FEATURE

The Safety and Allergenicity of Genetically Modified Foods—Impact on the Global Markets for Cereals and Oilseeds

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- The cereals and oilseeds that have been commercially produced by agricultural biotechnology have been adequately assessed for safety.
- International guidelines exist for the safety and allergenicity assessment of genetically modified crops.
- Despite these guidelines, additional testing is often demanded and/or conducted using nonvalidated methods of questionable value.
- Assessing possible alterations in the endogenous allergenicity of a genetically modified food is of questionable value, especially in situations such as corn and rice where the food has a very low risk of allergenicity in the first place.

Agricultural biotechnology has already had considerable impact on the production of certain agricultural food crops, particularly corn, soybeans, and canola. Certainly, agricultural biotechnology has the near-term potential to impact other significant cereal crops including wheat and rice. So far, a rather limited number of beneficial traits, improved insect resistance or enhanced herbicide tolerance or both, have been introduced into commercial crops. These traits primarily provide agronomic benefits to farmers, although they may also have environmental benefits such as the use of less externally applied pesticide. Consumer resistance to genetically modified foods, sometimes driven by governmental positions, certainly exists and is more manifested in some countries than others. The consumer and governmental attitudes are often driven by concerns over the safety or environmental assessment of genetically modified foods.

For the future, agricultural biotechnology offers the potential for the development of crops with more direct consumer-oriented benefits. The beneficial traits might include enhanced nutritional and nutraceutical composition, prolonged shelf-life, resistance to spoilage, improved flavor and appearance, and the elimination of naturally occurring toxicants including allergens. Additional and important agronomic traits such as enhanced yield, better disease resistance, and improved drought tolerance are also possible in the future. Agronomic traits and consumer-oriented traits could easily be stacked, which would lead to easier production of crops with enhanced benefits. Genetically modified crops offer technology within the seed itself, which offers advantages to subsistence farmers due to the reduced need for other inputs. Thus, in the most optimistic vision, agricultural biotechnology offers the hope of feeding the world in increasingly challenging conditions and feeding it better. Of course, many challenges exist to the realization of such an optimistic vision of the future.

Soybean photo courtesy of the Agricultural Research Service/Scott Bauer.

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Safety Assessment—An Asset or an Obstacle?

Obviously, the safety evaluation of foods produced through agricultural biotechnology is critically important to ensure that newly introduced foods are safe to consume. Genetically modified foods have been subjected to considerably more thorough safety assessments than have conventionally bred crops and foods. The genetically modified foods thus far brought into the marketplace have been subjected to an intensive safety assessment. Global scientific and regulatory experts have recommended the best practices for this safety assessment and the Codex Alimentarius Commission has adopted this guidance (2). Certainly, the adoption of uniform safety assessment approaches and procedures is critical to the successful worldwide marketing and distribution of genetically modified cereals and oilseeds. The safety assessment data generated for individual commercialized products have been reviewed by regulatory authorities around the world. Thus, the conclusion could be reached that the currently approved and marketed genetically modified products are quite safe for human and feed animal consumption.

However, despite the existence of the Codex Alimentarius Commission safety assessment guidelines for genetically modified foods (2), regulatory agencies in certain countries and individual scientists and scientific groups continue to raise

safety concerns and request or conduct unique tests. On the other hand, commercial agricultural biotechnology companies have made mistakes that have contributed to some degree to existing concerns. These actions, especially those by governments and companies, serve to limit the worldwide distribution of genetically engineered foods and push the optimistic vision of the potential for agricultural biotechnology further into the future. In this review, we will focus on several examples and the safety risks associated with each. Since genetically engineered foods often closely resemble their conventional counterparts, both phenotypically and biochemically, the evaluation of the safety of genetically engineered foods often focuses on assessing the safety of any unique components or components present at altered levels; these components are often proteins (23). This is the concept of substantial equivalence. And, since many of the unique components are proteins, the safety assessment of novel proteins, and especially the assessment of the potential allergenicity of such proteins, has become an important focus (6). Many of our examples will involve the allergenicity assessment of genetically modified foods.

Safety Assessment Guidelines

As noted earlier, the guidelines currently adopted by the Codex Alimentarius Commission are the best approach to the overall safety assessment (2). In general, this approach emphasizes the comparison between the transgenic variety and the conventional counterpart to identify unique compositional differences that become the focus of the safety assessment under the concept of substantial equivalence. Several key points of concern have arisen in the implementation of the overall safety assessment of genetically modified foods.

