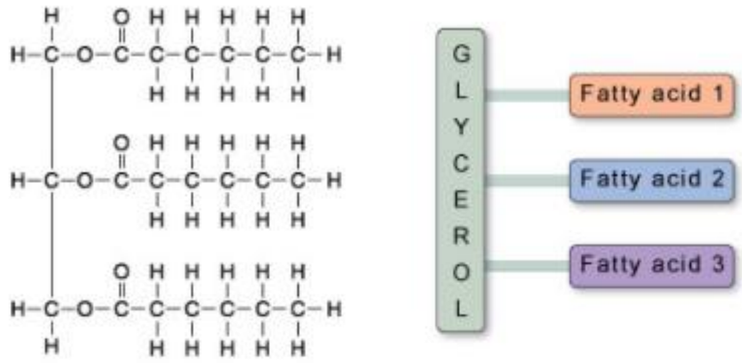


Figure 4. A molecule of triacylglycerol showing the three fatty acids covalently linked to a glycerol molecule.

Cells can use dietary triacylglycerols as a source of energy. They are broken down in the gut into individual fatty acid chains and delivered to cells in the blood circulation. If they are not needed immediately, the fatty acids are recombined with glycerol and stored as triacylglycerols inside adipocytes (fat cells).

In food labelling, fats are often categorised into saturated fat (or just saturates) and unsaturated fats. Saturated fats tend to be solid, animal-derived fat, for example the fat in meat. Unsaturated fats tend to be liquid oils derived from plants, for example corn oil. In saturated fats, all the covalent bonds between the carbons in the fatty acid chains are single bonds. In unsaturated fats, on the other hand, there are one or more double bond carbons in the fatty acid chains. These fats are therefore ‘unsaturated’ with hydrogen (some of the carbons are making C=C double bonds instead of C–H bonds).

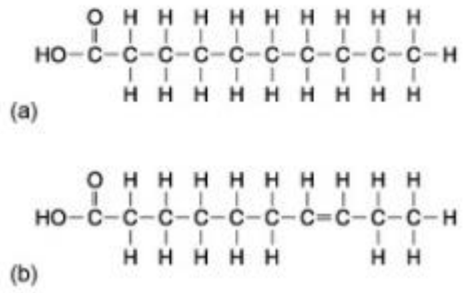


Figure 5. Example of (a) a saturated and (b) an unsaturated fatty acid chain.

Why is eating lots of saturated fats bad for your health?
Go to Appendix 3 for the answer.

Proteins

The body's cells constantly synthesise new proteins using **amino acids** obtained from food. Each type of protein is composed of several hundred amino acids linked together in a particular order or 'sequence'. There are twenty different amino acids commonly occurring in animal proteins.

In a body cell, what is the name of the structure (located in the cytoplasm) where protein synthesis takes place?
Go to Appendix 3 for the answer.

The amino acid with the simplest chemical structure is called glycine (shown in Figure 6). In glycine the R group is a hydrogen atom, but the other amino acids have a larger R group composed of several atoms. Each type of amino acid has a different chemical structure, but they all have the same chemical 'groups' attached to either end of the molecule. At one end is a group of atoms called an amino group (NH_2, highlighted in blue in Figure 6) and at the other end is a different group of atoms called a carboxyl group (COOH, highlighted in pink in Figure 6). These two chemical groups are crucial in the process of joining amino acids together to make proteins.

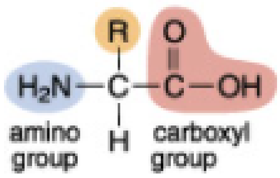


Figure 6. Structural formula of glycine.

The bond that forms between amino acids is called a **peptide bond** and links the amino (NH_2) group of one amino acid to the carboxyl (COOH) group of another amino acid, forming a new covalent bond between the two amino acids and releasing a water molecule (Figure 7).

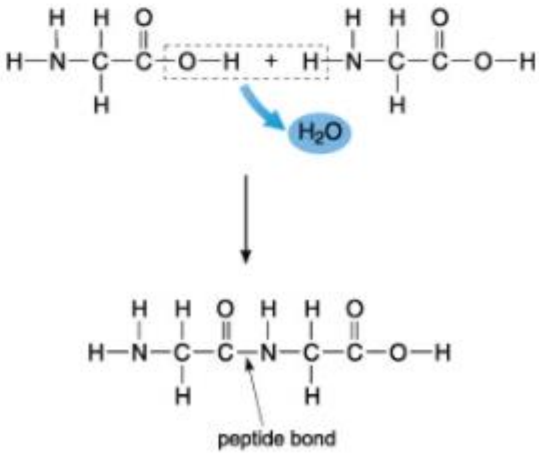


Figure 7. Two amino acids link together by covalent bonding to form a dipeptide

You may have noticed that this a condensation reaction (meaning water is released) similar to the one that links monosaccharides together.

