

The fate of plant DNA and novel proteins in feeds for farm livestock: A United Kingdom perspective

D. E. Beever¹ and R. H. Phipps

Centre for Dairy Research (CEDAR), Department of Agriculture, The University of Reading,
Earley Gate, Reading, United Kingdom RG6 6AT

ABSTRACT: This article considers safety aspects related to the feeding of genetically modified (GM) crops to farm animals, based on experiences in the United Kingdom, where several food scares, including bovine spongiform encephalopathy, have increased public awareness over food safety and systems of livestock production. Issues addressed include the feeding of GM crops to livestock in relation to effects on animal health and performance, the possible transfer and accumulation of novel DNA and(or) proteins in animal products, and safety aspects associated with humans consuming foods derived from animals receiving GM feeds. The impact of feed processing, including grinding, milling, heating, and steam pressure, on plant DNA integrity is considered, concluding that heat (> 95°C) and high pressure substantially disrupt plant DNA but grinding has no effect. There is no clear evidence that ensiling of forages causes significant disruption of plant DNA. The digestive processes of ruminants and nonruminants are highlighted with specific reference to the fate of DNA and RNA within the alimentary tract. Extensive

degradation of DNA and RNA occurs within the rumen, but the concomitant synthesis of microbial nucleic acids results in more than 80% of the nucleic acids entering the intestines being of microbial origin, with little evidence of direct incorporation of plant DNA by the microbes. Evidence is presented of extensive degradation of microbial (and surviving plant) nucleic acids in the small intestine. Studies designed to examine the effect of GM feeds on animal performance are reviewed, providing no evidence that chemical composition, feed intake, meat, milk, or egg production are affected compared with non-GM equivalent feeds. Several studies have failed to detect the presence of novel DNA and(or) proteins in animal products, but evidence of plant DNA fragments in white blood cells and chicken tissues from other studies is presented. Finally, the article considers the improvements in analytical procedures to detect GM fragments in animal tissues and products but urges caution with respect to overinterpretation of the data, where the presence of DNA fragments does not confirm functional integrity, while suggesting that some results may have been affected by methodological issues.

Key Words: Eggs, Genetically Modified Crops, Livestock, Meat, Milk, Nucleic Acids, Proteins

©2001 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 79(E. Suppl.):E290–E295

Introduction

Crops with genetically modified (GM) traits, such as herbicide tolerance (HT) in soybeans and corn and insecticide tolerance (Bt) in corn, are grown in the United States, Canada, and Argentina. However, they cannot now be grown in the European Union (EU), despite significant imports of GM soy and corn, because of demands for exhaustive testing of GM crops in relation to safety to the environment, to animals consuming the crops, and to humans consuming the feeds either directly or as animal products.

Public concern over GM crops within the EU was heightened by several food scares, including bovine spongiform encephalopathy (BSE) after it was linked with new variant Creutzfeldt Jakob disease (nvCJD). The infectious agent (prion) is believed to have entered the food chain due to methodological changes in the production of meat and bone meal that led to incomplete deactivation of infected tissues. Confirmed BSE cases and a compulsory cull of herd cohorts led to the slaughter of over one million cattle, with a total ban on meat and bone meal and exclusion of cattle over 30 mo from the food chain. Other food scares included salmonella in poultry and more recently *Escherichia coli* (O157), identified in cooked meat and responsible for 20 deaths in Scotland. Its occurrence in meat and meat products can be attributed to questionable practices in the production of food from farm livestock (Williams, 1998).

Concerns over GM crops are different but have been fueled by media coverage aimed at bringing fear rather

¹Correspondence: E-mail: d.e.beever@reading.ac.uk.

Received September 12, 2000.

Accepted June 26, 2001.

than reassurance. Government-sponsored GM trials have been openly attacked by activist groups seeking popular support, and supermarket opinion has been equivocal. Consumers claim a desire to be GM-free, yet many believe that GM technology has a long-term future and will be accepted once customer concerns are allayed. It is this scenario that best describes the current dilemmas within the EU food-supply chain.