Some have raised questions about possible unintended effects or differences that might occur. But, the possibility that such unintended effects, which might be significant in terms of the overall safety evaluation of the transgenic variety, would escape detection in compositional comparisons or phenotypic comparisons seems relatively small. Yet some governmental regulatory agencies, apparently under the hope that animal feeding trials would identify such differences, continue to insist upon trials, usually 90-day trials (e.g., India, European Union, and China), even though this approach is not recommended in the Codex Alimentarius Commission guidelines. Animal feeding trials are a relatively crude tool to use in safety assessment because the animals are unlikely to respond to small compositional differences and the animals will be sensitive to possible nutritional imbalances in their diets resulting from the introduction of large amounts of a particular food, e.g. corn into their diets. Acute rodent feeding trials have been required in many countries including the United States, especially for genetically modified crops containing pesticidal proteins such at Bt toxin. Typically, these tests involve administration of a single high dose of the novel protein followed by 12–14 days of observation (8). Acute toxicity tests could conceivably identify any acutely toxic proteins, although few such proteins exist (ricin and botulinum toxins). No toxic effects have thus far been uncovered in these studies. Furthermore, acute toxicity testing is only helpful in assessing the toxicity of the novel protein and is too insensitive to use with the whole food. The use of 90-day subchronic feeding trials has long been used in the safety assessment of food additives and many other chemicals. The subchronic trials usually conducted in rodents are quite useful in the evaluation of the toxicity of specific chemicals, but, as noted, are relatively crude tools to use in the evaluation of whole foods because of the vast mixture of chemicals—with most present at quite low concentrations. However, 90-day trials have been used in the safety assessment of genetically modified crops (7). Animal performance or nutritional studies have often been conducted with genetically modified foods, especially on chickens (22). While not specifically intended as part of the safety assessment, these animal feeding trials could be potentially useful in identifying the presence of potentially harmful components that might inhibit growth or exert other apparent effects. These studies are intended to determine if the genetically modified crop is substantially equivalent to its conventional counterpart in terms of nutritional performance. Thus, animal feeding trials, especially with whole foods, are not particularly helpful in the safety assessment of genetically modified crops

Additionally, the choice of the conventional counterpart variety for comparison purposes can be critical in the interpretation of safety assessment data. Often, the recommendation is made to use a near-isogenic variety for comparison to the transgenic variety. While this choice makes sense, the overall variability in composition of all of the commercial varieties of the crop should be taken into consideration. Certainly, a large number of varieties exist for commercial crops such as corn and soybeans. Considerable variations also exist in composition as a result of agronomic differences in growing conditions as well.

A recent debate about safety studies performed by Monsanto in support of their MON863 transgenic corn variety, which is resistant to corn root worm, is illustrative. As part of this evaluation, Monsanto conducted a 90-day rat feeding trial. European regulators examined the safety data, including the results of this trial, and approved this corn for human consumption in the EU. Subsequently, independent evaluation of the results questioned this original conclusion because a comparison of liver and kidney weights for the rats fed the MON863 corn were different from rats fed a near-isogenic corn variety. However, the liver and kidney weights from rats fed either diet were not significantly different from those of animals fed other commercial varieties of corn in the same experiment. The expanded comparison is relevant because it allows evaluation of responses to the range of varieties of commodity crops in use, and leads to the conclusion that minor statistical differences in animal feed performance are unlikely to indicate potential changes in nutritional value or endogenous toxicity.

In some specific cases, compositional comparisons can be very useful in the toxicological evaluation of newly developed crops, whether genetically modified or conventionally bred. For example, potatoes are known to contain small (and safe) concentrations of a naturally occurring glycoalkaloid neurotoxin called solanine. Regulatory agencies in the United States and European Union require that new varieties of potatoes be evaluated for solanine content. Both conventionally bred and genetically modified potatoes have been developed that had elevated levels of solanine (15,25), but, as a result of the solanine tests, these varieties were never commercialized.

Allergenicity Assessment Guidelines

Four potential risks in descending order of importance could occur as a result of genetic modification: 1) the transfer of an allergenic protein from one source to another, 2) the transfer of a gene encoding a protein that is sufficiently similar in sequence and structure to an allergen that allergic individuals may suffer a cross-reaction if they are exposed to the new protein, 3) the transfer of a gene from a source with no history of allergenicity that encodes for a protein that becomes a new food allergen under the new circumstances

of exposure, and 4) the possible up-regulation of endogenous allergens in the host plant as a result of the transformation (6). Clearly, the first two of these scenarios bear the greatest risk to allergic consumers. While all four scenarios must be addressed in the allergenicity assessment, the appropriate level of scrutiny requires some judgment about the likelihood of the scenario and the comparative impact on risk.

