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New technology: Issues relating to the use of genetically modified crops*

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ABSTRACT

With increasing population and decreasing area of land available for food production the development and use of genetically modified (GM) crops is considered as an important tool to ensure global food security. The rigorous safety evaluation, which can take up to 10 years by independent Regulatory Agencies prior to final approval of GM crops, is noted. The rapid uptake of GM technology is illustrated by the increase, between 1996/1999, from 2 to 40 million hectares and that while 72% is grown in the USA a further 15 countries grew GM crops. The paper discusses a number of safety issues including antibiotic resistance marker genes, potential allergenicity, substantial equivalence, consumption of transgenic protein and transgenic DNA and their detection in milk, meat and eggs. Far from increasing the risk of allergenicity GM technology can offer the opportunity to reduce/eliminate protein allergens that occur naturally in foods such as rice, wheat and peanuts and that GM crops are compositionally (laboratory analysis) and nutritionally (animal feeding studies) equivalent to their conventional counterparts. The paper notes that while concern has been expressed about the possible accumulation of transgenic protein and DNA in milk, meat and eggs, and the possible implications of this on animal and human health, the regulatory agencies and the World Health Organisation concluded that there is no inherent risk in consuming DNA, including that from GM crops as mammals have always consumed significant quantities of DNA from a wide variety of sources, including plants, animals, bacteria, parasites and viruses. To date transgenic protein and DNA have not been found in milk, meat and eggs. The paper concludes, by providing numerous examples of the potential benefits to the farmer, consumer and the environment in both developed and developing countries, with particular emphasis on the ability of GM technology to increase crop yield, improve food quality and to reduce the environmental impact of agriculture by amongst other things the lower use of less toxic agrochemicals.

KEY WORDS: GM crops, food security, public perception, safety issues, benefits

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BACKGROUND TO GLOBAL FOOD SECURITY

In the late 18th century the political economist Thomas Malthus proposed that the earth could not support its growing population. In his first essay he said "The power of population is infinitely greater than the power of the earth to produce subsistence for man". As agricultural scientists we believe that he was wrong.

In the 1960's the arrival of the Green Revolution ensured that the world's population of 3 billion could be fed. Much of its success revolved around the introduction of new short stemmed cereal varieties, which tolerated increased fertiliser inputs and produced large increases in grain yields and also the increased use of herbicides for effective weed control. The result was that between 1961 and 1989 cereal yields in Developing Asia increased by three fold. If the 1961 average cereal yield of 980 kg/ha had remained then a further 600 million ha of land of similar quality would have been required to meet the 1997 harvest yield (Borlaug, 2000). The effect of these technologies turned India from a net importer to a net exporter of cereal grains. However, it should be noted that during the last 40 years the amount of herbicide and pesticides used in crop production has increased markedly and is certainly an area of concern for the well being of the environment.

Norman Borlaug in his acceptance speech for the Nobel Peace Prize said that the Green Revolution had won a temporary success in man's war against hunger, which if fully implemented could provide sufficient food for humankind through to the end of the 20th Century. But he warned that unless the frightening power of human reproduction could be curbed the success of the Green Revolution would be ephemeral. He now says that the world has the technology, either available or well advanced in the research pipeline, to feed an expected population of 10 billion people, but the question is will farmers be permitted to use this new technology?

In this scenario of rapidly increasing world population and the static or declining area and quality of land available for crop and livestock production, new technology is required to ensure food security and improved nutrition in an environmentally acceptable and sustainable way. It is in this context, that the development and use of genetically modified (GM) crops could offer considerable potential to developing countries. It is access to new technology that will be the salvation of the poor and not as some would have us believe, maintaining them wedded to outdated, low yielding, and more costly production technology (Borlaug, 2000).

PUBLIC PERCEPTION OF NEW TECHNOLOGY.