The Issues

We intend to address those factors associated with the digestive fate of DNA and novel proteins in crops consumed by farm livestock, supported by limited evidence from animal feeding studies designed to establish "substantial equivalence." In this respect, although substantial equivalence has no universally accepted definition and is considered more as a concept, there have been several attempts to describe it. Most recently, in a WHO/FAO Expert Consultation (2000) it was proposed "that this concept embodies a science-based approach in which genetically modified is compared to its existing, appropriate counterpart. This approach is not intended to establish absolute safety, which is an unattainable goal for any food. Rather the goal of this approach is to ensure that the food, and any substance that has been introduced into the food as a result of genetic modification, is as safe as its traditional counterpart." This article will also consider how the processing of animal feeds prior to feeding may affect the integrity of plant DNA. The principal issues of concern can be listed as follows: 1) Could DNA of inserted or modified genes and/or their products (proteins) cause health problems in animals consuming GM crops? 2) Could DNA fragments or novel proteins be transferred to and accumulate within animal products? and 3) Will the consumption of crop materials or animal products derived from GM crops cause adverse effects on human health?

Many groups have focused on such issues over the last few years, in addition to those relating to environmental issues such as the possible escape of GM pollen to non-GM relatives (Masood, 1998). In a recent review published by the Royal Society (The Royal Society, 1998) its expert committee examined "various aspects of the controversy, including the scientific evidence concerning the risk of transfer of genes from GM crop plants to wild species and non-GM crops, the uptake of genes from GM crops by the digestive system and the current state of the regulatory system. The experts concluded that the chances of gene transfer happening were slight provided that the regulatory processes are followed, but that this must be kept under consideration."

Livestock Systems

Systems of farm livestock production in the United Kingdom are in many respects similar to those prac-

ticed in the United States, although unlikely to be managed at the same level of intensification. Poultry, for both meat and egg production, are largely kept indoors and fed highly processed cereal grain-based diets with the inclusion of suitable protein sources, soybean meal being the most popular. In specialist units providing products for niche markets, the birds are allowed some access to pasture, but such practices represent a relatively small proportion of total poultry production. The situation is broadly similar with respect to pigs, the majority being kept indoors, but an increasing number of sows are now managed through farrowing at pasture, with their litters transferred indoors at weaning. Here again most of the feeds for both breeding and growing (finishing) stock are based on highly processed grains and protein sources, and as with poultry the opportunity to include by-product feeds is quite limited. Ruminant-based systems, conversely, still rely on extensive use of forages, and grazed pasture is an important component in sheep (lamb) production and beef production. Grazed grass is also an important component of the diet of dairy cows, especially those that calve in the spring, although it is possibly less suited to cows with annual lactation yields above 8,000 kg. Better ensiling techniques have led to more grass silage being fed to dairy and beef cattle, and increased popularity of corn silage has allowed many diets, especially those designed for dairy cows, to be based on at least two forages. However, whereas most systems of ruminant production still rely quite extensively on forages, dairy cows in particular receive between 1 and 2 t of "concentrate" feed per lactation, according to level of production, with both on farm-processed grains and purchased concentrates contributing to this total. Thus, both cereals and protein sources are extensively used in ruminant diets, but there is also extensive use of by-product feeds, including canola meal (after oil extraction as for soybean meal), maize gluten feed (as a protein source), and sugar beet feed or wheat feed (as digestible fiber sources).

Integrity of DNA During Feed Processing

In attempting to assess the magnitude of the problem in relation to the possible survival of dietary DNA, especially that of transgenic origin, it is important first to assess the likely load of total DNA and transgenic DNA that an animal may receive. The review of Beever and Kemp (2000) attempted to assess this and concluded that for a dairy cow consuming 24 kg of DM/d, with 40% derived from maize silage and 20% from maize grain and with both sources being of transgenic origin, the consumption of novel DNA represented only 0.00043% of total DNA intake. Reevaluation of these data, however, revealed an error in the calculations, and the revised figures indicate a total DNA intake of 57 g/d, of which only 54 μ g would be represented as transgenic DNA, indicating the novel DNA to be less than 0.000094% of total DNA intake. Such amounts are small, but of course it may be argued that such

calculations are irrelevant if the novel DNA survives digestion and retains full functional integrity.