The approaches to the assessment of the allergenicity of genetically modified crops have evolved in a series of expert consultations beginning with the International Life Sciences Institute–International Food Biotechnology Council in 1996 up through the current Codex Alimentarius Commission recommendations in 2003 (2,4,16). The Codex Alimentarius Commission recommendations reflect the most practical and scientifically defensible approach to the assessment of the potential allergenicity of genetically modified crops (2). The assessment framework includes an evaluation of the potential allergenicity of food derived from genetically modified plants based on the source of the gene (allergenic or not) and the characteristics of the newly expressed protein compared to those of known allergens including sequence homology to known allergens (>35% overall sequence identity to known allergens over 80 amino acid windows), IgE-binding to the novel protein with sera from individuals allergic to the gene source if it is known to be allergenic, and comparative resistance to pepsin digestion. The Codex Alimentarius Commission guidelines removed certain approaches that had been recommended in earlier expert consultations, including targeted serum screening (IgE binding to the novel protein with sera from individuals allergic to more distantly related gene sources) and animal models, because these approaches have not been validated as predictive (4). While the Codex Alimentarius Commission guidelines from 2003 also included sequence homology searches for the identity of short amino acid sequences (2), usually either 6-mer (number of amino acid units) or 8-mer, this approach has subsequently been documented to be nonpredictive (11,19, 20). Changes in the endogenous allergenicity of the host (recipient) plant have also been considered as a criterion on frequent occasions (16), even though this has not been specifically recommended by any of the expert consultations. Furthermore, the level of expression of the novel protein in the genetically modified food can be considered (16), although no specific criterion has been recommended; certainly a highly expressed protein is more likely to be sensitizing than a protein that is expressed at very low levels. A series of case studies illustrates the issues associated with the allergenicity of genetically modified foods.

Nutritionally Enhanced Soybean

Soybeans are inherently deficient in sulfur-containing amino acids. The development of a soy variety containing higher levels of methionine would improve the nutritional qualities of soy for animal feeding. In the early 1990s, Pioneer Hi-Bred International, Inc., now part of DuPont, developed a high-methionine soybean variety by cloning the gene for a methionine-rich protein from Brazil nuts into soybeans. At the time, Brazil nuts were a known allergenic food, but the identification of the major allergenic protein in Brazil nuts remained unknown. The developers recognized that they must determine if the methionine-rich protein was an allergenic protein. Specific serum screening with sera from individuals with Brazil nut allergy was used to document that this high-methionine 2S albumin from Brazil nuts was likely the major allergen of Brazil nuts, *Ber e 1* (17). As a result, Pioneer Hi-Bred International decided not to commercialize this variety. This high-methionine soybean remains the only example of the development of a genetically engineered crop with significant allergenic potential. Of course, this example also illustrates that an assessment strategy can identify and eliminate such potential risks.

StarLink Corn

The genetic modification of corn to allow expression of insecticidal Bt proteins has been one of the success stories for agricultural biotechnology. Many different Bt proteins exist in nature and they have differing insecticidal specificities. In the 1990s, a corn variety was genetically modified to contain the Cry9c gene and the resultant Bt protein. The gene was from a source with no history of allergenicity, the Cry9c protein was not homologous to known allergens either by overall structural identity or by short mer matches, and no serum screening was necessary because of the lack of any match to known allergens. However, the Cry9c protein was more resistant to pepsin than other Bt proteins, which resulted in regulatory uncertainties that prevented its approval for food uses. StarLink corn was approved for animal feed use, but ultimately contaminated corn intended for human consumption also. Since StarLink corn was not approved for food, corn products containing StarLink were considered unfit for human consumption. Massive recalls occurred and frequent testing of corn ensued as it was delivered to elevators. However, despite the uncertainties, no allergic reactions were ever linked to ingestion of StarLink corn. Since the expression of the Cry9c protein in StarLink corn was quite low, the risk of allergic sensitization of consumers was also likely quite low (21). But, no reasonable way existed to resolve the uncertainty about the digestive stability of the Cry9c protein, so this variety was abandoned for further development.