The *status quo* is a comfort zone and when this is challenged by new technology it is a worrying event for most people. It is certainly true that there are many examples of new technology creating or being used to create controversy. For example when Jenner was working to produce a smallpox vaccine his work was attacked by the anti-vaccination society who claimed that it would produce deformed humans. The use of anaesthetics was frowned upon until Queen Victoria took a whiff of chloroform during childbirth. In the 1920's there was great reluctance to accept frozen foods. When telephones were first introduced it was suggested that you ran a serious risk of being electrocuted if you used them. With a more agricultural flavour, the introduction of artificial insemination led to sermons being preached in the churches of East Anglia against this unnatural practise and the idea of pasteurisation of milk was blocked for some time as it was alleged that, amongst other things, it destroyed the natural goodness of milk. This act alone resulted in many thousands of additional cases of tuberculosis. These are a few examples of new technologies which started as being controversial but were accepted and resulted in huge benefits for large sectors of the population. Now when we have just entered the 21st Century we have genetic modification of crops and animals, but with some organisations campaigning for a world-wide ban on the development and growing of GM crops. Whether in fifty years when we look back, the furore currently surrounding genetic modification of crops will rank above or below that of the anti-vaccination society or the resistance to the use of artificial insemination we will have to wait and see. However, the general effect of controversy is that it creates a breathing space to ensure that new technologies are being critically assessed and carefully evaluated, to ascertain the benefits and address the concerns expressed about that technology.

In July 2000 the Premier of Saskatchewan, (Hon. Roy Romanow) addressed the 6th International Symposium on Biosafety of GMO. In his address he rightly drew attention to the fact that "we must resist the urge to dismiss criticism of biotechnology as 'Luddite.' It is certainly true that many of the concerns are raised out of emotions and perceptions, made worse by poor media reporting and deliberate manipulation of public opinion" and he went on to say that "our excitement and our enthusiasm for these technologies must be tempered by our recognition of the legitimate concerns people have about these new technologies. Our willingness to adopt the new technologies must be tempered by an equal willingness to adopt safeguards that will ensure safety for the environment and for people."

REGULATORY AGENCIES AND THEIR VIEWS

Regulatory agencies in Europe, US, Canada, Japan, and other countries all require GM crops to be subjected to extensive safety trials and field trial evaluation before being released for agricultural use. Such procedures can take between 7 to 10 years before final commercialisation of new GM crops.

Views on the safety of GM crops are presented below.

- Dr J Henny Commissioner at the US Food and Drugs Administration stated "we have seen no evidence that the bioengineered foods now on the market pose any human health concerns or that they are in anyway less safe than crops produced through traditional breeding. All the proteins that have been placed into foods through the tools of biotechnology that are on the market are non-toxic, rapidly digestible and do not have the characteristics of proteins known to cause allergies. We are not aware of any information that foods developed through genetic engineering differ as a class in quality, safety or any other attribute from foods developed through conventional means.
- *Circumstantial evidence.* Between 1996 and 1999 the area of GM crops grown world-wide increased from 2 to 40 million hectares. While the majority of GM crops were grown in the USA, Argentina and Canada, GM crops were also grown in China, Australia, South Africa, Mexico, Spain, France, Portugal, Rumania and Ukraine. During the last 3-5 years many hundreds of millions of people have consumed GM products. While this fact alone is not proof positive, in the classical experimental format, it is extremely strong circumstantial evidence as to their safety as there has not been a single independently authenticated incident of GM food adversely affecting human health.
- *Government Health Warning.* Finally, written in a somewhat flippant mode, and noted from the internet, but perhaps not too far from the truth, and focussing on the reduced level and toxicity of agrochemicals used with GM compared with conventional crops the following label for GM products has been suggested.

Label

This product is made from Genetically Modified Organisms (GMOs). Making GMOs a significant part of your daily diet could significantly restrict your normal daily dietary intake of pesticides, herbicides and foreign matter and contribute to unemployment in various chemical industries.

TECHNOLOGY UPTAKE

The Global Review of Commercialised Transgenic Crops (James, 1999) states that between 1996 and 1999 the area of GM crops grown globally increased from 2 to 40 million ha at adoption rates which are unprecedented and the highest for any new technology in agriculture (Table 1). While the area grown in 2000 has increased the rate of increase has slowed due to the controversial nature of the technology. Whilst North America and Argentina were responsible for the vast majority of the area grown, China, Australia, South Africa, Mexico, Spain, France, Portugal, Rumania and the Ukraine all grew transgenic crops. In the European Union, France and Spain grew 1,000 and 30,000 ha of Bt maize, respectively, while Portugal grew 1,000 ha of Bt maize for the first time in 1999.