Food and energy

In science, **energy** is usually described as the capacity to produce change in a system. For example, one chemical substance can be changed to another by the energy transferred during the breaking and making of chemical bonds. The life of an organism is sustained by energy from the environment in the form of nutrients. Chemical energy obtained from the digestion of food molecules can be used in chemical reactions in the body that build new molecules, produce heat or cause movement.

The energy provided by food is measured using an SI unit of energy called the **joule** (which has the symbol J). You may have noticed that packaged foods usually have a nutrition information label showing the total energy provided by the food in kilojoules (kJ) per serving or per 100 g.

However, a non-SI unit of energy called the **calorie** (cal) is commonly used in nutrition. A calorie is equal to the amount of energy per unit mass required to raise the temperature of 1 g of water by 1^{o}C. One calorie is equivalent to 4.184 J. When reading nutrition labels on food packaging, you will see food calories expressed as kilocalories or Cal (sometimes denoted with a capital C).

1 nutritional calorie (Cal) = 1 kilocalorie (kcal) = 1000 calories (cal) = 4184 joules (J)

NUTRITION INFORMATION

	per 100g	per average slice (29.9g)
Energy	1195 kJ	359 kJ
	285 kcal	87 kcal
Fat	8.3g	2.5g
- of which saturates	1.3g	0.4g
mono-unsaturates	3.0g	0.9g
polyunsaturates	4.0g	1.2g
Carbohydrate	38.9g	11.6g
- of which sugars	2.6g	0.8g
Fibre	6.0g	1.8g
Protein	10.3g	3.1g
Salt	0.95g	0.28g

Figure 8. Food labelling for brown bread.

How many kilojoules are in a Calorie?
Go to Appendix 3 for the answer.

The total amount of energy made available when food is metabolised in the body depends on the combination of nutrients the food contains. Table 1 shows the energy density – the average energy available per gram – of fat, protein and carbohydrate.

Table 1. The average amount of available energy in 1 gram of different types of macronutrients

Macronutrient	**Energy / kJ g^{-1}**	**Energy / kcal g^{-1}**
Fat	37	9
Protein	17	4
Carbohydrate	17	4

How does the energy available of 1 gram of fat compare to that of protein or carbohydrate?
Go to Appendix 3 for the answer.

Compare the food nutrient content shown in the food labels of pistachio nuts and a baked corn snack (Table 2). Which food shows the highest energy content per gram?

Table 2 Food nutrient content on food labels

	Pistachio nuts (100 g)	**Baked corn snack (100 g)**
Protein /g	18.3	6.0
Carbohydrate total / g	28.3	60.5
Fat total / g	47.8	24.6
Fibre / g	9.1	1.7
Sodium/g	0.004	0.6

Go to Appendix 3 for the answer.

Food calorimeters

Figure 9 shows the simple food **calorimeter** that you will use in this practical to find the amount of energy stored in some food. The basic principle of this instrumentation is that energy transferred during the combustion of food (as heat) causes the water in the surroundings to increase its temperature.