The allergenicity assessment of StarLink corn also illustrates the problems that exist in the use of animal models for such assessment. As indicated earlier, the Codex Alimentarius Commission has not included animal models in its guidelines for allergenicity assessment because no animal model has been validated for such purposes (3). Ideally, validation would require that the results obtained in the animal exposed to the transgenic variety or novel protein contained therein would mirror human responses (18). In the case of StarLink corn, the Cry9c protein was fed to brown Norway rats and stimulated an IgE response. However, it has subsequently been documented that brown Norway rats display IgE responses to the administration of many different food proteins including some proteins that are not known food allergens (1,12). Thus, this response is not predictive, but it further complicated the allergenicity assessment of StarLink corn.

Another Bt Example

Some expert consultations have recommended using identity matches of short amino acid segments between the novel protein and known allergens as one of the criteria in the allergenicity assessment. Segments as short as six amino acids have been recommended (4). DuPont (Pioneer Hi-Bred International) developed a genetically modified corn variety containing the gene for Cry1F, another Bt protein that is toxic to lepidopteran larval pests such as the European corn borer (14). As with all Bt products, the gene is from an organism not known to cause allergies. The sequence is not significantly identical to any known allergen based on overall alignment and is less than 35% identical to any 80 amino acid segment of known allergens. This Bt protein was susceptible to pepsin hydrolysis. The product was approved by U.S. and Canadian regulators. However, when a bioinformatics comparison to known and

suspected allergens was performed to identify any six amino acid matches with allergens, a single match was identified to the house dust mite allergen Der p 7 (14). Although the proteins did not have any other alignment similarity, regulators in Taiwan required serum IgE binding tests with sera from individuals allergic to dust mites to evaluate potential cross-reactivity. Though recommended by one expert consultation, the criterion of a six amino acid match has since been repeatedly demonstrated to be nonpredictive (5,11, 20). Six-mer matches occur often by random chance. The results of the serum IgE test demonstrated a lack of IgE binding to Cry1F using sera from allergic subjects who had clear IgE binding to Der p 7 (14). The results satisfied the regulators in Taiwan and the product was approved. However, such testing is expensive and a chance always exists of obtaining a false positive result since in vitro IgE binding does not always correlate with actual allergic disease. The ultimate result was predictable in advance based on the lack of overall sequence identity. Requiring serum IgE tests to evaluate proteins with only short sequence matches to nonhomologous sequences is not scientifically justified.

LibertyLink Rice

Three similar varieties of LibertyLink rice (LLRICE62, LLRICE06, and LLRICE601) were developed by Aventis CropScience (now Bayer CropScience) by inserting one of two related herbicide tolerance genes encoding phosphinothricin-N-acetyltransferase (PAT). All three rice varieties were transformed with the same DNA construct. The two related genes encode proteins that are 85% identical and both are referred to as PAT (24). The PAT genes were not obtained from an allergenic source. The PAT protein (from *bar*) does not share significant sequence identity with any known allergens (10). The PAT protein is rapidly digested by pepsin under standardized conditions (10). Based upon this evaluation, the likely risk that PAT would become a food allergen is very low. Rice varieties containing both genes have been approved in the United States since 1999, but are not yet marketed. Furthermore, one or more countries have approved genetically modified crops containing the PAT gene, including cotton, corn, soybean, canola, and sugar beet. These approvals included an examination of the evidence contained in the allergenicity assessment. However, since rice has been reported to cause some allergic reactions, regulators from Canada asked the developer to perform an in vitro IgE binding study of LLRICE62, the event chosen for commercial development, compared to a nontransgenic rice variety to evaluate whether there were differences in IgE reactivity that might indicate a change in endogenous allergen expression. No significant differences were noted in IgE binding between LLRICE62 and a genetically similar traditional rice variety using sera from 15 individuals with clinical histories of rice allergy or food allergy and positive IgE to rice proteins by skin prick tests or in vitro IgE assay (D. Mitten, Bayer CropSciences, 2006, personal commun.). Obtaining sera from rice-allergic individuals or even rice-reactive (it might even be erroneous to refer to these patients as rice-sensitized since the binding may simply indicate sensitization to grass pollen and cross-reaction with rice) individuals is extremely difficult due to the comparatively rare occurrence of rice allergy. Also, the value of such determination is questionable because anyone with rice allergy would be predicted to avoid LLRICE62 and all other rice varieties. Recently it was discovered that event LLRICE601 germplasm exists as a low level contaminant in one commercial nontransgenic rice variety. While this is an unapproved event, the presence of the same or similar gene in rice or other crops lessens the likelihood of any risk to consumers. Even though a serum screening study had been performed on the similar variety and the same gene is approved in other crops, regulators have asked Bayer CropScience to do serum screening with the LLRICE601 variety to determine if changes exist in the level of endogenous rice allergens. This study has not been performed due to the difficulty in obtaining sera from a sufficient number of clinically allergic subjects to perform a statistically valid study. However, the question should be asked about the value of such studies. Even a major change in expression levels of endogenous rice allergens would have a rather small impact on human health. Sufficient scientific justification does not exist in the case of rarely allergenic foods like rice and corn to require studies on changes in endogenous allergen content.