To consider this in some detail, Forbes et al. (1998), as part of a MAFF-sponsored study, examined the effect of grinding and milling, heat treatment, and steam pressure on commercial feed sources (all nonGM), as well as the ensiling of forages. Using a series of different grinding treatments, they were unable to detect any DNA fragments less than 21 kb in size and this led them to conclude that grinding did not cause any significant disruption of the DNA contained in wheat, as well as a series of other feed sources. In contrast, the use of heat was much more effective in disrupting plant DNA. Application of 90°C heat for durations of 5 to 30 min resulted in all of the DNA of maize grain being of a size greater than 21 kb (i.e., intact). At a temperature of 93°C for between 5 and 15 min, average DNA size was reduced to between 20 and 2,500 bp, with further reductions to less than 100 bp at temperatures of 95 to 150°C for periods of up to 30 min. They extended their studies to consider the impact of steam at both high (> 106 kg/cm²) and low pressures (> 0.53 kg/cm²) and reported extensive degradation with high pressure and high temperature but failure to achieve full disruption at low pressure when the temperature was below 95°C.

Using commercially available feedstuffs without further processing, these workers reported DNA fragment sizes above 21 kb for intact soybean grains and untreated rapeseed, suggesting that the plant DNA was still intact, but with extracted soy and expelled and extracted canola the DNA fragment sizes were significantly reduced, indicating that processing had led to extensive degradation of plant DNA. They completed their studies by considering specific parts of forage corn and found that the plant DNA was still intact in the whole plant, in leaves and the cob as well as the resulting silage, but these results are contrary to unpublished data from the University of Munich (KarlHeinz Engel, personal communication) in which some disruption of plant DNA during the ensiling of forage was noted.

The Digestive Fate of Plant DNA

Nonruminants and ruminants differ substantially in the anatomical structures of their respective alimentary tracts, and thus in the physiological processes of digestion. Adult ruminants are characterized by a complex arrangement of forestomachs in which bacteria, protozoa, and fungi reside and are responsible for extensive digestion of plant carbohydrates, principally but not exclusively plant cell walls (cellulose and hemicellulose), as well as dietary starch and some dietary protein (Beever, 1993). The rumen is a major site of microbial synthesis, and it is this along with any undigested feed that eventually enters the small intestine. Thereafter, the processes of digestion are broadly similar to those seen in nonruminants. Thus, in nonruminants the digestion of DNA and RNA may be initiated in the mouth,

where various DNAase and RNAase are secreted in saliva, and the pancreas is probably the most important site of nuclease secretion. Ruminants also have DNAase and RNAase in saliva along with pancreatic and intestinal nucleases. However, it is in the rumen where extensive degradation of dietary nucleic acids occurs through the action of microbial nucleases, and this is followed by extensive synthesis of microbial nucleic acids such that as much as 85% of the nucleic acids entering the small intestines have been identified to be of microbial origin (McAllan, 1982). As indicated, the pancreas and the small intestine of both ruminants and nonruminants are significant sources of enzymes that degrade RNA and DNA, and studies have shown extensive degradation prior to the terminal ileum. In the study of McAllan (1980), which used growing cattle fed hay and concentrate diets, examination of DNA and RNA in gut contents following slaughter of the animals led to the conclusion that over 80% of duodenal DNA was apparently digested prior to the large intestine; the author suggested that true digestibility was likely to be more than 95%. Examination of the breakdown products of DNA and RNA confirmed these results; the extensive appearance of purine and pyrimidine nucleotides immediately postabomasum was associated with extensive removal of these degradation products prior to the terminal ileum. On the basis of these data, it would be reasonable to conclude that opportunities for the absorption of intact (genetically functional) DNA seem to be very remote.

