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GM crops have altered levels of nutrients and toxins

“N*o one can scientifically claim to be able to predict all consequences of the presence and functioning of a new gene (and even less for several) in a genome which has never been exposed [to] or contained this gene. The potential hazard here is not a consequence of the action of modification [of] the plant genome, but of the fact that it generates high levels of unpredictability.”*¹⁰³

— European Commission

1. Numerous studies on GMOs reveal unintended changes in nutrients, toxins, allergens, and small molecule products of metabolism.

2. These demonstrate the risks associated with unintended changes that occur due to genetic engineering.

3. Safety assessments are not adequate to guard against potential health risks associated with these changes.

Previous pages in this section describe how the GM transformation process may alter the composition of GM crops. Unfortunately, biotech companies avoid using modern techniques to identify and quantify many known nutrients, antioxidants, mutagens, carcinogens and toxins in plants. Instead, they typically measure only a few items at a gross compositional level (e.g. total protein, total carbohydrates) rather than specific components (e.g. what proteins, what carbohydrates). Furthermore, studies are designed to make it difficult to identify significant differences (see part 3).

Reviews of safety assessments for GM crop approvals in the United States¹⁰⁴ and Europe¹⁰⁵ show that compositional analyses are highly inconsistent between submissions. In several, “no declarations even on essential inherent plant toxins and antinutrients could be found.”¹⁰⁶ Reviewers call for “consistent guidelines” that specify harmful compounds to be evaluated for each species¹⁰⁷ and the US National Academy of Sciences recommends “the establishment of a database for natural plant compounds of potential dietary or other toxicological concern.”¹⁰⁸ Even without consistent and meaningful measurements, there is plenty of evidence of unexpected compositional changes in experimental and commercialized GMOs.

Changed metabolites

Metabolites are small molecules that are the intermediate and end products of metabolism. They can be beneficial or harmful (e.g. nutrients or toxins). In four lines of potatoes engineered to alter sugar metabolism, scientists measured the presence of 88 metabolites. Most levels had been changed and 9 of the 88 were only present in the GM potatoes—not controls.¹⁰⁹ David Schubert writes, “Given the enormous pool of plant metabolites, the observation that 10% of those assayed are new in one set of transfections [GM transformation events] strongly suggests that undesirable or harmful metabolites may be produced and accumulate.”¹¹⁰

In most cases, changed metabolites in GM crops are not measured. By knowing which major compound has been altered, sometimes one can infer changes in intermediate products. For example, the stems of *Bt*-corn varieties MON 810 and *Bt*-11,¹¹¹ as well as Roundup Ready soybeans, have markedly increased levels of lignin (by 20%)—a woody, non-digestible compound.¹¹² Lignin is produced through a complex series of steps, which also create other important plant constituents. Since lignin has increased, the amount of the other related compounds may have changed. According to David Schubert, “Components of

this same biochemical pathway also produce both flavonoids and isoflavonoids that have a high nutritional value, and rotenone, a plant-produced insecticide that may cause Parkinson’s disease.”^{113,114} No tests have been done to evaluate changes in these other components. In fact, even the increased lignin content in corn was not discovered until the varieties had been on the market for five years. The higher lignin in soybeans was only identified after the stems of plants inexplicably split in the heat at the height of the growing season.

It is odd that lignin increased in three separate GM products. Schubert and Freese write, “Normally, one would expect that each non-repeatable, unique transformation event [gene insertion] would yield unique unintended effects.” They suggest that an increase in lignin, and possibly other undetected effects, may be an unintentional response to the insertion of a unique gene, as opposed to the usually random mutations caused by the genetic engineering process.

Examples of unpredicted changes

Tobacco: When genes were inserted into tobacco to produce a particular acid, the plant also created a toxic compound not normally found in tobacco.¹¹⁵

Yeast: Yeast DNA was inserted with multiple copies of its own genes in order to increase alcohol production. This unexpectedly raised levels of a naturally occurring toxin and potential carcinogen by 40 to 200 times. The authors said that their results “may raise some questions regarding the safety and acceptability of genetically engineered food, and give some credence to the many consumers who are not yet prepared to accept food produced using gene engineering techniques.”¹¹⁶

Potatoes: When Oxford University scientists attempted to suppress a potato enzyme, the starch content increased substantially. Plant scientist Chris Leaver said, “We were as surprised as anyone. . . . Nothing in our current understanding of the metabolic pathways of plants would have suggested that our enzyme would have such a profound influence on starch production.”¹¹⁷ In other potatoes inserted with a soybean gene (glycinin), some vitamins were reduced and dangerous toxins (solanine and chaconine) increased. And although the insertion was designed to increase protein content, the transgenic version has *less* protein than the controls.¹¹⁸