CONCLUSION

The safety assessment of genetically modified foods is an important step to reassure consumers. Because the primary compositional differences are often restricted to the presence of unique proteins and because most food allergens are proteins, the allergenicity assessment of genetically modified foods is a key component of the overall safety assessment. The currently approved genetically modified foods contain rather low levels of the novel proteins conferring insect resistance or herbicide tolerance. These approved varieties were subjected to allergenicity assessment using recommended approaches. Because these proteins are not structurally similar to known allergens and are rapidly hydrolyzed by pepsin, they are unlikely to become allergens. Allergenicity assessment will become more important when genetically modified foods contain novel proteins expressed at higher levels. The methionine-enhanced soybean example illustrates that situation. However, the existing allergenicity assessment approaches seem well suited to these situations as well. In the vast majority of cases, the tests recommended by the Codex Alimentarius Commission (2) will provide reasonable assurance regarding possible allergenicity. Expert judgment is often crucial to determine if additional tests are warranted, but such testing is likely desirable only in a few special circumstances. For example, the assessment of changes in levels of endogenous allergens, however, is of questionable relevance in situations where the prevalence of these allergies is comparatively low (e.g., rice, corn, and perhaps even soybeans), and these consumers would already be practicing avoidance diets that would eliminate the new variety. The assessment of endogenous allergens assumes importance in situations where an effort is made to develop a variety with low allergenicity, such as peanuts lacking the allergen Ara h 2 (13) or soybeans lacking the P34 allergen (9). In these cases, effects on levels of other endogenous allergens should be assessed to determine if the overall allergenicity of the new variety is, in fact, diminished. The development of additional, well validated approaches for allergenicity assessment could add confidence in the future, but the validation of such approaches is crucial prior to their implementation. However, the current use of approaches of questionable validity, especially in situations where the potential risk is extremely small, is of questionable value.