Other studies have demonstrated that extensive salvage of purine and pyrimidines may occur, with adenine incorporation into tissue adenine and guanine (D'Mello, 1982), but Henderson and Paterson (1973) showed the presence of adenine and guanine deaminases in domesticated livestock, presumably to prevent excessive levels of purines (and pyrimidines) that could be a potential problem, especially in ruminants due to the ubiquitous supply of microbial biomass.

Animal-Feeding Studies

Against this background of the issues raised earlier in relation to the safety of GM crops when fed to farm livestock, considerable experimentation has taken place over the last 3 to 4 yr to consider the important issue of substantial equivalence. In this series, Clarke and Ipharraguerre (2000) provided a detailed consideration of over 20 studies involving dairy cows, beef cattle, and poultry. Additionally, there has been a considerable research effort to consider the impact of genetic modification on the nutritional characteristics of different feeds compared to their non-GM equivalents (i.e., controls).

Compositional Evaluations

As reported by Padgett et al. (1996), amino acid composition of HT soybeans was found to be almost

identical to that of non-GM soy. The increasing availability of such data is quite reassuring after an earlier suggestion of increased tryptophan levels as a consequence of introducing herbicide tolerance into sugar beets. This led to considerable concern within U.K. regulatory authorities (especially MAFF) due to its possible association with fog fever (pulmonary emphysema) in ruminants, but subsequent analysis of the data concluded that cattle would have to consume over 100 kg of DM/d of the affected sugar beets before potentially dangerous levels of the specific amino acid were achieved. Subsequent research has failed to confirm this effect, and, although the earlier observations caused some concern at the time in relation to the potential problems that could occur as a consequence of animals consuming GM crops, it is reassuring that the issue was raised and properly dealt with by the appropriate regulatory agencies.

Extensive analysis of HT and non-HT soybeans by Padgett et al. (1996) and Taylor et al. (1999) revealed no differences with respect to fatty acid composition, whereas Stein (unpublished data) found no effect of inserting the *Bt* gene into corn on proximate analysis, including fiber and nitrogen-free extractive levels. Thus, it seems from available data that neither HT nor *Bt* gene insertion into soy and/or corn has any significant effect on nutritional value as determined by extensive laboratory analysis. However, as further genetic manipulations are considered for introduction to the marketplace, it will be important that substantial nutritional equivalence be established in all cases, especially in those crops in which deliberate perturbations to specific nutritional entities are being sought (e.g., high-oleic-acid soybeans). With crops that have been genetically modified to provide substrates for industrial use (e.g., canola), it will be important to evaluate any by-product feeds obtained from the processing of such materials, because these cannot simply be assumed to be of nutritional equivalence to the by-products derived from non-GM crops.

Animal Performance and Product Composition

In a comparison of HT and conventional soybeans. Hammond et al. (1996) included unprocessed beans in the diets of dairy cows (10% total ration DM) and reported no significant effects on total ration intake (mean 23 kg of DM/d), milk yield (approximately 35 kg/d), or milk fat or protein content. When these authors fed the same beans to broiler chickens at a higher (33%) level of inclusion, no significant effects on feed intake, daily live weight gain, or bird survival rates were noted. Similar studies by Daenicke et al. (1999) in Germany examined *Bt* corn fed after ensiling to Holstein bulls, and a comparison with non-*Bt* corn indicated no effects on daily live weight gain, carcass weights, or composition. Also in this study, no effects on apparent digestibility of the dietary organic matter, fiber or nitrogen-free extractive fractions were established, suggesting substan-

tial equivalence between the two corn varieties with respect to both nutrient digestion and utilization.

Extensive beef and dairy studies conducted in the United States considered the possible fate of *Bt* protein and *Bt* DNA in corn, but examination of several tissues, including muscle and spleen, as well as milk failed to establish the presence of either the novel protein or DNA. A study with laying hens in which corn grain comprised 64% of the total diet DM failed to establish the presence of *Bt* protein in egg white and egg yolk or in dark or light muscle types.

