Soya – a plant at the forefront of biotechnology

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Soya is a global staple food and it is claimed that genetic manipulation of the plant allows considerable reduction in herbicide use

History of soya

The soya plant *Glycine max* was cultivated in China before 3000 BC, and was classified as one of the five sacred crops. The first written record is a 2200 BC farming manual advising Chinese farmers how to get the best from their crop. Missionaries brought soya to Europe in the seventeenth century but climatic and soil conditions were unsatisfactory. Soya was introduced in the USA in the early nineteenth century (originally arriving as ballast aboard returning clipper ships), but soya farming in the USA only expanded dramatically after the Second World War, when production in China was devastated.

Cultivation of soya

Soya is a frost-sensitive summer annual, and it takes about 75–80 days for the beans to fully mature; plants may reach 1 metre high. Seeds are borne in hairy pods growing in clusters of three to five; each pod contains two or three seeds, which resemble peas. When the seeds are mature, the upright vine and foliage begin to shrivel and the leaves fall away. Harvesting by machine must be completed before the pods shatter.

ABSTRACT

The history and cultivation of the soya plant, *Glycine max*, are briefly outlined, and its use as a food ingredient and a source of phytoestrogens described. The process of genetic manipulation of the plant to make it resistant to the herbicide *Roundup*, including the technology, regulation, production, processing and labelling, are discussed, as well as consumer attitudes to genetically engineered products in the food chain. Finally, a list of sources of further information on the general topic is provided.

Roundup® and other non-selective herbicides are used extensively for weed control in soya cultivation, but they cannot be applied to weeds within growing crops because they will kill the crop as well as the weeds. Using biotechnology, plants are being developed that are tolerant to *Roundup* herbicide; farmers will thus be able to spray soya crops during the growing season.

Soya is now a global staple food and about 110 million tonnes of beans are produced, mainly in the United States (50%+), Brazil (20%), Argentina (10%) and China (8%). Individual farmer's crops are bulked before export. European oil mills process about 15 Mt of soya beans annually, mainly imported from the USA. Soya beans and their products account for 25% of US agricultural exports to the EU and were worth more than 2 bn dollars last year.

Soya as a food ingredient

About two-thirds of all manufactured food products contain derivatives or ingredients made from soya. Before they can be used in food products the soya beans have to be cleansed, cracked, dehulled and rolled into flakes, which ruptures the oil cells for easy extraction. The oil is extracted using a food-grade solvent, hexane – mostly for production of vegetable oil and margarine. In its pure form as a vegetable oil, it is often used in salad dressings and mayonnaise; as a vegetable fat it is used for baking and frying. Soya lecithin acts as an emulsifier in some chocolate, breakfast cereals, ice cream, sweets and margarine. Soya oil is also used in a wide variety of non-food products, such as soap, biological detergents, plastics, and CFC-free cooling agents; the derivative glycerine is used in the manufacture of emulsifiers for skin cream and softeners for gelatine capsules.