TABLE 1

Global area of transgenic crops, countries growing the major proportion of the 1999 crop, main crop and transformation grown (James, 1999)

Year	Hectares (x 10^6)	Country	% 1999 total
1996	2	USA	72
1997	11	Argentina	17
1998	28	Canada	10
1999	40	China	1
		Australia	<1

1999 crop	% of area	1999 crop	% of area
Soyabean	54	Ht soyabean	54
Maize	28	Bt maize	19
Cotton	9	Ht canola	9
Canola	9	Bt/Ht maize	5
Potato	< 1	Ht cotton	4
Squash	< 1	Ht maize	4
Papaya	< 1	Bt cotton	3
		Bt/Ht cotton	2

SAFETY ISSUES

While it is not the primary aim of this paper to review in detail all the issues associated with human, animal and environmental safety a number of topics will be highlighted. These will include:

- Antibiotic resistance marker genes
- Potential allergenicity
- Substantial equivalence
  compositional equivalence lased on laboratory analysis
  nutritional equivalence based on animal performance
- Consumption of transgenic protein and transgenic DNA
- Detection of transgenic protein and transgenic DNA in milk, meat and eggs.

Antibiotic Resistance Marker Genes

In the development of some, but by no means all GM crops, antibiotic resistance marker genes were introduced to allow efficient selection of successfully modified plants following the procedure of transferring the DNA containing the gene of interest.

Concern was raised that these genes could transfer to microbes and eventually increase antibiotic resistance in humans. This is a very understandable concern and has been the subject of numerous scientific assessments and the issue has been addressed by regulatory bodies world-wide. They concluded that the potential for any transfer and thus risk to public health was virtually zero. Indeed a recent article in *New Scientist* (March 25th 2000) reported that scientists have so far failed to get bacteria to incorporate this gene even though it was, in their words, offered it on a plate. Even if it did happen Sir Robert May, Chief Scientist to the UK Government considered "it would be a drop in a bucket compared with over prescription for humans and widespread use on farms. But, again, we should be concerned to prevent such accidental releases from GM crops." All this apart, it should be noted that antibiotic resistance markers are, due to public perception, undesirable and are in the process of being phased out with the development of new biotech products.

Potential allergenicity

One of the primary concerns over the safety of GMOs is the possibility that the novel protein expressed by the introduced gene may cause an allergic reaction. A decision-tree approach (Metcalfe et al., 1996) has been widely adopted as an allergy assessment strategy. This is described in detail in the report prepared by the Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology (May 2000). The strategy focuses on the source of the gene, level and site of protein expression, sequence homology of the newly introduced protein to known allergens and the physicochemical properties of the newly introduced proteins. As evidence of the success of this approach reference is often made to the fact it detected the potential allergen in Brazil nuts modified to have increased methioninet content.

Far from increasing the risk of allergenicity the Joint FAO/WHO report stated that genetic modification offers the opportunity to reduce or eliminate protein allergens that occur naturally in specific foods such as rice, wheat and peanuts and recommended that further work in this area should be encouraged (Astwood and Fuchs, 1996; Nakamura and Matsuda, 1996).

Substantial equivalence

Compositional equivalence. The primary objective is to establish that GM crops are nutritionally equivalent on laboratory based analyses to unmodified commercial varieties and that they present no more of a risk than their conventional counterparts. As a consequence plant tissues from GM crops are routinely analysed for major and minor nutrients including total protein, amino acids, structural and non-structural carbohydrates, lipid, fatty acids, minerals, and vitamins, plus possible anti-nutritional factors and other specific attributes of the crop. These data are then compared to the equivalent variety and a range of conventional varieties. Padgette et al. (1996), Taylor et al. (1999) and Stein (2000) all provide excellent examples of the analyses conducted during this process, which is referred to as substantial equivalence by FAO/WHO. They illustrate that for the events examined there were no significant nutritional differences between the non-GM and GM plants examined. Whilst the Joint FAO/WHO (2000) report recognised that the concept of substantial equivalence has attached criticism, it considered that it was unfounded as it was perceived as the end point of safety assessment rather than the starting point. The report concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework. It was recognised that whole foods do not lend themselves to the standard safety evaluation principles (WHO, 1987) used for feed additives and other chemicals and that the quantitative assessment of risk of individual whole foods from whatever source cannot be achieved. The report agreed that assessing safety relative to existing food offered the best means of assessing the safety of genetically modified foods. Safety should be based on the nature of the product and not the method by which they are modified.