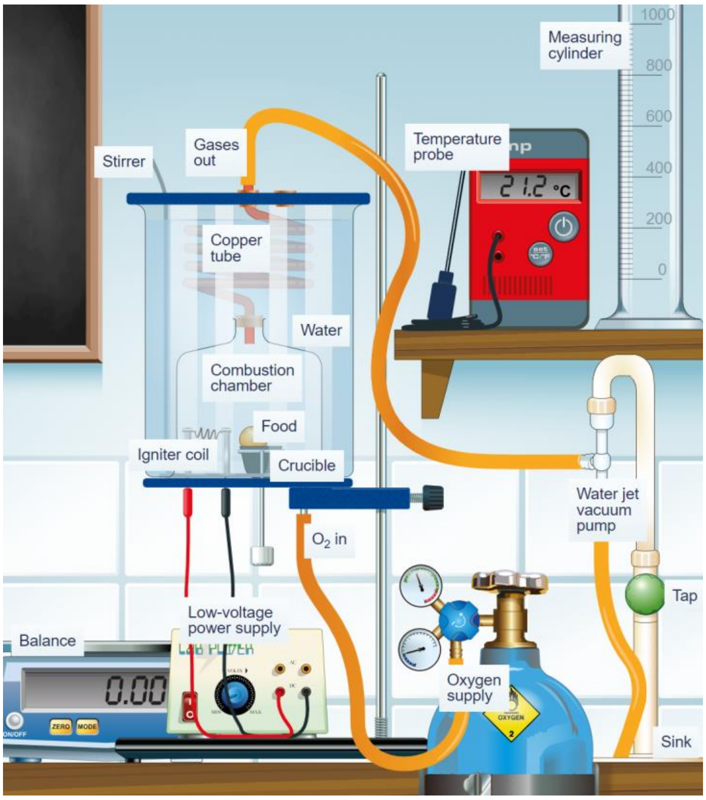


Figure 9. Simple food calorimeter

The instrument consists of a borosilicate water jacket surrounding an integral combustion chamber which is opened at the base. The combustion chamber is connected to a copper spiral heat transfer tube through which products of combustion will be drawn out using a vacuum pump. A wire stirrer and a temperature probe are fitted through the lid of the borosilicate jacket. The base of the calorimeter comprises a metal disk that forms the floor of the combustion chamber with some clips to hold the water jacket securely. It has an inlet for oxygen supply for a more efficient burn of food and a couple of pillars carrying the low voltage igniter coil. There is also a moveable crucible support on the base, enabling the crucible to be raised to the igniter coil from outside the calorimeter.

When the ignition coil gets hot, it ignites the food in the crucible and the oxygen flowing inside the combustion chamber ensures that the food continues burning. The gases produced in the combustion of food rise through the copper coil and heat the known volume of water inside the borosilicate jacket. The water jacket acts as a heat exchanger and as an insulator of the combustion chamber. The manual stirrer will ensure uniform temperature measurements.

Is the combustion of food an exothermic or endothermic reaction?
Go to Appendix 3 for the answer.

Which gases are produced in the combustion of food?
Go to Appendix 3 for the answer.

To calculate the energy transferred from the combustion of food to the water (q) you will use the equation:

$q = m\, c\, \Delta T$

where m is the mass of water in the conical flask, c is the **specific heat capacity** of water (4.18 J $g^{-1}\,^{o}C^{-1}$) and ΔT is the increase in the temperature of water.

Remember that the density of water is 1 kg/l so if you are using a volume of 100 ml of water in your experiment, this volume is equal to 100 g of water.

In a food calorimeter, a small amount of brown seeded bread was burned and was used to heat 1000 ml of water at an initial temperature of 21.5°C. When the temperature of water increased to 23.2°C, the mass of bread burned was 0.62 g. Calculate the experimental number of kilocalories released per 100 grams of food.
Go to Appendix 3 for the answer.

In industry, energy from food combustion is usually measured using more sophisticated instruments such as a **bomb calorimeter** which is shown in Figure 10. A known mass of the combustible sample (in solid or liquid phase) is placed in a sealed thick-walled metal reaction chamber (the ‘bomb’) which has an oxygen inlet. The term ‘bomb’ comes from the possibility of these combustion reactions being vigorous releasing heat very rapidly like explosions. The bomb is immersed inside an insulated water bath with a motorised stirrer and thermometer. Electrical leads connect to a heating coil which heats and ignites the sample, and the heat evolved from the combustion is transferred to the water raising its temperature. A bomb calorimeter works at constant volume and these robust devices are built to withstand large pressures produced from the combustion gases.