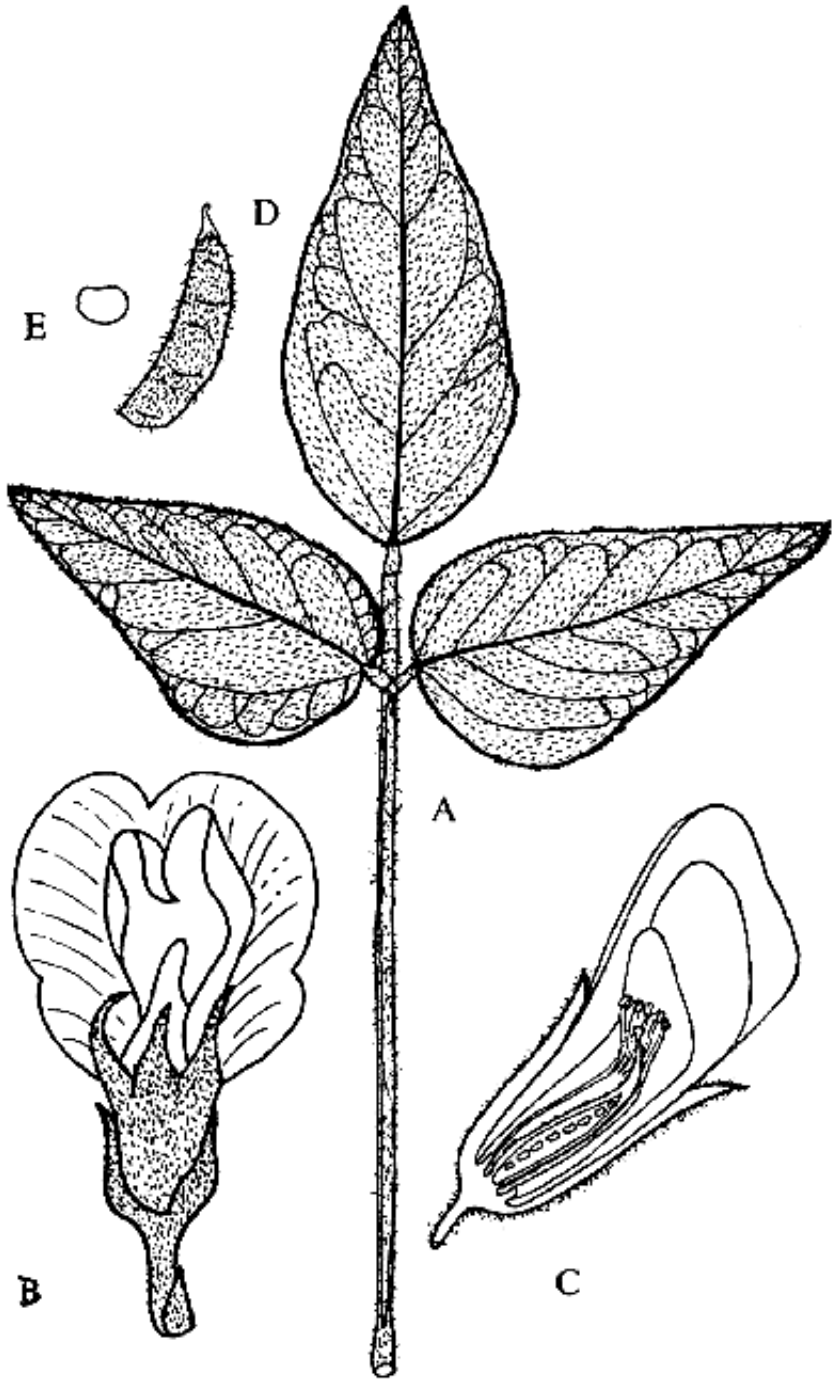

Figure 1

Parts of the soya plant, *Glycine max*.
A: leaf (× 0.5); B: flower from below (× 7); C: flower in longitudinal section (× 7); D: pod (× 0.5); E: seed (× 0.5). (Reproduced from *Tropical crops: Dicotyledons I* by J. W. Purselove, London: Longman, 1968.)

Soya flours were developed in the 1940s by grinding and screening defatted flakes; these are used to increase the shelf-life of many products and improve the colour of pastry crusts; the flour is free of gluten, so cannot replace all the wheat or rye flour in bread-making but can be used at about 15 per cent to give a dense bread with a nutty flavour and moist quality. Texturised soy protein (TSP or TVP) is made from soya flour that is compressed until the fibres change in structure. It is available to home cooks as a dried, granular product and in chunk-sized pieces for rehydrating and use as a meat-replacer.

Following the development of methods to produce isolated soya proteins in the 1950s, it is also processed for use as soya protein in biscuits, sweets, diet drinks, pasta and frozen foods; it also improves the consistency of meat products. It is added to many foods including pizzas, noodles, bread and foods for special dietary needs such as soya drinks, which serve as a substitute for cows' milk. Various cheese and other milk and meat substitute products, such as miso, tofu and tempeh, can be made by fermenting soya protein. In addition, naturally brewed soya sauce uses a starter culture called koji, a member of the *Aspergillus* family, with a mixture of soya beans and wheat.

Soya in nutrition

Soya bean protein quality is comparable to meat and eggs. The vegetable oil is polyunsaturated, has a low level of saturated fatty acids and is free from cholesterol, but contains both essential fatty acids – linoleic and linolenic. Soya beans and the foods made from them are also rich in iron, B vitamins, calcium and zinc. Soya protein is said to have the effect of reducing cholesterol levels in hypercholesteroaemic people (Anderson, Johnson and Cook-Newell, 1995).