Nutritional equivalence based on animal performance

In these studies GM crop materials are fed to a range of animal species including broiler chickens, trout, catfish, goats and most farm animal species. The aim is to determine if the use of genetically modified crops in animal feed will adversely affect animal health and production. Of the GMOs that are currently commercialised, the two main genetic transformations are herbicide tolerance and insect protection and soyabean and maize are the two main crops into which they have been introduced. In the recent Symposium in Baltimore, Clark and Ipharraguerre (2000) reviewed 23 studies in which genetically enhanced crops were fed to chickens, sheep, beef cattle and dairy cows. They reported that data from the 23 studies showed that the genetically enhanced maize and soyabeans currently available in the marketplace are not only substantially equivalent in composition but also similar in digestibility and have a similar feeding value for livestock. One such example of the recent studies with lactating dairy cows is shown below in Table 2 (Folmer et al., 2000a) in which there were no effects on milk yield and composition of feeding Bt modified maize silage and maize grain. Similar data have been presented by a number of other workers (Hammond et al., 1996; Folmer et al., 2000b). The studies in Germany and USA (Daenicke et al., 1999; Folmer et al.,

TABLE 2
The effect of feeding Bt modified maize silage and maize grain on milk yield and composition of lactating dairy cows

	Genetic background				SEM
	N4242		N7333		
	Non-Bt	Bt	Non-Bt	Bt	
Milk yield, kg/d	28.6	29.2	28.5	28.7	0.3
Fat, %	3.82	3.80	3.73	3.70	0.06
Protein, %	3.55	3.54	3.52	3.51	0.02

2000a) have also examined the effect of feeding Bt maize residues and maize silage to beef cattle. Their studies have shown that in comparison with non-Bt maize the authors reported no effect on daily liveweight gain, carcass weight or composition, apparent digestibility of dietary organic matter, fibre and nitrogen free extract. These data indicate substantial equivalence between the GM and non-GM varieties with respect to both nutrient digestion and utilisation.

Consumption of novel protein and DNA derived from GMOs

Europe has raised many issues regarding GM crops including concern about the safety of food derived directly or indirectly from such crops. Of particular concern is the fate of transgenic proteins and transgenic DNA derived from introduced traits. This resulted in the following questions being posed:
- Could transgenic proteins and transgenic DNA be transferred to and accumulate in milk, meat, eggs derived from animals fed GM crops?
- Will consumption of animal products derived from GM crops lead to adverse health effects in humans?

With respect to the consumption of DNA, both the World Health Organisation (1993) and the US Food and Drug Administration (1992) concluded that there is no inherent risk in consuming DNA, including DNA from genetically modified crops. The basis of their conclusion was that mammals have always consumed significant quantities of DNA from a wide variety of sources, including plants, animals, bacteria, parasites and viruses. This is also not considered as a safety issue by regulatory agencies in US, Canada, Japan or the EU.

Beever and Kemp (2000), Beever and Phipps (2000) and Phipps (2000) have recently reviewed a number of issues relating to the production and utilisation of GM crops, including the scientific and regulatory procedures associated with DNA in animal feed derived from genetically modified crops and calculated the maximum possible exposure of dairy cows to GM-derived DNA assuming no degradation of DNA in the gut following ingestion. They estimated that the consumption of GM DNA amounts to 54 µg/day in a 600 kg Holstein cow receiving 40 and 20% of its diet as GM maize silage and maize grain. This compares with a total diet DNA intake of 54 g/d, equating to a GM DNA of 0.000094% of total dietary DNA. At such low levels it is difficult to provide realistic estimates of DNA intake for typical diets, whilst nutritional studies have demonstrated that most of the DNA is enzymatically degraded in the alimentary tract, usually prior to the small intestine. On this basis it appears that even when no breakdown of DNA is assumed exposure to introduced DNA of GM crop material will be negligible compared with normal exposure to non-GM crop DNA. Once DNA is fragmented its functionality will be lost and often even its source cannot be identified. They also noted that other sources would contribute to DNA in gut contents, including shed epithelial cells and white blood cells, along with bacteria and protozoa resident in the gut.

