# Feeding a growing world: More to explore – Potatoes

## Background notes

### The tale of the potato

After the last ice age, various plants became domesticated and diverged from their wild ancestors. In the Andes of South America, the flourishing Inca culture relied on tubers, including the potato, *Solanum tuberosum*, a resilient plant that prefers moist and cool conditions but is now grown in almost every climate. Europeans first encountered the potato in 1537 and many regarded it with suspicion, as it was related to the poisonous deadly nightshade and was not mentioned in the Bible.

In the Andes, potatoes mature when day and night length are roughly the same. In Europe, potatoes mature in autumn, when frost is imminent. As potato plants crop heavily and provide much energy to those consuming them, horticulturists in the 18th and 19th centuries worked to hybridise them and develop new varieties. In Ireland, farmers with small plots of land came to rely on potatoes to feed their families, as potatoes produced four times as many calories and more essential nutrients per hectare than did wheat. However, the fungus-like oomycete *Phytophthora infestans*, which causes late blight in damp weather, spread to Ireland from Belgium during the 1840s, destroying the crop and causing the Great Famine in which a million people died. Since then, new potato varieties have been developed that are more resistant to late blight, and plant geneticists have developed genetically modified (GM) resistant varieties.

Potatoes rank fourth in the world as a staple crop, after rice, maize and wheat. China, India and the USA grow the largest crops, much of which are used in processed food, such as potato crisps, and fast food, such as chips. In 2002, acrylamide, a carcinogen, was found to be formed in potatoes cooked at temperatures above 120°C. This compound is formed from reducing sugars and the amino acid asparagine in the tubers in a reaction known as the Maillard reaction (the reaction between amino acids and reducing sugars during high-temperature cooking that gives browned foods much of their flavour). GM low-sugar varieties of potato have been developed for use in the processed food industry to reduce the amount of acrylamides. However, their use has been limited because of concern over consumer reactions.

### Nutritional facts

Potatoes are very nutritious, as well as high-yielding. The edible tubers of a plant make up 75% of the mass of the plant, whereas the edible part of grain crops, such as maize or wheat, accounts for just 33% of the mature plant's mass. Hence a potato crop provides more energy and nutrients per hectare than grain crops. The protein in potatoes is of high biological value, 73, a number that indicates the available nitrogen provided by this protein, which can be absorbed into the body for growth and maintenance. The biological values of other plant proteins are: soya 72, maize 54 and wheat 53.

A medium-sized potato eaten with its skin provides

- half of your daily vitamin C requirement
- almost a fifth of your daily potassium requirement
- a tenth of your daily vitamin B6 requirement
- calcium, magnesium, phosphate, iron, zinc, folate, thiamine and niacin – all essential nutrients.

The same potato contains around 26 g of carbohydrate, mostly starch but some reducing sugars.


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Potatoes also contain phytochemicals such as carotenoids and phenols, important antioxidants that react with and remove free radicals produced during respiration or by fat deposition in artery walls or via smoking. Free radicals are implicated in tumour formation (cancer) so these antioxidants are protective. Carotenoids also maintain healthy skin, bones and immune function.

## Developments in agriculture

Settled agriculture allowed the human population to grow rapidly. Beans (broad beans or fava beans) were amongst the first plants cultivated. Not only are they an important source of protein, like other legume plants they contain symbiotic nitrogen-fixing bacteria in their root nodules that can reduce atmospheric nitrogen to ammonia, which can then be used to make amino acids. Such plants therefore grow in soil depleted of nitrates by cultivation of other crops such as maize. Legumes evolved about 65 million years ago during a period of poor soil fertility. Only a few species are cultivated, but many more non-agricultural species inhabit poor soils in many parts of the world.