Further studies by Faust (unpublished data) involved feeding Holstein cows on a complete diet in which 30% (DM basis) was provided as green chop corn, either as the *Bt* or non-*Bt* variety. Neither feed intake nor milk yield, which averaged 38 kg/d for the two groups, was affected by corn type, and analysis of the milk failed to establish the presence of the *Bt* protein. The validity of this finding was further enhanced when spiking of control milk with *Bt* protein and subsequent analysis of the milk resulted in a 100% detection rate. Recently, Rutzmoser and Mayer (2000) compared *Bt* forage corn silage with a non-*Bt* isogenic line using sheep to determine diet digestibility and lactating dairy cows to examine feed intake and milk yield and composition. No effects on digestibility were determined and neither milk yield nor milk fat, protein, and lactose contents were affected. More detailed analysis of the milk with respect to specific protein fractions, vitamins (A, B₂, and E) and minerals (chloride and iodide) also revealed no effects of feeding GM corn as part of the diet.

In a recent study, Klotz and Einspainer (1998) were unable to detect native (vegetable) or transgenic DNA in the milk of cows receiving a diet containing HT soy, but they reported the existence of plant DNA fragments (soybean Rubisco) in white blood cells using the highly sensitive PCR method. In the same study, however, attempts to detect the presence of DNA from the GM transgene EPSP synthase were not successful, despite its presence being detectable in the GM soybean. Similar findings have also been reported by Schubert et al. (1994, 1997, 1998) in which microbial DNA was fed directly into the gastrointestinal lumen of mice. Fragments of this DNA were detected in some mouse white blood cells at 24 h or more after exposure. More recently, Klotz and Einspainer (2000) fed *Bt* corn to lactating dairy cows and were unable to detect novel DNA fragments in samples of tissue and milk, despite being able to detect its presence in duodenal digesta. In contrast, when the same *Bt* corn was fed to chickens, a short chloroplastic (199 bp) DNA fragment could be detected in muscle, liver, spleen, and kidney, but interestingly they did not detect any in eggs or excreta. They were also not able to detect the *Bt* corn-specific fragment (CryIa(b) gene) using the same methodology. Ash et al. (2000), who fed Ht soybeans to laying hens, concluded on the basis of their results that "the digestive processes of the laying hen effectively break down the GM protein

from soybean meal . . . hence no modified protein is manifested in the liver, egg or faeces.”

Such debates are likely to continue for some time, which is both appropriate and desirable if the safety of animal products derived from feeding GM feeds is to be established. Those studies that have suggested the possible presence of foreign DNA in animal tissues and products are of concern, although functional integrity of the foreign DNA has not been established in any situation. However, Beever and Kemp (2000) in reviewing safety issues associated with novel DNA and proteins in animal feed derived from GM crops raised concerns over analytical uncertainty. In particular, although the sensitivities of PCR and *in situ* hybridization (FISH) methodologies have improved dramatically, they contended that in many cases the sample concentration of DNA may have been close to the limits of the detection methods. In particular, they drew attention to the need when using a mouse model to represent a cow that the dose of a single copy foreign gene to both animals must be compared on an equimolar basis in relation to body size if meaningful results are to be obtained. Furthermore, they drew attention to the studies of Schubert et al. (1994, 1997, 1998) that reported the transfer of a minute quantity of microbial DNA from the digestive tract of animals into white blood cells and possibly mammalian cells, suggesting that the use of unmethylated DNA may have affected the results. In particular, unmethylated DNA may upregulate inflammatory cell activity and thus stimulate immune response, leaving these authors to conclude that the frequency of plant DNA being taken up into cells is probably much lower than indicated by those studies that used unmethylated DNA as the test substance.