However, it should be noted that fragmentation of DNA starts with food processing. Forbes et al. (1998) noted that while grinding and milling had little effect on DNA fragment size, mechanical expulsion or chemical extraction of oil from seeds caused extensive DNA fragmentation. Dry heat applied to plant material at 90°C appeared to have no effect, while 95°C for 5 min caused considerable fragmentation of the plant DNA. Equally steam heat at low to moderate pressures effected substantial DNA fragmentation, whilst ensiling of forage had no detectable effect.

In addition ingested DNA is rapidly cleaved into small fragments by the mechanical processes of mastication along with buccal and gastro-intestinal enzymatic digestion and acid hydrolysis. The enzymes involved in DNA hydrolysis include high concentrations of DNase I, an endonuclease that disrupts the double stranded DNA and is produced and secreted by the salivary glands, as well as the pancreas, the liver and the Paneth cells of the small intestine. DNase I has optimal activity at neutral pH. DNase II is a more recently characterised enzyme (Yamanaka et al., 1974; Baker et al., 1998) and has a pH optima of between 4.6 and 5.5. McAllan, (1982) estimated that more than 85% of the plant DNA consumed by ruminants is reduced to nucleotides or smaller constituents before entering the duodenum, with most of the larger nucleic acid fragments in small intestinal contents arising from rumen microbes.

Beever and Kemp (2000) considered that a small proportion of plant or microbial DNA fragments remaining in intestinal digesta could potentially be absorbed through the intestinal mucosa either directly by epithelial cells or by antigen presenting cells of the immune system. If the intestinal epithelial surface has been damaged, DNA and other macromolecules may also diffuse into the lamina *propria*. It is suggested however that most of this DNA would be phagocytised by tissue macrophages, dendritic cells or other terminally differentiated phagocytes of the immune system.

Detection in milk, meat and eggs of transgenic protein and DNA derived from GM crops

In a recent seminar in Baltimore, Faust (2000) reviewed the available literature on the composition and detection of transgenic protein/DNA in a range of livestock products. Her paper showed that, as expected, the *Cry 1Ab, PAT* and *CP4 EPSPS* transgenic plant proteins could be detected in a range of feedstuffs such as fresh green chop maize, maize silage and total mixed rations (Table 3) that would be fed to livestock.

TABLE 3

Presence of transgenic plant proteins in feedstuffs (Faust, 2000)

Feedstuff	Transgenic protein	Detection
Maize. Fresh green chop.	Cry 1Ab	Detected
Fresh green chop.	PAT	Detected
Maize. Silage	Cry 1Ab	Not detected
Silage	Cry 1Ab	Detected
TMR	Cry 1Ab	Detected
TMR	PAT	Detected
Maize Grain. Wet milled	Cry 1Ab	Not detected
Dry milled	Cry 1Ab	Detected
Soyabeans. Raw	CP4 EPSPS	Detected
Meal	CP4 EPSPS	Detected

Dairy cows

Data from Iowa State (Faust and Vlachos, unpublished, 1997) presented in Table 4 shows that there was no difference in milk yield and composition of high yielding Holstein dairy cows fed isogenic lines of non-Bt or Bt maize. Milk analyses could not detect the presence of either the *Cry 1Ab* protein or transgenic DNA from the Bt 11 construct. However, the *Cry 1Ab* protein was detected in spiked milk samples and while DNA from plant sources could not be detected that of animal origin could be detected.

Laying hens

In a recent abstract presented at the poultry science association annual meeting Ash et al., (2000) reported a study to determine the fate of genetically modified protein from Roundup Ready soyabeans in the laying hen. Whole egg, egg white, liver and faeces were all negative for GM protein. They concluded that

TABLE 4

Milk yield and composition and presence of novel protein and DNA derived from isogenic lines of the Bt11 construct

Milk production	Non-Bt 11 control	Bt 11
Milk yield, kg/d	40.4	38.2
Fat, %	3.41	3.47
Protein, %	2.72	2.80
Protein/DNA detection		
Cry 1Ab	Not detected	Not detected
Spiked milk	Detected	Detected
Bt 11 construct	Not detected	Not detected
Plant DNA	Not detected	Not detected
Animal DNA	Detected	Detected

the digestive tract of the laying hen effectively breaks down the GM protein from the soyabean meal portion of the diet hence no modified protein is found in the liver, eggs or faeces. No analysis for transgenic DNA was reported

The conclusions of the review presented by Faust (2000) were that transgenic proteins and transgenic DNA had not been found in milk, meat and eggs, but that fragments of endogenous plant chloroplast DNA had been detected in mammalian systems (Klotz and Einspanier, 1998).