As nitrogen is important for making proteins, nucleic acids and other important life chemicals such as NAD and ATP, the cultivation of beans allowed the human population to expand. Incorporating legumes into a crop rotation system increased food productivity after the Agricultural Revolution. In the 1800s, guano (bird droppings) rich in nitrates, phosphates and potassium was exported from South America for use as a fertiliser to boost crop production. After 1870, saltpetre excavated from the desert of Chile superseded guano as the source of agricultural nitrates. Saltpetre has another use – explosives. During the First World War, Germany could not obtain saltpetre. The German chemist Fritz Haber developed a process for producing ammonia from nitrogen and hydrogen by heating them together with a catalyst at high pressures. The Haber process is now used to make cheap fertiliser, vastly increasing agricultural productivity, to the extent that now most of the nitrogen in our bodies gets there via the Haber process.

During the 1940s through to the 1960s, the Green Revolution occurred. It encompassed a series of research initiatives led by Norman Borlaug, who is credited with saving over a billion people from starvation and who won the Nobel Prize in 1970. It included development of irrigation systems, selective breeding of high-yielding cereal grains (often from mutant varieties that were gibberellin-deficient and had short stems, therefore putting more energy into grain production rather than stem growth), modernisation of management techniques and greater availability to farmers of synthetic pesticides and fertilisers. It was so successful, with cereal production more than doubling in many developing countries, that the food surplus produced was ‘turned into people’ and the human population expanded. Thomas Malthus had been proved wrong. Indeed, as Ester Boserup predicted, science, technology and human endeavour had prevented (or deferred) the crisis of population expansion that Malthus had predicted.

Although the rate of increase has now slowed (probably mainly owing to more women in the developing world being educated, less likely to view a large number of children as necessary to provide for them in their old age, and better able to access contraception), the human population is predicted to reach nine billion by 2050. Demand for food both to feed humans directly and to feed animals producing meat and milk will increase – as humans become more affluent they want to eat more high-quality protein food – and the production of grain and other staple crops will need to double yet again. It is not sustainable to keep increasing the use of fertilisers and pesticides, as they have unwanted side-effects and ultimately deplete soil fertility. Neither is it possible to greatly increase the amount of land used for farming.

## Land-sharing or land-sparing

Organic farming bans the use of certain chemicals, but permits others (e.g. copper sulfate, which is toxic). It uses more land than conventional agriculture for the same amount of crop, although this use of land has a less negative effect on biodiversity than intensive farming. However, the main pool of biodiversity is on land that is not farmed at all, so focusing on increasing crop production on land already farmed will not reduce biodiversity much further.

The use of GM crop plants could well be part of the solution, as many are resistant to pests and therefore reduce the need for pesticide use, or are frost-, drought- or flood-resistant. Some may incorporate the pathway for ammonia synthesis, now only present in mycorrhiza and nitrogen-fixing bacteria such as *Rhizobium*, *Azotobacter*, some species of *Clostridium* and cyanobacteria. The metabolic pathway for synthesising ammonia from atmospheric nitrogen and hydrogen derived from respiration is costly in terms of energy use (the hydrogen originates from respired carbohydrate) so any future GM crops that could fix nitrogen might have a slightly reduced yield. However, more plants could be grown in areas of poor soil fertility without the need for synthetic fertilisers, thereby reducing the risk of eutrophication.

## Did you know?

Alder trees have root nodules symbiotically infected with *Frankia alni*, a nitrogen-fixing actinomycete. Alder trees are among the first to appear in forests after a glacial period or fire. One acre of alder trees fixes about 50 kg $N_2$ per year, enriching the forest soil.

*Alnus glutinosa*, the alder, is a pioneer species that can colonise poor and wet soil.

Lauren Holden / Wellcome Images

## Research background

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A selection of reports on potato breeding and genetic modification from *Farmers' Weekly*:

**www.fwi.co.uk/arable/blight-and-nematode-resistant-gm-potato-in-the-pipeline.htm**

**www.fwi.co.uk/arable/conventional-potato-varieties-resist-pcn-and-blight.htm**

**www.fwi.co.uk/arable/us-fast-food-giants-reject-newly-approved-gm-potatoes.htm**