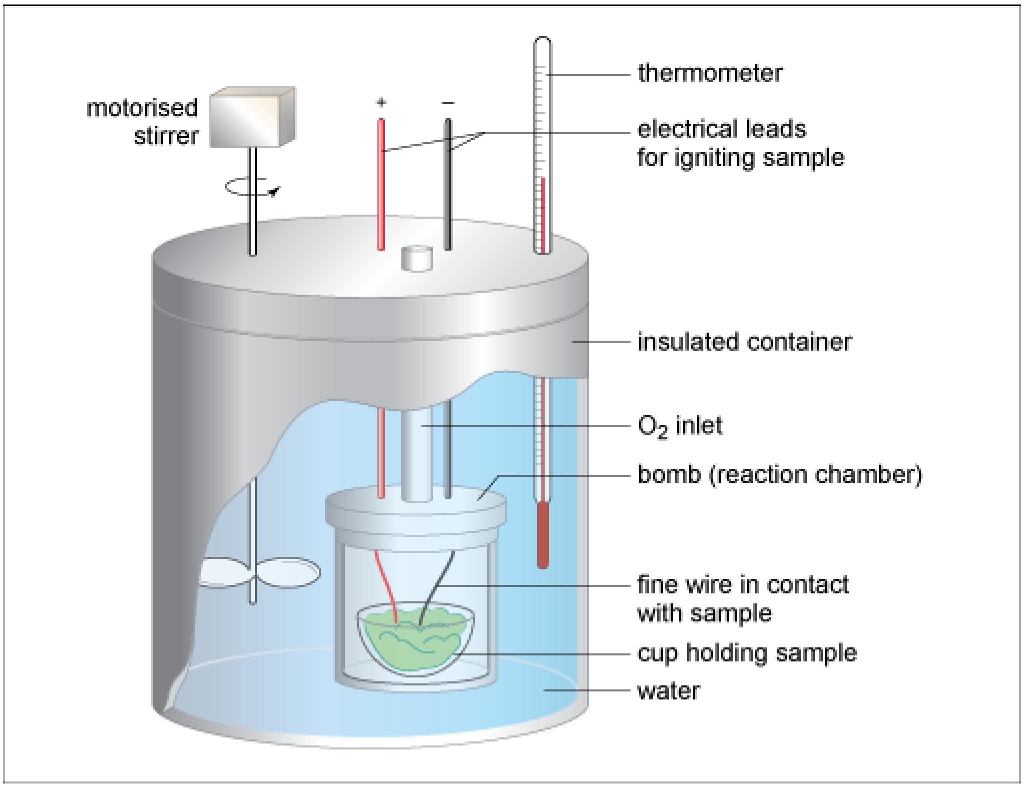


Figure 10. A bomb calorimeter

Bomb calorimeters need to be calibrated before their use to determine the heat capacity of the entire calorimeter (including bomb, water, thermometer, stirrer) using a calibration sample of known heat given off value. Each instrument will have a different value for its heat capacity. This **calibration** step allows for very accurate results.

It is important to understand that our bodies do not metabolize food in exactly the same way as a food is burned in a calorimeter; it is a more complex process. There are certain components of food (such as fibres) that despite burning in a calorimeter we are not able to digest.

Practical activity

In this online experiment you will determine which food stores more chemical energy using a simple food calorimeter.

Task 1: You will perform a series of calorimetry experiments for different food: plantain chips, millet porridge, fufu, coconut peanuts and puff puff mix.

Task 2: Using the data of your calorimetry experiments, you will determine the number of calories per gram in different foods.

Task 1: Food calorimeter experiments

You will now carry out your calorimetry experiments. Remember that all your data should be recorded in your laboratory notebook.

The change in the temperature of water during the combustion of food is measured using a thermometer and it is a direct measure of the energy in food. Food samples should be weighed before and after the combustion to calculate the actual mass of food burned to heat one litre of water.

The food samples were prepared for analysis by drying them in an oven at around 50-60^{o}C overnight.

Detailed instructions are provided within the experiment. In preparation for the experiment read and reflect on the following summary of the steps you will need to take:

1. Choose a type of food from the list provided.
2. Weigh the crucible containing your selected food and record the initial mass.
3. Place the crucible with food on the moveable support of the calorimeter metallic base.
4. Move the empty glass water jacket with its integral combustion chamber and the attached copper spiral tube onto the calorimeter base. The manual stirrer used to homogenize the temperature of water is already placed inside the water jacket.
5. Add 1000 ml of fresh tap water into the glass water jacket. Once water has been transferred, the application will place the lid of the glass water jacket for you. The oxygen source and the water jet vacuum pump will be also connected to the in- and outlets of the food calorimeter.
6. Turn on the temperature display and the probe will be moved inside the glass water jacket.
7. Stir the water to ensure uniform temperature throughout the glass water jacket before taking a temperature reading.
8. Open the water tap to start the water jet vacuum pump. This will ensure suction of gases out of the combustion chamber.
9. It is now safe to open the regulator valve of the oxygen cylinder.
10. Bring the crucible and food closer to the igniter coil.
11. Turn on the low-voltage power supply. A video will start playing showing the combustion of your selected food. The application will turn off the power supply for

you as soon as the food sample starts burning. The crucible will be moved to its original position. While the video is playing all the different parts of the calorimeter are locked down and you can't change any settings.

12. Once the flame is extinguished, stir the water before recording the final temperature.
13. Close the regulator valve of the oxygen cylinder.
14. Close the water tap to stop the water-jet pump.
15. Remove temperature probe by switching off display and the application will start dissembling of food calorimeter for you.
16. Reweigh crucible with any remaining food residue and record the final mass.

Repeat these steps at least twice for each food. The water in the conical flask will be refreshed each time. Planning your experimental work will help your experiments to run smoothly in the virtual laboratory.

Table 3 shows a template you could use to record your observations.

Table 3 Calorimeter data for combustion of different foods.