Perhaps we should asked, why if we go to these lengths for crops produced by GM technology, where one or two extremely well characterised genes are introduced, no such procedures are contemplated for new varieties developed from conventional breeding techniques where many thousands of genes are dumped into the new variety with little or no knowledge as to the possible effects of the vast majority of the new genes.

Indeed Sir Robert May (UK Government Science Advisor) writing on GM foods stated that "The added genes are extremely well understood. In this sense the production of new GM plants is a much more controlled and understood process, with less unforeseen consequences than conventional artificial breeding." The US House Committee on Basic Research supports this view. It stated that "new methods are more precise and allow better characterisation of the changes being made, plant breeders and food producers are in a better position to assess safety than when using classical breeding methods.

POTENTIAL BENEFITS OF GM CROPS

Developed countries

Farmers

The rapid uptake of this new technology by farmers certainly indicates grower satisfaction with GM crops, and some of the advantages are shown below.

- Flexible crop management systems, improved productivity and increased financial returns, a safer working environment, and reduced environmental impact of farming systems through reduced use of conventional herbicides and pesticides and the use of less toxic chemicals have all been indicated as reasons for switching to GM crops.
- A recent report from the Department of Agricultural and Food Economics at The Reading of University (Bennett and Kitching, 2000) considered the economic implications in the UK of demand for livestock feed that contains no GM ingredients. This detailed and comprehensive report finds that the additional cost of feeding non-GM maize and soya ingredients to UK livestock would be around £61 million/annum. This figure may rise as other GM ingredients become readily available as maize and soya represent just 15% of livestock concentrate feed rations. The report states that the UK livestock industry is already suffering financial problems and a further element that increases costs and reduces profitability could prove disastrous for many producers.

Consumers

The consumer has seen this first generation of GM crops as primarily benefiting the farmer and offering them little or no benefit. This is incorrect and some consumer benefits are illustrated below.

- There is clear evidence that the introduction of this first generation of GM crops has not only significantly reduced the use of agrochemicals but has also effected a change to the use of much less toxic products that are less persistent than those used in conventional production systems (Agricultural Outlook, 2000). This must be good news for the consumer. This is particularly pertinent to Europe where weed control in the 6 million ha of maize grown for silage and grain is achieved by the use of Atrazine. This is a long lasting residual herbicide, which presents a consumer/environmental risk as it can move down through the soil profile into the water reserves. It is estimated that in Austria approximately 70% of the country's rural drinking water wells contain some Atrazine (Austria's Agriculture, Forestry and Water Management, 1998). This must be of concern to consumers especially as in a draft report the Environmental Protection Agency in the USA has just upgraded Atrazine from a "possible" to a "likely" carcinogen.

- While the use of insect protected (Bt) crops will increase yields by reducing insect damage it also reduces mycotoxin contamination arising from fungal attack on damaged grain (Munkvold et al., 1998). The result, more grain and safer grain for both humans and livestock.

The second generation of GM crops will provide consumers with more tangible benefits. Many biotech products in development with provide consumers with healthier and more nutritious food. Some examples of this second generation of GM crops are shown below.

Soyabeans modified to contain:

- Conjugated linoleic acid that can help in the prevention of certain types of cancer.
- High oleic acid content which when fed to cattle and chicken can reduce the saturated fat levels in milk and meat making both products more nutritious.
- Low phytate content which will allow better phosphate availability to the animal that consumes it ' thereby reducing /avoiding phosphates entering waterways.
- High isoflavones which help lower blood serum cholesterol levels, reduce the incidence of certain types of cancer and increase bone density in post menopausal women.

Modified fruit

Various fruits have been genetically modified to slow their ripening process, so that they can be allowed to stay on the tree longer prior to harvest. The papaya has been genetically modified to resist the viral disease Papaya Ring Spot Virus that was so devastating that it had almost made it impossible to grow papaya in Hawaii. Numerous other food crops are being modified to provide the consumer with a safer and healthier food supply.

