Feeding a growing world: Potato variations

Teacher notes

The issue

The Earth's resources are limited, but the human population is growing fast. How can we ensure food security – adequate safe, healthy food – for everyone? To guarantee a sufficient supply of safe, nutritious food that is resilient to climate change and to economic and natural challenges, people will have to consider developing new forms of agriculture, cutting wastage, ensuring better food storage, and using technology to improve crop yields, nutrition and safety, amongst other possible contributions to a solution.

Introduction

> *Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. (World Food Summit, 1996).*

The world population is set to increase by 50% to about 9 billion over the next 20 years. In addition, with increasing wealth more people want to eat more meat. If this is to be possible, global grain production will have to double over this period, as some of the extra grain will be used for livestock feed. The production of many other staple crops will also need to be increased to ensure food security.

Potatoes are a main staple in many countries, including the UK. The spread of cultivation of this versatile vegetable has changed world history. The Spanish brought potatoes from South America to Europe in the second half of the 16th century. At the time people viewed this novel food with suspicion and it was not widely grown until the 19th century. Once potatoes had been accepted in Europe, however, their high yield contributed to the large population growth that occurred in the 19th century. These days they are also very popular in the form of fast food such as chips and crisps, but we now know that acrylamide, a carcinogen, is formed in potatoes when they are cooked at temperatures above 120 °C. It is created in the Maillard reaction between reducing sugars and the amino acid asparagine in the potato. Can we identify potatoes that will produce only small amounts of acrylamide on processing, and can we find ways to reduce that amount further?

You will find more detailed background notes on the potato and the development of agriculture in 'More to explore' on The Crunch website, **thecrunch.wellcome.ac.uk/schools**.

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The practical investigations

The first main practical investigation involves students investigating the reducing sugar content of different varieties of (non-GM) potato, providing an opportunity to teach or revise the test for reducing sugars. Extensions of this work involve observation of starch grains in tubers and investigating the synthesis of starch from glucose-1-phosphate using an enzyme extracted from potato tubers. There are also opportunities for students to plan and carry out investigations into the effect of storage time or storage temperature on the reducing sugar content of potatoes as an extended project.

You can carry out as many or as few of these activities as seem appropriate. There are opportunities for differentiation in the activities selected, in the degree of planning done by the students, and later in the related discussions.

Research informing the investigation

Dr Nigel Halford, Programme Leader, Plant Biology and Crop Sciences, at Rothamsted Research, carries out research into low-acrylamide potatoes.

Professor Jonathan Jones FRS is a senior scientist at the Sainsbury Laboratory in Norwich. He uses molecular and genetic approaches to study diseases in plants. A video about this, 'Potatoes – research and the biotechnology of genetic modification', is available on The Crunch website, **thecrunch.wellcome.ac.uk/schools**.

Professor Rod Scott, Head of the Department of Plant Genetics at the University of Bath, works on biotechnological approaches to increase crop yields.

Some current aspects of research into food security and the factors that put it at risk are considered in the links on The Crunch website, along with references on research into potato characteristics, breeding and genetic modification.

Assumed prior learning

- cell structure
- plant structure
- enzymes
- photosynthesis; respiration.

Learning objectives

- Investigate the reducing sugar content of different varieties of potatoes, *Solanum tuberosum*, using standard food tests.
- Use qualitative reagents to identify biological molecules.
- Analyse the data and draw conclusions.
- Be able to: formulate a suitable hypothesis, identify dependent, independent and control variables, design and carry out a quantitative practical.
- Plan an investigation to test a hypothesis, including selecting suitable apparatus and carrying out a risk assessment and deciding how to treat the data generated.

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- Evaluate the relative safety of the various cooking methods for this staple vegetable.
- Consider the role of staple crops in feeding a growing world population.
- Discuss the role of genetically modifying crops to help meet the increased demand for food during the 21st century.

Activities

Aim

Students investigate the reducing sugar content of different varieties of potato, with the aim of finding which potatoes will produce the least acrylamide when cooked at high temperatures.

Introductory activities

The student activity sheet contains some background information that explains the real-world context and the purpose of the practical investigation. This sheet could be provided in advance as a homework reading task before the lesson for some classes. The investigations can also be contextualised in starter activities, so if you prefer you can hand out the student activity sheet in class and refer students directly to the practical instructions.

The presentation 'Potato variations' provided on The Crunch website (**thecrunch.wellcome.ac.uk/schools**) can be used to introduce ideas about staple crops around the world and lead into a Q&A on potatoes: historical aspects, how they were viewed with suspicion, their high yield compared with other crops, versatility, nutrient content, whether they would be accepted now if newly introduced, growing conditions, GM varieties and their potential uses.