Food	**T water at start / ºC**	**T water at end / ºC**	**ΔT / ºC**	**Mass of food plus crucible at start / g**	**Mass of food plus crucible at end / g**	**Mass food burned / g**
Plantain chips						
trial 1						
trial 2						
Millet porridge						
trial 1						
trail 2						
Fufu						
trial 1						
trial 2						
Coconut peanuts						
trial 1						
trial 2						
Puff puff mix						
trial 1						
trial 2						

Click on the icon to access the OpenSTEM Africa Virtual Laboratory Calorimetry homepage. Watch the introductory video before entering the experiment to carry out Task 1.

Calorimetry: Energy in food

Go to the OpenSTEM Africa Virtual Laboratory.

Click on on the icon to access the Calorimetry application homepage.

Watch the introductory video before entering the experiment.

Task 2: Data analysis and discussion

Use your data from Task 1 to calculate your experimental energy of foods. Table 4 shows a template you could use to record your values.

Table 4 Experimental values of food energy

Food	Energy transferred / kJ	Energy per g of food / kJ	Energy per 100 g of food / kJ	Energy per 100 g / kcal
Plantain chips				
Millet porridge				
Fufu				
Coconut peanuts				
Puff Puff mix				

Now let’s discuss your experimental values of energy in different foods and compare your data with values of energy in food labelling.

Which food shows the highest experimental energy content per gram?

Go to Appendix 3 for the answer.

Do your calculated experimental values of energy make sense compared to values shown in food labels (Table 5)?

Table 5 Values of energy on food labels

Food	Energy per 100 g of food / kcal
Plantain chips	517
Millet porridge	37
Fufu	315
Coconut peanuts	553
Puff Puff mix	361

If you were going to repeat these experiments, what would you do differently?

Go to Appendix 3 for the answer.

Summary

Carbohydrates, fats and proteins are required in relatively large amounts in our diets and provide most of the energy required to our bodies. The total amount of energy made available when food is metabolised depends on the combination of nutrients the food contains.

Energy in food can be determined using a calorimeter. The basic principle of calorimetry is that the energy produced during combustion of food is absorbed by a known amount of water and thus increases its temperature.

In this experiment you used a simple calorimeter to compare the heat energy from burning different types of food. The change in the temperature of water during combustion was measured using a temperature probe and it is a direct measure of the food energy content. A crucible containing the food was weighed before and after the combustion to calculate the mass of food burned to heat the water. The experimental number of calories per gram in different foods was calculated and compared to nutritional information on food labelling.

Quiz

Answer the questions, then search for the correct answers in Appendix 4.

Question 1

For each of the questions below select the correct answer:

1. Which are the two functional groups in an amino acid?
   a) Amino group and alcohol group
   b) Amino group and carboxyl group
   c) Amino group and aldehyde group
2. Which macronutrient stores more energy?
   a) Protein
   b) Fat
   c) Carbohydrates
3. Which of the following values is equal to 2 kilocalories (kcal)?
   a) 8400 joules (J)
   b) 4.2 kilojoules (kJ)
   c) 2000 nutritional calories (Cal)

Question 2

Which of the following statements is correct?

a) In unsaturated fats, all the covalent bonds between the carbons in the fatty acid chains are single bonds.

b) The complete combustion of food requires the presence of a good supply of oxygen.

c) Carbohydrates are made of hydrogen, nitrogen and oxygen.

Question 3

Complete the equation below, used to calculate the energy transferred from the combustion of food to the surrounding water by selecting one option to fill in the gap.

Energy = ________ x specific heat capacity of water x change in temperature of water

[volume of water, mass of water, mass of food]

Glossary

Alimentary canal – The continuous passage which carries the food through the different parts of the digestive system.

Amino acid – Simple block forming proteins that is made of an amino group (NH_2), a carboxylic group (COOH) and a R group composed of several atoms which are unique to each amino acid.

Bomb calorimeter – A calorimeter consisting of a robust sealed metal vessel (known as 'the bomb') that houses the sample in an oxygen environment.

Calibration – A process of making sure that a scientific instrument will produce results which are accurate.

Carbohydrates – Biomolecules that contain carbon, hydrogen and oxygen, normally with a two-to-one ratio of hydrogen to oxygen. One of the three main macronutrients (alongside fats and proteins).

Calorie (cal) – A non-SI unit of energy used in nutrition; one calorie (cal) is equivalent to 4.184 J. If denoted with a capital C in food labels, 1 Cal is equivalent to 1000 calories (cal).

Calorimeter – Device used to determine the energy involved in a chemical process.

Condensation reaction – A reaction of two or more small molecules to form a larger compound involving the removal of water molecules.

Covalent bond – A chemical link between two atoms where electrons are shared.