Summary

Despite the fact that GM crops have been available for a relatively short period of time, there has been considerable research activity in relation to the establishment of substantial equivalence in relation to the use of such crops for feeding to farm livestock. Studies have been undertaken to consider the effect of gene insertion on the chemical composition of the resultant feed with specific reference to nutritional entities. To date, no significant deleterious effects have been confirmed. Studies in which GM feeds have been compared with non-GM feeds in diets for ruminants and nonruminants have to date reported no adverse effects on animal health and performance or product quality. Occasional reports of the existence of foreign DNA or protein fragments in the tissues or products of animals receiving GM feeds remain some cause for concern, but there are also many studies in which the presence of novel DNA and proteins has not been established. If methodological and/or analytical uncertainties are in part contributing to such effects, it is incumbent upon molecular scientists to reconcile this issue as quickly as possible.

Given the profile that GM crops now have in many countries, it is inevitable that issues relating to the safety of such feeds will continue for the foreseeable future. Although there is an increasing body of data supportive of substantial equivalence with no indication of adverse effects on animals or humans (Phipps and Beever, 2001), it is unlikely that such information alone will be sufficient to allay public concerns. This raises a number of interesting dilemmas. First, decisions will need to be made as to the type and extent of research required, and in this respect one important question will be the applicability of data on an international rather than national basis. Will U.K. consumers, for example, be prepared to accept data produced in the U.S. or elsewhere? Clearly, open collaboration between scientists is to be encouraged because it would undoubtedly reduce the amount of time and the costs involved in testing individual GM-containing feeds. Indeed, there is growing evidence of this occurring within Europe and elsewhere. But over and above all of this effort, the question is still likely to remain as to whether or not indisputable data can ever be provided. Increased analytical sensitivity has brought a new dimension to the testing of feeds and animal products for the presence of GM ingredients (residues), but we must harness such technology positively toward the overall aim of establishing the safety of such feeds and not allow them to become a means in their own right. Finally, it will be necessary against continuing media pressure to remain focused on the primary aim of proving food safety, and in this respect one is entitled to ask what the real issue is, given that humans have a historical consumption of plant and animal DNA that hitherto seems to have caused no problems. This is an important observation when it is realized that most common feeds have never been tested in the rigorous manner in which GM crops and animal products derived from such are now examined.

Implications

Genetic manipulation (GM) of crops should benefit all involved in the production of food for human consumption, through reduced input costs, increased food security, and improved food quality. However, a significant part of these crops will not be consumed directly by humans but as meat, milk, and eggs derived from animals consuming diets containing GM ingredients. Evidence to date indicates that such practices present no threat to the health and well-being of the animals consuming the crops or the humans consuming the animal products. However, as more GM crops are commercialized, rigorous evaluation, similar to that already undertaken for the herbicide and insecticide tolerance traits of soybeans and corn, must be sustained, and in this respect close collaboration among all biological science disciplines will be essential.

