The Science of Popcorn
Introduction
This resource has been designed to support the Key stage 4 of the National Curriculum for England, with particular relevance to Science: Sc1 Scientific enquiry, Investigative skills and Sc4 Physical processes; Mathematics, Ma1 Using and applying mathematics, Ma2 Number and algebra and Ma4 Handling data.

This resource is particularly well adapted for practicals, extended course work or science clubs.

This activity was originally delivered in Norfolk schools as part of National Science Week 2001. It was funded using a National Science Week Grant from the Biotechnology and Biological Sciences Research Council and has now been developed as a self sufficient unit for classroom use.

Yes, you can photocopy this pack!
The contents of this pack can be photocopied for educational use. The A4 electron microscope images (pp 12 & 13) could also be photocopied onto OHP acetates for demonstration in the classroom.

Background
Popcorn is not just a modern snack for cinema-goers. We are familiar with electric popcorn makers and microwave packs, but for generations people in South America, India and some parts of Africa have produced a tasty, nutritious snack by popping maize and other grains such as sorghum and millet on hot metal plates or on very hot sand.

Recently, scientists have found that the protein in porridge made from milled popped sorghum is more digestible than that made from ordinary sorghum flour. Scientists at the Institute of Food Research are interested in this difference in availability of protein from popped compared to unpopped sorghum.

Popcorn is an excellent source of protein, carbohydrates, vitamins and fibre. Popcorn can be a healthy snack provided not too much salt or sugar is added.

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What is special about popcorn?
Types of corn and how to prepare in advance.

Hydrated corn
This can be made by soaking normal popping maize in water overnight. Drain and pat dry before use. Unpopped popcorn bought in shops contains approximately 14% water. This is the optimal water content for popping maize. By soaking it overnight, the water content in the kernel is raised above the optimum level.

Broken maize
Maize can be slightly damaged by placing it in a transparent plastic bag and cracking the pericarp with a rolling pin. You are aiming to damage the pericarp without breaking the kernels open. Popping maize requires a high pressure to build up in the kernel. If the pericarp (outer casing) is broken, this high pressure cannot be maintained and the maize will not pop.

Non-popping maize
Maize that is used for feeding animals can be obtained from pet shops. You may need to extract these from a mixed feed. Starch granules in popcorn are very tightly packed within the cells. This tight packing is essential for popping. Other varieties have less tightly packed starch.

Normal popcorn
Popcorn can be bought in bags ready to pop from most supermarkets. Do not use microwave popcorn.

Suggested Equipment
Measuring cylinders (of varying volume 10 — 20 cm³ for unpopped maize and 50 — 100 cm³ for popped samples). Popcorn machine or heavy based saucepan with lid and oil for popping.

Popcorn machines can be purchased at many catalogue stores. These do not require the use of oil and normally cost £15 — 25 each.

Predictions
You may wish to go through the information on Explaining the Popcorn Explosion with students before they make their predictions.

Method
Measure a small volume of each sample, approximately 10 cm³. Record this initial volume in the table. Pop each of the samples if you are using a popcorn machine, follow the manufacturer’s instructions. Otherwise heat 10 cm³ of oil in the pan and then add one sample of the maize, cover and place on a high heat. As soon as the maize starts popping, turn the heat down and wait for popping to stop. Measure the volume of popped maize and record the final volume in the table. In each case a time limit should be recorded for the control sample and maintained when popping other samples. You should make sure that the maize is popped at the approximately same temperature to make it a fair test.

By using the results table to determine changes in volume, the students will be able to make a fair comparison of different samples.

Observations and discussion points;
Some popping may occur in all cases. However, the volume of the normal popcorn will be greater than that of the other maize samples. The normal popcorn can be used as a comparison and is called a control.

Students may be asked to:
- make comparisons between samples
- use their observations and results to draw conclusions
- judge level of uncertainty in observations

Risk assessment
It is necessary to reinforce the message to students that even though the laboratory where the experiment is done may be clean. It is not good practice to consume food which has been in the laboratory.

Because of the high temperatures involved in popping maize, the equipment used is likely to be hot.
A Tasty Profit

You can use the pupils experimental results to deliver the next project A tasty profit? Students use the data they have collected to work out the profit that might be made by popping and selling popcorn in the cinema. They are also asked to consider other costs which might be incurred by the retailer.

The following is a worked example of the calculation. If pupils don t know how much items cost, they can be encouraged to guess. The following are approximate figures:-

Cost of bag of cinema popcorn is £3.10 = 310 p
Volume of bag is 2 litres = 2000 cm³
Cost per cm³ = Cost of whole bag ÷ volume of bag = 310 ÷ 2000 = 0.155 p/cm³
Cost of bag of unpopped supermarket popcorn = 55 p
Volume of bag = 0.5 litres = 500 cm³

Using the results from the experiment:
If each 1 cm³ of unpopped maize produces 15 cm³ of popcorn, then 500 cm³ of unpopped maize will produce 500 x 15 = 7500 cm³ of popcorn.

Profit = (selling price of popped corn x volume sold) — (original price of supermarket bag)
= (0.155 x 7500) — 55
= 1107.5 p
= £11.08

Answers will depend on volumes obtained during the experiments.
Other costs that will affect the producer s final profit include transport costs, maintaining hygiene standards, overheads in cinema including rent, staffing, heating, equipment, lighting also advertising, toppings, wastage, cost of oil packaging etc. The students may come up with many more.

Extension Activities

You might like to encourage students to look for maize (often called corn) in ingredients lists on food packaging.

Both maize starch, derived from the endosperm, and maize oil, from the embryo, are used in food products.