Diet – The combination of foods regularly eaten by an individual or a population.

Energy – Capacity of producing a change in a system.

Fats – One of the three macronutrients in our diet alongside carbohydrates and proteins – most of the fat in our diet comes from triglycerides.

Fatty acid – A compound containing a carboxylic acid functional group and a long hydrocarbon chain.

Functional group – A group of atoms that primarily determines the type of reaction taking place, and the particular chemical properties of an organic molecule.

Glucose – Monosaccharide made of one sugar unit that is vital for human life as source of energy.

Joule (J) – An SI unit of energy.

Lipids – Organic compounds that have a slippery or greasy feel to the touch and are not soluble in water.

Macronutrients – Dietary components that the body requires in relatively large amounts (e.g. carbohydrates, fats and proteins).

Micronutrients – Dietary components that the body requires in very small amounts (e.g. vitamins and minerals).

Minerals – Elements required in our diet to sustain health (e.g. calcium).

Monosaccharides – Simple sugars with five or six carbon atoms that cannot be broken down into smaller units.

Nutrients – The chemical substances in food that provide the body with the nourishment it requires.

Organic molecule – The combination of one or more atoms of carbon covalently linked to atoms of other elements (most commonly hydrogen, oxygen or nitrogen).

Peptide bond – Bond between amino acids linking the amino (NH_2) group of one amino acid to the carboxyl (COOH) group of another amino acid.

Protein – A large macromolecule, or biopolymer, which is composed of amino acids.

Specific heat capacity – Amount of energy needed to raise the temperature of 1 Kg of a substance by 1^{o}C.

Triglycerides – The major component of fat in food that is formed from the reaction between long-chain fatty acids and glycerol.

Vitamins – Organic compounds whose absence from the diet leads to deficiency symptoms that have a devastating effect on health (e.g. Vitamin A is required for a healthy immune system, production of blood cells and eye function).

Appendix 1: Teacher notes – organisation of the lesson

Combined with using the Calorimetry: Energy in food, this lesson links to the following units in the Teaching Syllabus for Chemistry:

- SHS 1 Section 1 Introduction to chemistry, Unit 2 Measurement of Physical quantities
- SHS 2 Section 1 Energy and energy changes, Unit 1: Energy changes in physical and chemical processes
- SHS 2 Section 1 Energy and energy changes, Unit 2: Energy cycles and bond enthalpies
- SHS 3 Section 2 Basic biochemistry and synthetic polymers, Unit 1: Fat and oils
- SHS 3 Section 2 Basic biochemistry and synthetic polymers, Unit 2: Proteins
- SHS 3 Section 2 Basic biochemistry and synthetic polymers Unit 3 Carbohydrates

Ideas for organising this exemplar lesson link directly to activities and teaching examples in the OpenSTEM Africa CPD units *Linking Science to everyday life* and *Using ICT to support learning*.

A full list of the OpenSTEM Africa CPD units can be found at: https://www.open.edu/openlearncreate/CPD_units

Overview

If it can be arranged through your Head of Science and the Head of ICT, this lesson should take place in the ICT Lab in your school. If the lesson takes place in the ICT Lab, it may be possible for each student to work individually at a computer; otherwise divide the class so that students are in small groups at a computer.

If it isnot possible to use the ICT Lab for this lesson, then try to set up this lesson in your classroom. You may be lucky enough in your school to have a set of 'empty' tablets or mobile phones which students can use. Or you may be able to bring a lap-top connected to the internet or to your school intranet – and perhaps connected to a projector to make it possible for the whole class to view at once. If access to ICT is a real challenge in your school but you want your students to view an experiment, you might be able demonstrate it to small groups of your students at a time using your own mobile phone.

Whatever way(s) you set up the class, it would still be helpful to the students to be able to work in pairs or small groups for at least some of the lesson. Do remember as well that students need desk space to be able to write in their notebooks and to draw diagrams.

Steps in organising the lesson

Step 1: This takes place in the lesson before the one where you and your class access the OpenSTEM Africa Virtual Laboratory Calorimetry: energy in food application. Have students work in pairs to pre-read the Background section of the exemplar lesson. They should ask each other the questions in the Background section and check with each other that each understands the answers. You may want students to complete their reading of the Background section for homework or continue into a second lesson. If you do allocate more than one lesson to the Background work, consider changing the pairs of students around. In that way each student can check their understanding of what they have learned with a new partner. While they are doing so, you may want to walk round the class, checking they can identify macronutrients and understand their contribution to the energy stored in food. Understanding how to determine the energy transferred in the combustion of food using data from calorimetry experiments is essential for successful completion of the lesson.