Soya and phytoestrogens

Soya is an important source of a group of non-nutrients known as the phytoestrogens, compounds with structural and functional similarities to the natural oestrogenic hormones present in the body. Examples are daidzein and genistein, present at levels of around 3 mg/100 g wet weight in raw beans. In

Figure 2
Soya is widely used in processed foods. (Photograph, IFR.)

certain situations these chemicals can behave like a very weak form of oestrogen.

Epidemiological studies (primarily from Japan, where soya consumption is high) suggest a beneficial, protective effect for the phytoestrogens against certain sex hormone-dependent cancers – including breast and prostate cancers. Phytoestrogens present in a wide range of food plants (including soya) may have deleterious effects on reproductive efficiency when consumed by animals; there is no evidence for a parallel effect in humans. Work is under way which will give a better understanding of how the phytoestrogens in soya behave in humans, since these actions are complex and not completely understood.

Babies may be given soya-based formula milks for one of the following reasons: (1) a small number of babies cannot tolerate cows' milk; (2) some parents choose for themselves to feed their baby soya-based formulae because they have a family history of allergy or for other reasons; (3) soya-based formulae are made entirely from plants and this makes them acceptable to vegans and other groups who do not want to use feeds based on cows' milk. At present there is no evidence that phytoestrogens in soya-based formulae cause any problems.

The UK's Chief Medical Officer recommends that:

If your baby is under one year of age and your doctor has recommended that you feed your baby with a soya-based infant formula, you should continue to do so. If your baby is over one year of age, you should ask your doctor or health care professional about introducing your baby to cows' milk as babies can outgrow allergies. If you are using a soya-based formula, but not on the advice of your doctor or another health care professional, talk to your doctor or other health care professional about whether to continue using it or whether to switch to another type of feed.

Genetically-engineered soya – the technology

Monsanto, the US-based multinational speciality chemical and pharmaceutical company, has developed a new soya bean plant that is genetically-engineered to be resistant to the Monsanto herbicide, *Roundup*.

In traditional soya varieties, *Roundup* blocks the build-up of essential substances for growth of the soya plant, but the modified plant, *Roundup Ready*™, produces a new type of protein enabling it to circumvent this blocker. One of the claimed advantages of using *Roundup Ready* soya beans is that weeds can be controlled after the young beans have started to grow, with just one herbicide. Monsanto estimate that around one-third less herbicide overall can be used with this variety compared with conventional crops.

Monsanto say that genetically modified (GM) soya is indistinguishable from conventional beans in composition, nutrition and processing characteristics; a US company Genetic ID claims to have a test available that can detect the genetic alteration, but this method will only work prior to processing. The new protein is not found in soya oil or lecithin and it is claimed that protein traces in soya meal are inactivated during processing. People who are allergic to conventional soya products will also be allergic to the genetically modified soya products.

Genetically engineered soya – regulation

Oversight of this technology and other genetic modification techniques is provided by the US Department of Agriculture, the Food and Drug Administration and the Environmental Protection Agency. FDA ensures the safety of foods developed by genetic engineering through science-based risk evaluations. This requires developers of foods from modified plants to address whether known allergens have been transferred to the modified product; to demonstrate that the new food does not contain increased levels of previously known toxic substances or new hazardous substances; and that the nutritional value of the product has not been compromised.

The final US approval for use of *Roundup* herbicide with herbicide-tolerant soya beans was granted in Spring 1995 by the US Environmental Protection Agency. The EU authorities issued an import licence according to EC directive 90/220 (product release directive) in Spring 1996 – although this approval is restricted to import and processing. It is also approved as safe by Japan, Argentina and Mexico.

Genetically-engineered soya – production, processing and labelling

The 1996 USA crop of 64 million tonnes contained about 2 per cent of GM soya beans; by 1997, this had risen to 15 per cent. Monsanto says that segregating beans for mass markets would be economically and physically impractical for farmers, grain companies and shippers. The arrival of deliveries of mixed GM and traditional soya beans in Europe (9 Mt out of a total European market of 13–14 Mt) has resulted in widespread discussion about the safety and labelling of genetically-engineered ingredients in foods.