Literature Cited

- Ash, J. A., S. E. Scheidler, and C. L. Novak. 2000. The fate of genetically modified proteins from Roundup Ready soybeans in the laying hen. *Poult. Sci.* 79(Suppl. 1):26 (Abstr.).
- Beever, D. E. 1993. Rumen function. In: J. M. Forbes and J. France (ed.) *Quantitative Aspects of Ruminant Digestion and Metabolism*. pp 187–215. CABI, Wallingford, Oxon, U.K.
- Beever, D. E., and F. Kemp, 2000. Safety issues associated with the DNA in animal feed derived from genetically modified crops: A review of scientific and regulatory procedures. *Nutr. Abstr. Rev.* 70:197–204.
- Clarke, J. H., and I. R. Ipharraguerre. 2000. Livestock performance: Feeding biotech crops. *J. Dairy Sci.* 84(E. Suppl.):E9–E18.
- D'Mello, J. P. F. 1982. Utilization of dietary purines and pyrimidines by non-ruminant animals. *Proc. Nutr. Soc.* 41:301–308.
- Daenicke, R., K. Aulrich, and G. Flachowsky. 1999. GMI in animal feedstuffs: Nutritional properties of Bt-maize unaffected. *Mais* 27:135–137.
- Forbes, J. M., G. E. Blair, A. Chiter, and S. Perks. 1998. Effect of feed processing conditions on DNA fragmentation. Scientific rep. no. 376. Ministry of Agriculture, Fisheries and Food, London.
- Hammond, B., J. L. Vicini, G. F. Hartnell, M. W. Naylor, C. D. Knight, E. H. Robinson, R. L. Fuchs, and S. R. Padgett. 1996. The feeding value of soybeans fed to rats, chickens, catfish and dairy cattle is not affected by genetic incorporation of glyphosate tolerance. *J. Nutr.* 126:717–726.
- Henderson, J. F., and A. R. P. Paterson. 1973. *Nucleotide Metabolism: An Introduction*. Academic Press, London.
- Klotz, A., and R. Einspainer. 1998. Nachweis von 'Nove-Feed' im Tier? Beeinträchtigung des Verbrauchers von Fleisch oder Milch ist nicht zu erwarten. *Mais* 3:109–111.
- Klotz, A., and R. Einspainer. 2000. Detection of chloroplast- and Bt-maize-DNA in farm animals fed transgenic plants: Methods and first results. In: *Proc. Joint Conf. Genetically Modified Organisms in the Food Chain*, Munich, Germany. p 72.
- Masood, S. 1998. Organic farmer takes gene battle to court. *Nature (Lond.)* 394:8.
- McAllan, A. B. 1980. The degradation of nucleic acids in, and the removal of breakdown products from the small intestines of steers. *Br. J. Nutr.* 44:99–112.
- McAllan, A. B. 1982. The fate of nucleic acids in ruminants. *Proc. Nutr. Soc.* 41:309–317.
- Padgett, S. R., N. B. Taylor, D. I. Nida, M. R. Bailey, J. MacDonald, L. R. Holden, and R. I. Fuchs. 1996. The composition of glyphosate-tolerant soybean seeds is equivalent to that of conventional soybeans. *J. Nutr.* 126:702.
- Phipps, R. H., and D. E. Beever. 2001. *New Technology. Issues relating to the use of genetically modified crops*. Polish Academy of Science, Warsaw, Poland. (In press).
- Rutzmoser, K., and J. Mayer. 2000. Milk yield and milk contents after feeding maize silage of starin 'Pactol' and the genetically modified Bt-Hybrid 'Pactol CB'. *Proc. Joint Conf. on Genetically Modified Organisms in the Food Chain*, Munich, Germany. p 76.
- Schubbert, R., C. Lettman, and W. Doerfler. 1994. Ingested foreign (phage M13) DNA survives transiently in the gastrointestinal tract and enters the bloodstream of mice. *Mol. Gen. Genet.* 242:495–504.
- Schubbert, R., D. Renz, B. Scmitz, and W. Doerfler. 1997. Foreign (M13) DNA ingested by mice reaches peripheral leukocytes, spleen and liver via the intestinal wall mucosa and can be covalently linked to mouse DNA. *Proc. Natl. Acad. Sci. USA* 94:961–966.
- Schubbert, R., U. Hohlweg, D. Renz, and W. Doerfler. 1998. On the fate of orally ingested foreign DNA in mice: chromosomal association and placental transmission of the fetus. *Mol. Gen. Genet.* 259:569–576.
- Taylor, N. B., R. L. Fuchs, J. MacDonald, A. R. Shariff, and S. R. Padgett. 1999. Compositional analysis of glyphosate-tolerant soybeans treated with glyphosate. *J. Agric. Food Chem.* 47:4469–4473.
- The Royal Society. 1998. *Genetically modified plants for food use. Report of Working Group*, August 1998. (available by E-mail: angleahalpin@royalsoc.ac.uk).
- WHO/FAO Expert Consultation. 2000. *Safety aspects of genetically modified foods of plant origin*. Washington, DC.
- Williams, N. 1998. UK government tries to assure wary public. *Science (Washington, DC)* 282:856–857.