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References

1. Atkinson, H. A. C., and Miller, K. Assessment of the brown Norway rat as a suitable model for the investigation of food allergy. Toxicol. 91:281, 1994.
2. Codex Alimentarius Commission. Alinorm 03/34. Joint FAO/WHO Food Standard Programme, Codex Alimentarius Commission, Twenty-Fifth Session, Rome, Italy 30–5 July, 2003. Appendix III, Guideline for the conduct of food safety assessment of foods derived from recombinant-DNA plants and Appendix IV, Annex on the assessment of possible allergenicity, p. 47–60. Rome, The Assoc-iation, 2003.
3. Dearman, R. J., and Kimber, I. A mouse model for food allergy using intraperitoneal sensitization. Methods 41:91, 2007.
4. FAO/WHO. Evaluation of allergenicity of genetically modified foods. Report of a Joint FAO/WHO Expert Consultation on Allergenicity of Foods Derived from Biotechnology. Rome, Food and Agriculture Organization of the United Nations (FAO), 2001.
5. Goodman, R. E. Practical and predictive bioinformatics methods for the identification of potentially cross-reactive protein matches. Mol. Nutr. Food Res. 50:655, 2006.
6. Goodman, R. E., Hefle, S. L., Taylor, S. L., and van Ree, R. Assessing genetically modified crops to minimize the risk of increased food allergy: A review. Int. Arch. Allergy Immunol. 137:153, 2005.
7. Hammond, B. G., Dudek, R., Lemen, J. K., and Nemeth, M. A. Results of a 90-day safety assurance study in rats fed grain from corn borer-protected corn. Food Chem. Toxicol. 44:1092, 2006.
8. Harrison, L. A., Bailey, M. R., Naylor, M. W., Ream, J., Hammond, B. G., Nida, L., Burnette, B. L., Nickson, T. E., Mitsky, T. A., Taylor, M. L., Fuchs, R. L., and Padgette, S. R. The expressed protein in glyphosate-tolerant soybean, 5-enolpyruvylshikimate-3-phosphate synthase from Agrobacterium sp. strain CP4, is rapidly digested in vitro and is not toxic to acutely gavaged mice. J. Nutr. 126:728, 1996.
9. Herman, E. Soybean allergenicity and suppression of the immunodominant allergen. Crop Sci. 45:462, 2005.
10. Herouet, C., Esdaile, D. J., Mallyon, B. A., Debruyne, E., Schulz, A., Currier, T., Hendrickx, K., van der Klis, R.-J., and Rouan, D. Safety evaluation of the phosphinothricin acetyltransferase proteins encoded by the *pat* and *bar* sequences that confer tolerance to glufosinate-ammonium herbicide in transgenic plants. Regul. Toxicol. Pharmacol. 41:134, 2005.
11. Hileman, R. E., Silvanovich, A., Goodman, R. E., Rice, E. A., Holleschak, G., Astwood, J. D., and Hefle, S. L. Bioinformatic methods for allergenicity assessment using a comprehensive allergen database. Int. Arch. Allergy Immunol. 128:280, 2002.
12. Knippels, L. M. J., and Penninks, A. H.. Assessment of the allergenic potential of food protein extracts and proteins on oral application using the brown Norway rat model. Envion. Health Perspect. 111:23, 2003.
13. Konan, K. N., Viquez, O. M., and Dodo, H. W. Towards the development of a hypoallergenic peanut through genetic transformation. Appl. Biotechnol. Food Sci. Policy 1:159, 2003.
14. Ladics, G. S., Bardina, L., Cressman, R. F., Mattsson, J. L., and Sampson, H. A. Lack of cross-reactivity between the *Bacillus thuringiensis* derived protein Cry1F in maize grain and dust mite Der p7 protein with human sera positive for Der p7-IgE. Regul. Toxicol. Pharmacol 44:136, 2006.
15. Matthews, D., Jones, H., Gans, P., Coates, S., and Smith, L. M. J. Toxic secondary Metabolite production in genetically modified potatoes in response to stress. J. Agric. Food Chem. 53:7766, 2005.
16. Metcalfe, D. D., Astwood, J. D., Townsend, R., Sampson, H. A., Taylor, S. L., and Fuchs, R. L. Assessment of the allergenic potential of foods derived from genetically modified crop plants. Crit. Rev. Food Sci. Nutr. 36(S):165, 1996.
17. Nordlee, J. A., Taylor, S. L., Townsend, J. A., Thomas, L. A., and Bush, R. K. Identification of a Brazil nut allergen in transgenic soybeans. N. Engl. J. Med. 334:688, 1996.
18. Penninks, A. H., and Knippels, L. M. J. Determination of protein allergenicity: Studies in rats. Toxicol. Lett. 120:171, 2001.
19. Silvanovich, A., Nemeth, M. A., Song, P., Herman, R., Tagliani, L., and Bannon, G. A. The value of short amino acid sequence matches for prediction of protein allergenicity. Toxicol. Sci. 90:252, 2006.
20. Stadler, M. B., and Stadler, B. M. Allergenicity prediction by protein sequence. FASEB J. 17:1141, 2003.
21. Sutton, S. A., Assa'ad, A. H., Steinmetz, C., and Rothenberg, M. E. A negative, double-blind, placebo-controlled challenge to genetically modified corn. J. Allergy Clin. Immunol. 112:1011, 2003.
22. Taylor, M. L., Hartnell, G., Nemeth, M., Karunanandaa, K., and George, B. Comparison of broiler performance when fed diets con-taining corn grain with insect-protected (corn rootworm and European corn borer) and herbicide-tolerant (glyphosate) traits, control corn, or commercial reference corn—Revisited. Poultry Sci. 84:5878, 2005.
23. Taylor, S. L. Safety assessment of genetically modified foods. J. Nematol. 33:178, 2001.
24. Wehrmann, A., Van Vliet, A., Opsomer, C., Botterman, J., and Schulz, A. The similarities of bar and pat gene products make them equally applicable for plant engineers. Nature Biotechnol. 14:1274, 1996.
25. Zitnak, A., and Johnston, G. R. Glycoalkaloid content of B5141-6 potatoes. Am. Potato J. 47:256, 1970.

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