Step 2: At the beginning of this exemplar lesson, check students' understanding of relevant chemistry by asking (again!) the questions in the Background section. Organise the class, if possible, to work in the same pairs as in the previous lesson. Have each person in the pair create the tables for their experimental data in their own laboratory notebook in preparation for their data collection from the practical activity.

Step 3: Within each pair, have them check each other's work and that each has set the tables out correctly with the correct headings.

Step 4: Make sure that each pair has access to/can see the computer screen to begin the actual investigation and observation and carry out the calorimeter experiments. Ensure that each pair knows how to perform the experiments – or if you are using a laptop/projector, that you draw on the expertise of the class as you go through each step of the investigation, selecting food, taking measurements of mass and temperature, using equipment – e.g. ask them what the next step is.

Step 6: Have the class follow the instructions. Make sure, if working in a pair on a PC, that each student in the pair gets to follow all the steps; if working in a group on a PC, have the group leader ensure that everyone in the group is involved.

Step 7: Five to ten minutes before the end of the lesson, tell the students to complete the quiz.

Appendix 2: Teacher notes – outputs from the lesson

Task 1

All students will have the same choice of foods. The initial weight of each type of food will be slightly different for each student (± 0.02 g).

The initial and final weight include the mass of the crucible; students are only interested in the difference between these values:

Mass of food burned = Initial weight – Final weight

The initial temperature of the water is 21.1 ± 0.2ºC

The table below summarises expected experimental data of mass of food burned and increases of water temperature:

Food	**Mass burned / g**	**ΔT / ºC**
Coconut peanuts	0.81	3.8
Plantain chips	0.65	2.7
Puff Puff	1.15	2.9
Fufu	1.48	3.2
Millet Porridge	0.81	0.6

Students should supply data from at least two replicates.

Due to lab safety issues and/or deviations from the procedure that could introduce experimental error, there are some alerts appearing in the application and advising students in various situations (e.g. opening the oxygen source before starting the water-jet pump, stirring the water before taking a temperature reading).

Task 2

The table below gives the expected set of experimental data for energy in food and the actual values on food labelling:

Food	**Energy transferred / kJ** *(exp data)*	**Energy per 100 g / kJ** *(exp data)*	**Energy per 100 g / kcal** *(exp data)*	**Energy per 100 g / kcal** *(food label data)*
Coconut peanuts	16.1	1988	475	553
Plantain chips	11.3	1743	416	517
Puff Puff	12.1	1054	252	361
Fufu	13.4	904	216	319
Millet Porridge	2.5	310	74	37

Experimental data would be more reliable if greater masses of food were burnt (reducing uncertainty in weight and temperature measurements). Heat loss is also contributing to the error in this experiment.

Appendix 3: In-text question answers

Which minerals are essential for the body?

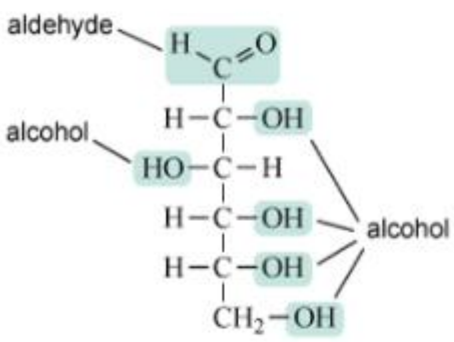
Answer:

There are around 20 elements required in our diet to sustain health. For example, calcium and phosphorus make the bones and teeth hard. Several minerals are important electrolytes in the body. Electrolytes are substances that dissolve in water to form ions, including sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and chloride (Cl^-) ions. All organisms must constantly maintain a balance between the concentration of electrolytes in the fluids inside and outside their cells. Other dietary minerals are essential components of enzymes and other molecules that regulate various body processes, e.g. iron is vital for oxygen transport to body's tissues.

Which are the functional groups in straight-chain glucose?

Answer:

The functional groups in a straight-chain glucose are given in the figure below:



Why is eating lots of saturated fats bad for your health?

Answer:

Eating lots of saturated fats can raise your cholesterol and increase your risk of heart disease. Cholesterol is a type of lipid molecule that has a bad reputation due to its tendency to collect on the walls of arteries to form fatty deposits, gradually blocking the blood flow in the arteries.

In a body cell, what is the name of the structure (located in the cytoplasm) where protein synthesis takes place?

Answer:

Proteins are synthesised on ribosomes.

How many kilojoules are in a Calorie?

Answer:

One Calorie (or kilocalorie) is equivalent to 4.184 kJ.

How does the energy available of 1 gram of fat compare to that of protein or carbohydrate?

Answer:

Fat releases much more energy than protein or carbohydrate.