- A very recent announcement (Sunday Times London, 6th September 2000) at the British Association Science Festival stated that apples and strawberries were modified to prevent dental decay. The gene for a peptide protein was discovered by immunologists at Guy's Hospital in London and has been added to both fruit at the International Institute of Horticultural Research in Kent. The peptide works by controlling the growth of *Streptococcus mutans* the bacteria that causes tooth decay. Professor James at the Institute said that genetically modified fruit would be an ideal method of delivering the peptide, particularly to children.

- Coffee plants have been modified to restrict the synthesis of caffeine, with the result that there is no need for the solvent extraction process currently used to remove caffeine and produce decaffeinated coffee. The removal of the potentially dangerous solvent extraction process should be seen as good news for consumers.

Environment

The potential benefits that can accrue from the use of GM crops are often overlooked in discussions on biotechnology. A number of these benefits are outlined below.

- Higher crop yields achieved through biotechnology can help to preserve forests and animal and plant habitats as less new land needs to be brought in to production to meet the food requirement of an increasing global population. Over 30% of the world's arable soil, often found in tropical regions, is affected by aluminium toxicity that can reduce yields by 80%. Such low yields often result in farmers expanding their cropping area into adjacent forests. Mexican research workers have shown that plants can be protected against aluminium toxicity by the addition of a single gene (Transgenic Plants and World Agriculture, 2000). Such crops could have a significant impact on reducing the area of natural habitat that is brought into cultivation.
- When farmers switch to GM crops the reduction in the quantity of agrochemical used and the switch to less toxic products that are less persistent should provide benefits for the environment and reduce the environmental impact of conventional agricultural systems. The Economic Research Unit of the USDA (Agricultural Outlook, 2000) estimated that there was a 4 million kg decrease in total pesticide use between 1997 and 1998 as a result of US farmers adoption of biotechnology. This surely is good news for the environment.
- A report in the Daily Telegraph (London, June 1st 1999) noted that farmers in America have reported increasing numbers of birds of prey and other wildlife in their crops of genetically modified cotton, soya and maize. After three years of practical experience with GM crops they say they have seen an upsurge in hawks and owls and other birds returning to their land since they switched much of their production to GM varieties. The recovery has been linked to increasing insect life on farms that cut back on pesticides sprayed previously.
- A summary of studies found that "no tillage" farming, which is facilitated by the use of GM crops could reduce soil erosion by 90%. Reduced soil erosion means less runoff of silt, and a decrease in the herbicides and fertilisers that may enter streams, rivers and lakes with subsequent detrimental effects on wildlife.

Developing countries

Many people believe that GM technology will provide a cheap, reliable and sustainable means of improving the basic nutrition and health of many millions of people in the developing world, whose staple diet is often deficient in one or more of the major or micro-nutrients.

It is beyond the scope of this paper to deal in detail with this issue but attention is drawn to a small number of examples.

- With the ever growing world population, the announcement by Japanese and American research workers (New Scientist, March 30th 2000) of genetically modified rice which could boost yields by up to 35% had been tested in China, Korea and Chile could be of great significance in combating world food shortages. Higher crop yields will also mean reduced need to bring further land into crop production.
- Many millions of the poorest people in the world live in marginal areas subjected to low and erratic rainfall, extremes of soils conditions, and extremes of temperatures. Work is in progress to modify plants to withstand abiotic stress. One example is plant modification to withstand aluminium in acid soils (Transgenic Plants and World Agriculture, 2000).
- There is also the example of sweet potato, a staple crop in countries such as Kenya where it has been genetically modified and hence protected against a particular virus disease that can decimate yields (Wambugu, 1996). Field trials began in Kenya in September 2000.
- Maize grain, which is the staple diet for millions of people in the developing world, is low in both protein and certain essential amino acids. Work on improving these traits through genetic modification is well advanced.
- One of the most publicised is that of Golden Rice in which beta carotene, a precursor for vitamin A, is greatly increased when compared with ordinary rice. It is currently estimated that up to 100 million children suffer from vitamin A deficiency, and that of these, 1 million die annually and 14 million suffer clinical eye problems (Time Magazine, July 31st 2000).
- An equally large number of women suffer from anaemia and crops modified for increased iron content would provide a major improvement in nutritional competence of many millions of people. Anaemia in pregnancy is a contributing factor to 20% of all maternal deaths after childbirth in Africa (Transgenic Plants and World Agriculture, 2000).
- Edible vaccines, which can reach more, people and offer a more sustainable method of health protection than the current programmes are in development (Brand, 1999). Dr C. S. Prakash, Director of the Centre for plant Biotechnology Research, Tuskegee considers edible vaccines delivered in locally grown crops

could do more to eliminate disease than the Red Cross, Missionaries and UN Task Forces combined at a fraction of the cost (Atlanta Constitution Editorial, December 5th 1999).