Some examples include:
Maize oil — cooking oils.
Maize starch — custard powder, maize derived snacks, tortillas.

Other uses for starch — as a biodegradable alternative to polystyrene packaging, to produce the gloss on magazines and as bulking agents in medicines.

Explaining the Popcorn Explosion

The explosion of hard kernels of sorghum to produce a light, foamy, protein-rich product has been investigated at the Institute of Food Research as part of a project to investigate the digestibility of this important African staple food. By using a high powered electron microscope, we are able to look at the factors that are important to the production of good-quality popcorn.

The maize kernel consists of the embryo (from which the new plant develops) and the endosperm. The cells of the endosperm contain both starch and protein. These are needed for the early growth of the embryo during germination. When we eat products made from endosperm flour, our bodies digest some of this starch and protein.

Glossary

Pericarp — outer casing of the kernel, derived from the ovary wall.
Embryo — early stage of the developing plant.
Endosperm — energy store for the growing plant during germination.
Kernel — the grain of a cereal consisting of the seed in a hard pericarp.
What is so special about popcorn?

You can t pop just any kind of maize. There are lots of different varieties which are used for canning, freezing, eating off the cob or feeding to animals. You can only pop specific varieties because the explosion relies on particular features of the maize.

In this experiment you will look at what makes popcorn pop. You will be using four types of maize:

- Hydrated popcorn maize (maize which has absorbed extra water)
- Broken popcorn maize (maize which has been damaged)
- Maize that is used for feeding animals
- Normal popcorn maize

You are going to pop samples of maize and compare the results you get from different types. You are going to measure the volume of popped maize in each case and look for any differences.

1. What equipment will you need?

2. What do you predict will happen?

3. Briefly describe what you are going to do.

4. Why is it important to know the change in volume per cm$^3$?

5. What comparisons can you make? What is your control?

It's a squeeze

In raw popcorn kernels, the starch granules in the endosperm are packed tightly together and the small protein bodies completely fill up the spaces between them. This tight packing is the first requirement for good popcorn. Varieties of maize with loosely packed starch granules do not pop.

A strong case

The strength of the casing around the kernel, the pericarp, is the second important factor in good popcorn maize. When we pop corn, we heat the kernels to a high temperature in a popcorn maker or a saucepan with the lid on. The pericarp must be strong enough to resist the high pressure which builds up in the kernel as it is heated. If the pericarp is weak or damaged, the pressure within the kernel would be released gradually rather than building up to an explosion.

H$_2$O

Good quality popcorn maize should contain about 14% water. In the centre of each tightly packed starch granule is a small hole. As the popcorn kernel is heated, water begins to vaporise, filling the hole with steam and softening the starch. Unlike a boiling kettle of water where the steam escapes out of the spout, in popcorn, the steam is trapped inside the starch granules and so the pressure starts to build up in the kernel. The temperature increases to 180°C and the pressure reaches 9 atmospheres (similar to the pressure inside a steam engine). At this point the kernel is ready to burst.

Ready to burst

Suddenly the pericarp yields to the pressure and splits, allowing each softened starch granule to be inflated by the steam inside it, like lots of tiny balloons suddenly being blown up. The contents of the kernel burst out of the pericarp and within milliseconds the hot kernel is turned into a flowing white foam, which quickly sets as it cools. The foam appears white because it contains thousands of tiny air bubbles, rather like clear egg white which becomes white when beaten.
A Tasty Profit

Having popped some maize yourself you will have noticed that there is a large change in volume of the maize during popping. Using the results from your experiments, together with some additional information, you can work out the profit that might be made by buying raw popcorn and selling it popped at the cinema.

### Additional Information

1. How much does a bag of popcorn at the cinema cost?  
2. What is the approximate volume of the bag?  
3. How much does popcorn at the cinema cost per cm³? 
   \[
   \text{cost of whole bag} : \text{volume of bag}
   \]  
4. How much does a bag of unpopped maize cost at the supermarket?  
5. What is the approximate volume of the bag?  

### Using your results for the normal popcorn from your experiment:

6. What volume of popcorn can you make from 1 cm³ of unpopped maize?  
7. What volume of popcorn could you make from the entire original supermarket bag?

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### Results

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<th>Hydrated Popcorn</th>
<th>Broken Popcorn</th>
<th>Animal feed Maize</th>
<th>Normal Popcorn</th>
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<tr>
<td>Initial Visual Observations</td>
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<td>Initial Volume</td>
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<td>Final Visual Observations</td>
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<td>Final Volume</td>
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<td>Change in volume (Final volume - Initial volume)</td>
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<td>Change in volume per cm³ (Change in volume - Initial volume)</td>
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6. From your experiments, explain what you think are the most important factors for maximising popcorn volume?

7. How could you make your experiment more accurate next time?
8. What profit could you make if you sold all the maize from the supermarket bag as popped maize at the cinema?

\[(\text{selling price of popped maize} \times \text{volume sold}) - \text{(original price of supermarket bag)}\]

9. Food products are usually produced on a much larger scale. Can you work out the profits you would make if you started with the following volumes of unpopped maize?

A. 10000 cm³  
B. 1 m³  
C. 1.5 m³

10. What is the catch? If it is this easy to make money on popcorn, wouldn’t we all be doing it? What other costs will affect the producer’s final profit?
**Additional Help**

Places for Further Information about popcorn
http://maize.agron.iastate.edu/
http://popcorn.org

About National Science Week
www.britassoc.org.uk
www.scienceyear.com

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Helen Penny demonstrating ion absorption

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