The UK's Advisory Committee on Novel Foods and Processes stated in 1994 that:

> *The* Roundup Ready *soya beans ... and products derived from these beans are equivalent to and as safe for human consumption as beans from conventional soya bean strains and products derived from them.*

At a UK press conference in August 1996, ACNFP Chairman, Professor Derek Burke, said:

> *The beans are processed by severe extraction procedures that destroy the plants' genetic material and also destroy the bacterial enzyme introduced to make it resistant ... In the products there is no bacterial DNA or bacterial enzyme. Flour from the new soya is analytically indistinguishable from the traditional soya.*

The USA's Institute of Food Technologists comments that:

> *Food labels have been established to provide 'material information' about a product, such as ingredients and nutrition information, or warnings about a health risk. Since genetically-modified foods do not pose any new or unique risks, such labels would not provide health or safety information and could mislead by implying that there is a risk.*

Commodity crops such as soya are traded on the international markets in huge amounts. Segregating of commodity crops requires separate production and handling facilities at every stage of the supply chain. The UK bread-baking industry has bought some supplies of 'identity-preserved' conventional soya from Canada, and the frozen-food supermarket chain, Iceland, is avoiding the use of genetically modified soya in its own-label products.

In response to consumer demand, the UK food industry and major retailers have agreed voluntary guidelines for labelling foods containing ingredients from GM soya. These guidelines will be developed and reviewed as circumstances, and consumers' needs, change. Consumer groups have also called for segregation – both on grounds of labelling and because of concern that new technology may lead to less discrimination in herbicide application.

Attitudes to genetic engineering in the food chain

Some pressure groups oppose all forms of genetic engineering, but others are either focusing on particular aspects of the technology in plants or animals, or on environmental concerns. Some prioritise the issue of consumer choice, demanding the labelling of foods containing GM ingredients.

Providing effective communication about the benefits and risks of new technologies depends on understanding the underlying concerns of the public as well as the more technical issues. The public's perception of the risks of genetic engineering is mediated by their recognition of the tangible benefits of specific products of the technology, for example genetically engineered products with health- or environment-related benefits.

If information about genetic engineering in the food chain is perceived by the public as coming from a source that they do not trust, or promoting a particular vested interest, there is a danger that this could result in an unnecessarily negative perception of the technology by consumers. It is also useful to address some of the wider social issues (for example, worries about ethics) in the information provided, as these might also be driving consumer reactions (Frewer and Shepherd, 1995; Frewer, Howard and Shepherd, 1996a, b).

Consumers around Europe have recently been questioned on their attitudes to GM foods. Across Europe, in a 5000-person MORI/Greenpeace poll, 59 per cent were opposed to its development and 22 per cent supported it, with the French and Danish coming out most strongly against. The British showed some of the most positive attitudes, with only 51 per cent opposing development. A separate survey in Germany found that 95 per cent of consumers wanted mandatory labelling of these foods.

References

Anderson, J. W., Johnson, B. M. and Cook-Newell, M. E. (1995) Meta-analysis of the effects of soy protein intake on serum lipids. *New England Journal of Medicine*, **333**, 276.

Frewer, L. J., Howard, C. and Shepherd, R. (1996a) Effective communication about genetic engineering and food. *British Food Journal*, **98**(4/5), 48–51.

Frewer, L. J., Howard, C. and Shepherd, R. (1996b) The influence of realistic product exposure on attitudes towards genetic engineering of foodstuffs. *Food Quality and Preference*, **7**(1), 61–67.

Frewer, L. J. and Shepherd, R. (1995) Ethical concerns and risk perceptions associated with different applications of genetic engineering: Interrelationships with the perceived need for regulation of the technology. *Agriculture and Human Values*, **12**(1), 48–57.

Further information

Useful items from *Nature* magazine

Distrust in genetically altered foods – editorial (1996). *Nature*, **383**, 559.

Genetic resistance spreads to consumers – news (1996). *Nature*, **383**, 564.

Trade war looms over gene-altered foods – news (1996). *Nature*, **384**, 301.

Europe agrees a compromise on food labels – news (1996). *Nature*, **384**, 502–503.

Pros and cons of foreign genes in crops – correspondence (1997). *Nature*, **385**, 290.

Useful contacts for further information

Biotechnology and Biological Sciences Research Council PR Department, Polaris House, North Star Avenue, Swindon SN2 1UH; tel: 01793 413200 (including the booklet *Ethics, morality and crop biotechnology* by Roger Straughan and Michael Reiss).

Food Advisory Committee, Ergon House, c/o Nobel House, 17 Smith Square, London SW1P 3JR; tel: 0171 238 3000 (including Q/A on GM soya beans attached to press release issued as FAC 15/96).