Investigating Materials Using Chocolate

Background

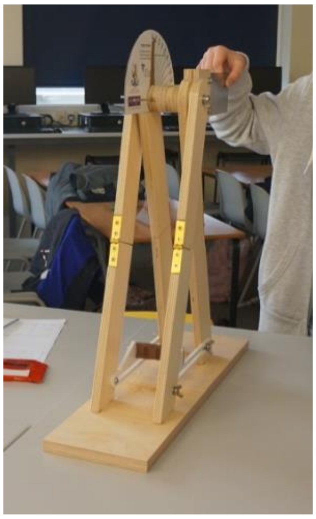
Learning about materials chemistry, structure, strengthening and properties can be a potentially dry task for anyone in KS3, but materials have been developed to complete all of this using chocolate as a reference point.

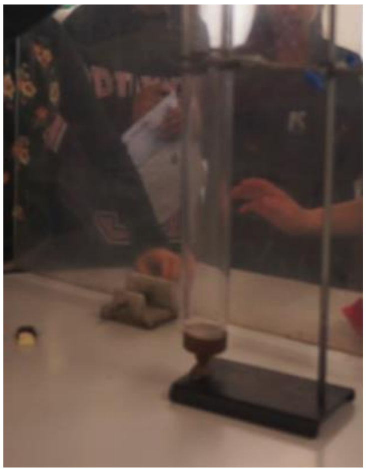
Properties covered include:

- Hardness
- Stiffness
- Fracture Energy
- Melting Point
- Density

Students will need to research:

- Difference between white chocolate, milk chocolate, dark chocolate
- How to test hardness, stiffness, impact energy and density
- What “allotropes” mean





Equipment Required

- Perspex guide tube[1], clamp stand, ruler and indenter for hardness tester, Perspex screen for safety protection
- Charpy impact tester for fracture energy
- Small G-clamp and 10g hanging masses for stiffness measurements
- Accurate mass balance and ruler for density measurements
- Method of melting chocolate and accurate thermometer for melting point measurement
- Chopping board and cutting equipment for sample preparation
- Chocolate bar molds for cooling rate investigation

Experiments

1. Fracture Energy investigation:
- Assemble Charpy Impact Tester as per instructions provided.
- Align 4 squares of chocolate across the guide holder.
- Reset the energy loss track to 100% and lift the arm to 90^{O}.
- Release the impact arm and record energy loss. This is shown as a percentage for ease of use but can be converted into an energy value in Joules for higher levels.
2. Stiffness investigation:
- In terms of chocolate, stiffness is indicated by how much force is required to snap off a square, hence the force required to snap the chocolate is being measured as minimal deflections in chocolate are hard to measure.
- Use a small G-clamp to attach a strip of 4 squares to the edge of a table with the other 3 squares overhanging.
- Slowly hang the hanging masses onto the end square until the chocolate snaps.

[1] Items underlined can be provided for hire by University of Oxford Department of Materials

- Record the force that caused fracture.

3. Hardness investigation:

- Suspend Perspex guide tube above the bench using a clamp stand. Position a Perspex screen infront of the setup for safety.
- Put a piece of paper on the desk, and drop the indenter down the guide tube recording the point of drop.
- Place a square of chocolate on the target point and release indenter from a constant height to impact the chocolate.
- Measure both diagonals of the indent using a ruler and record the area of the indent.
- Using the mass of the indenter, and the area of the indent, calculate the Vickers hardness $H_v = \frac{Load}{Indent\ Area}$

4. Density investigation:

- Cut a square of chocolate into a clean sided sample.
- Measure the volume of the sample using a ruler to measure each side.
- Measure the mass of the sample.
- Calculate the density $\rho = \frac{Mass}{Volume}$

5. Melting Point investigation:

- Melt the chocolate in a bowl slowly over a heat source (such as water in a pan).
- Once some chocolate has melted, take the temperature of the chocolate using a thermometer.
- Be careful that the temperature of the bowl is not taken.
- As an estimate, chocolate melts in your hands so a prediction of temperature range can be made.

Materials Used

Three areas of materials science can be investigated in this practical using the following samples:

CHOCOLATE	PRODUCTION METHOD
MILK	Can be bought
WHITE	
DARK	
MELT + LEAVE	Melt, pour into mold and leave
MELT + QUENCH	Melt, pour into mold and put in fridge / freezer instantly
MELT + TEMPER	Melt, using a thermometer, stir until the chocolate reaches 37°C then pour into mold and leave
STRENGTHENING PARTICLES	Can be bought e.g. raisin addition / cereals

Science Covered

The use of milk / white / dark chocolate investigates different matrix properties e.g. iron alloys vs copper alloys vs aluminium alloys. White chocolate contains large amounts of cocoa butter which acts as a plasticiser. Dark chocolate contains large amounts of cocoa solids which embrittle the chocolate. Milk chocolate contains a mix and so has properties between the two.

Using the same base material (milk chocolate is easiest to work with), the chocolate can be processed in 3 ways: melted, poured into a mold and left to air cool; melted, poured into a mold and put instantly into a fridge / freezer (quenched); and melted, stirred until it cools to 37ºC then poured into a mold and left to air cool (tempered). This simulates the different cooling rates and heat treatments used during casting of metals. By cooling in different ways, different allotropes (crystallographic and chemical forms) of chocolate are formed. These taste different, look different, have different melting points and different mechanical properties.

Finally, the addition of particles such as biscuit, fruit or (if able to use in the school) nuts, usually strengthen the chocolate, but often embrittle it too. A balance has to be made as to the size of the additions. This simulates either a composite material (for large additions) or particle strengthening (for fine additions) and encourages discussions about alloying and strengthening methods.

From all of the above tests, discussions about what makes a “good chocolate” can be had – whether we want chocolate to be strong, to have a good snap, to melt at a higher temperature, to be dense or light.

As a follow up, investigate one property, and a chocolate designed to maximise this by choosing the best matrix (chocolate type) cooling method and particle additions.

This can then be related back to a metallic alloying system and why the matrix, production method and particle additions were chosen for the given application.