Compare the food nutrient content shown in the food labels of pistachio nuts and a baked corn snack (Table 2). Which food shows the highest energy content per gram?

Table 2 Food nutrient content on food labels

	Pistachio nuts (100 g)	**Baked corn snack (100 g)**
Protein /g	18.3	6.0
Carbohydrate total / g	28.3	60.5
Fat total / g	47.8	24.6
Fibre / g	9.1	1.7
Sodium/g	0.004	0.6

Answer:

Pistachio nuts have higher fat content and consequently higher energy content. Corn-based snacks have more carbohydrates, but the energy released from carbohydrate is less than that released from fat.

Is the combustion of food an exothermic or endothermic reaction?

Answer:

Combustion or burning of food is an exothermic reaction, it releases thermal energy into the environment.

Which gases are produced in the combustion of food?

Answer:

When food is burned in the presence of oxygen, carbon dioxide gas and water vapour are produced. The combustion of food also releases heat.

In a food calorimeter, a small amount of brown seeded bread was burned and was used to heat 1000 ml of water at an initial temperature of 21.5°C. When the temperature of water increased to 23.2°C, the mass of bread burned was 0.62 g. Calculate the experimental number of kilocalories released per 100 grams of food.

Answer:

The energy transferred to the water is calculated as:

$q = m\ c\ \Delta T$

where m is the mass of water in the conical flask, c is the specific capacity of water (4.18 J $g^{-1}\ {}^{o}C^{-1}$) and ΔT is the increase in the temperature of water.

$q = 1000\ g \times 4.18\ J\ g^{-1}\ {}^{o}C^{-1} \times (23.2{}^{o}C - 21.5{}^{o}C) = 7106\ J = 7.106\ kJ$

In the experiment 0.62 g of bread was burned.

Energy per gram = 7.106 kJ / 0.62 g = 11.46 kJ g^{-1}

Energy per 100 g = 11.46 kJ /g x 100 = 1146 kJ

Energy per 100 g in kcal = 1146 kJ x (1 kcal/4.184 kJ) = 273.9 kcal

Due to the uncertainty of the measurements, the value should be reported with only three significant figures, energy per 100g = 274 kcal.

Which food shows the highest experimental energy content per gram?

Answer:

Coconut peanuts and plantain chips have higher energy content based on the experimental data. This matches the data you can find on food labelling as coconut peanuts and plantain chips have higher fat content than other foods. Fufu and Puff Puff mix have high carbohydrate content, but energy released from carbohydrate is less than that released from fat.

Typical nutrient content on food labels:

Food	Protein / g	Carbohydrates / g	Fat /g
Plantain chips (100 g)	2.3	64	30
Millet porridge (100 g)	3.5	23	1
Fufu (100 g)	7.9	68	3
Coconut peanuts (100 g)	17	44	32
Puff Puff mix (100 g)	9.7	76	1.4

Do your calculated experimental values of energy make sense compared to values shown in food labels (Table 5)?

Table 5 Values of energy on food labels

Food	Energy per 100 g of food / kcal
Plantain chips	517
Millet porridge	37
Fufu	315
Coconut peanuts	553
Puff Puff mix	361

If you were going to repeat these experiments, what would you do differently?

Answer:

The results would be more reliable if greater masses of snack were burnt. This would reduce the uncertainty in the mass and temperature measurements.

Appendix 4: Quiz answers

Correct answers are **highlighted in green**.

Question 1

For each of the questions below select the correct answer:

1. Which are the two functional groups in an amino acid?

   a) Amino group and alcohol group

   b) Amino group and carboxyl group

   c) Amino group and aldehyde group

2. Which macronutrient stores more energy?

   a) Protein

   b) Fat

   c) Carbohydrates

3. Which of the following values is equal to 2 kilocalories (kcal)?

   a) 8400 joules (J)

   b) 4.2 kilojoules (kJ)

   c) 2000 nutritional calories (Cal)

Feedback

1 nutritional calorie (1 Cal) = 1 kilocalories (kcal) = 1000 calories (cal) = 4184 joules (J)

Question 2

Which of the following statements is correct?

a) In unsaturated fats, all the covalent bonds between the carbons in the fatty acid chains are single bonds.

b) The complete combustion of food requires the presence of a good supply of oxygen.

c) Carbohydrates are made of hydrogen, nitrogen and oxygen.

Question 3

Complete the equation below, used to calculate the energy transferred from the combustion of food to the surrounding water by selecting one option to fill in the gap.

Energy = **mass of water** x specific heat capacity of water x change in temperature of water

[volume of water, **mass of water**, mass of food]

ACKNOWLEDGEMENTS

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