Recap on starchy vegetables and introduce the idea of sugar in potatoes. Describe the formation of acrylamides during cooking at high temperatures and elicit the idea that, for example, chips could be a source of acrylamide. Ask how students would select potatoes for chip-making (for example) to limit acrylamide formation. Recap on carbohydrate biochemistry and ask how students would test potatoes for sugar content; recap on food tests. The video clip on The Crunch website (**thecrunch.wellcome.ac.uk/schools**), 'Potatoes – research and the biotechnology of genetic modification', covers the biotechnology of genetic modification to create potatoes that can resist pests and diseases and that are low in sugar. This video can prompt discussion of the use of genetic modification, which is the subject of the second practical investigation in the kit.

Practical investigation: Potato reducing-sugar content

Safety

Carry out a risk assessment with the students. Ask what hazards they can predict and how to control them.

Refer to the technician notes for full safety information.

The practical investigations are described in the student activity sheet and the technician notes.

Use a few different varieties of potato. Each pair of students can investigate two varieties and then the class can share their findings. They can omit the Benedict's test and just use the test strips if time is tight. However, this version of the Benedict's test – as well as being helpful revision – is useful for introducing the idea of making a qualitative test partly quantitative. Students may also be able to compare their results using Benedict's reagent with those using the test strips. If they make enough starch-free extract when preparing for this sugar content test, they can use that extract for a further experiment, observing the synthesis of starch from glucose-1-phosphate. Extracts from both potato varieties can be mixed and used for this latter practical if necessary.

If time is likely to be tight, or the specified equipment is not available, there are alternatives.

- If blenders are not available, or the class is large enough for a queue to form by the blenders, then pestles and mortars can be used instead. Some blenders need a larger volume to operate than that specified in the student activity sheet, in which case you can double the amounts used to 100 g potato in 100 mL water.
- Similarly, the centrifuge step can become a bottleneck, or no centrifuge may be available. In this case students can filter their suspensions instead (as described in the student activity sheet). If they take the top few millilitres of the filtrate and leave the remainder to stand while they carry out the main investigation, it will clear further and can be used later for observation of the synthesis of starch from glucose-1-phosphate.

Additional activities

If time permits or if these activities fit into your specification (for example if students need to carry out an extended practical project) a range of additional activities is described online at **thecrunch.wellcome.ac.uk/schools**.

The additional questions may be set as part of homework if there is not enough time for students to address them all in the lesson.

'Observing starch grains' is a very simple and quick protocol – the leftover potatoes from the main investigation can be used – but it is interesting. It will refresh students' biological drawing skills and provide often necessary practice in measuring structures seen under an optical microscope.

The potato extract unused in the main investigation can be used in an additional activity to observe the synthesis of starch from reducing sugars, 'Starch synthesis'.

Students can also be challenged to plan further investigations into, for example, the effects of temperature and storage time on potatoes.

A set of topical play scripts and supporting resources from the Theatre of Debate is available on The Crunch website:
The Fat of the Land – Adam Hughes
The Super Safe Environment Compound – Elinor Roos
Fields and Fields and Fields – Jonathan Hall
The Chicken Temptation – Judith Johnson
Feed Me – Rhiannon Tise.

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Answers to questions in student activity sheet

1. Investigate sugar content as described in student activity sheet (test strips or semi-quantitative Benedict's test).
2. For discussion in class.
3. The potato variety that had the lowest concentration of reducing sugar, because lower amounts of reducing sugar produce less acrylamide, which is carcinogenic, when the potatoes are heated to temperatures above 120 °C.
4. Semi-quantitative; allows a rough idea of quantities but is not very precise/lacks intermediate values.
5. With two it is not possible to tell whether/which one is an anomaly.
6. Late blight can spread when rain splashes up from the soil onto leaves and stems, carrying spores with it; spores can float through films of water on the soil surface, and rain washes spores into the soil where they can infect the tubers.

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Research background

General

A selection of references on food security, threats, and agricultural techniques can be found in the teacher notes to the second practical investigation in this topic, pGLO transformation of *E. coli*.

Additional web resources on this topic will be found as links on **thecrunch.wellcome.ac.uk/schools**.

Bynum, H, Bynum, W. *Remarkable Plants That Shape Our World*. Thames and Hudson (in association with Royal Botanic Gardens, Kew), 2005

Reader, J. *The Untold History of the Potato*. Vintage, 2009.

Project to produce low-acrylamide potatoes (Dr Nigel Halford *et al.*): **www.acrylamide-potato.org.uk**

Stadler, RH, Black, I, Vang, N. *et al.* Acrylamide from Maillard reaction products. *Nature* 2002, *419* (6906), 449–450

Pelucci, G, Galeone, C, Levi, F. *et al.* Dietary acrylamide and human cancer. *International Journal of Cancer* 2006, *118*(2), 467–471

Modifying potatoes to increase disease resistance (Prof Jonathan Jones *et al.*):

Jones, JDG, Witek, K, Verweij, W, *et al.* Elevating crop disease resistance with cloned genes. *Philos Trans R Soc London B Biol Sci* 2014, *369* (1639), 20130087

Jones, JDG, Dangl, JL. The plant immune system. *Nature* 2006, *444* (7117), 323–29

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