These examples are not flights of fancy, and in some case are already a reality whilst in others they are close becoming a reality. What is surprising is that some environmental organisations want to impose a blanket ban on this technology. While some people claim that big business has the developing world by the throat, Dr Cyrus Ndirutu (Director of the Kenyan Agricultural Research Institute) stated that it was hunger, poverty and malnutrition that posed the biggest threat to Africa and not multi-national companies.

Thus it is perhaps not surprising that the Nuffield Council on Bioethics (1999) stated that "The moral imperative for making GM crops readily available to developing countries who want them is compelling."

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STRESZCZENIE

Nowa technologia: Zagadnienia dotyczące stosowania genetycznie modyfikowanych roślin

Wraz ze zwiększaniem się populacji ludności i zmniejszaniem się gruntów przydatnych do produkcji żywności rozważane jest wykorzystanie genetycznie zmodyfikowanych roślin (GM), jako mającym duże znaczenie sposobem zabezpieczenia światowej produkcji żywności. Rygorystyczna ocena prowadzona jest już od 10 lat przez niezależną agencję ustalającą odpowiednie przepisy przed ostatecznym zatwierdzeniem stosowania w żywieniu genetycznie modyfikowanych roślin. Szybki rozwój technologii GM można zilustrować zwiększeniem, pomiędzy rokiem 1996 a 1999, ilości hektarów przeznaczonych pod te uprawy z 2 do 40 milionów. Większość upraw modyfikowanych roślin, około 72%, znajduje się w USA, ale w dalszych 15 krajach rozwija się produkcja genetycznie modyfikowanych roślin. W tym opracowaniu dyskutowane są zagadnienia bezpiecznego stosowania takich modyfikowanych produktów, jak genetyczne znaczniki odporności na antybiotyki, potencjalna zdolność wywoływania alergii, równoważnik odżywczy, konsumpcja białka transgenicznego oraz transgenicznego DNA i ich wykrywanie w mleku, mięsie i jajach. Daleka od zwiększenia ryzyka zdolności wywoływania alergii technologia GM może oferować możliwość zmniejszenia bądź nawet wyeliminowania alergenów białkowych, które występują w sposób naturalny w pokarmach takich jak ryż, pszenica i orzeszki ziemne, a otrzymane na drodze GM są pod względem ich składu (analizy laboratoryjne) i wartości odżywczej (badania żywienia zwierząt) takie same jak ich odpowiedniki produkowane metodami konwencjonalnymi.

W opracowaniu zaznaczono, że gdy powstało zagadnienie możliwości akumulacji białka transgenicznego i DNA w mleku, mięsie i jajach oraz możliwości ich wpływu na zdrowie zwierząt i ludzi, to niezależne agencje ustalające odpowiednie przepisy i Światowa Organizacja Zdrowia (WHO) stwierdziły, że nie ma podstaw do związanego z tym ryzyka przy spożywaniu DNA włącznie z DNA w produktach otrzymanych na drodze modyfikacji genetycznej, ssaki bowiem zawsze pobierały duże ilości DNA z wielu różnych źródeł, jak rośliny, zwierzęta, bakterie, pasożyty i wirusy. Dotychczas nie znaleziono transgenicznego białka i DNA w mleku, mięsie i jajach. W podsumowaniu stwierdza się, podając liczne przykłady potencjalnych korzyści dla rolników, konsumentów i środowiska, tak w rozwiniętych jak też rozwijających się krajach, ze szczególnym naciskiem na zdolność technologii GM do zwiększenia plonów żywności i poprawienia jej jakości oraz zmniejszenia ujemnego oddziaływania rolnictwa na środowisko, przez między innymi zmniejszenie użycia toksycznych chemicznych środków stosowanych w rolnictwie.