Potatoes engineered to produce an insecticide (GNA lectin), contained 22% less protein than their own parent line. And the nutritional content of two different GM potatoes from the same parent line grown in identical condi-

tions was significantly different. Other GM potato varieties had problems with tissues¹¹⁹ and carbohydrate processing.¹²⁰

Wheat: One GM wheat variety showed lesions,¹²¹ another variety had higher levels of toxicity.¹²²

Rice: One GM rice unexpectedly produced 50% more vitamin B6.¹²³ Another designed to produce vitamin A altered other compounds (carotenoid derivatives).¹²⁴

Peas: GM pea varieties showed a fourfold increase in lectins and a doubling of trypsin inhibitor.¹²⁵

Squash: A USDA-approved GM squash contains 67 times less beta-carotene and 4 times more sodium than non-GM squash.¹²⁶

Soy: Monsanto's own study on Roundup Ready soy showed significant differences in the ash, fat, and carbohydrate content as well as a 27% increase in trypsin inhibitor,¹²⁷ a known allergen. Additional differences (which Monsanto had omitted from their paper but were later recovered in journal archives) showed that GM soy had significantly lower levels of protein, a fatty acid, and phenylalanine (an essential amino acid). The toasted GM soy meal contained nearly twice the amount of a lectin, which may interfere with assimilation of nutrients.¹²⁸

There was also a disturbing finding related to trypsin inhibitor. Cooking normally breaks down (denatures) this potential allergen, making it safer to consume, but "heat treatment appeared to have a far lesser denaturing effect on the trypsin inhibitor content of the GM lines."¹²⁹ The cooked soy had nearly as much trypsin inhibitor as the uncooked variety—as much as seven times more than non-GM soy.

In the same study, both rats and catfish fed various lines of Roundup Ready soybeans exhibited different growth rates, suggesting that the nutrition content of the soybeans varied significantly. Also, cows fed GM soy produced milk with a higher fat content than those fed non-GM soy.¹³⁰

In a 2004 study, cooked soybean meal from Argentina had about 18.5% less protein than meal from China and India. US soybean meal had about 8.5% less. These differences might be attributable to the genetic modification. At the time of the study, soy from Argentina was almost all GM, while soy from the United States was mixed. Soy from China and India, which had the higher protein content, was non-GM.¹³¹

Corn: In *Bt*-corn MON 810, 8 out of the 18 amino acids measured (44%) were significantly different than the controls. The Public Health Association of Australia (PHAA) points out that the expected new protein created from the transgene "constitutes less than 0.001% of the total protein ... the change in amino acid profile cannot be at-

tributed to the presence of this new, expected protein in the plant. It indicates that other proteins may have been produced, which may be potentially toxic."¹³² The calcium and beta tocopherols levels were also significantly different.¹³³

Roundup Ready corn varied significantly in five amino acids. As amino acids may form potentially harmful proteins, the PHAA, said it was "of concern that these results have not been followed-up with experiments of the whole food to determine if any new, unexpected substances are present which may cause disease."¹³⁴

In Liberty Link corn, two of six fatty acids, 7 of 18 amino acids, and calcium, phosphorus, protein, and carbohydrate levels were statistically different. (Calcium was down 64%.)¹³⁵

A high-lysine corn under review for commercialization "had higher levels in all of the 18 measured amino acids among the four commercial varieties used as references."¹³⁶ (115.17 mg/g compared to an average of 77.8 mg/g.)

Canola: Although the vitamin A (carotene) content of canola seeds was successfully increased (50-fold) with the addition of a bacterial gene, there was an unexpected and significant decrease in vitamin E (tocopherol). The fatty acid composition was significantly altered and chlorophyll levels were also reduced.¹³⁷

Monsanto's Roundup Ready Canola line Gt173 has significantly higher levels of amino acids compared to its parent line. The increase is greater than the additional protein produced from the inserted genes and, according to the PHAA, should have been further evaluated for possible toxicity.¹³⁸ The canola also had a significantly altered fat content.¹³⁹

Unexpected agricultural performance

In addition to lab tests, we can infer other compositional differences based on varied agronomic performance of GM crops and the reactions of plants to various conditions of disease and stress. The levels of certain toxins in potatoes (sesquiterpenes and the glycoalkaloids—PGAs), for example, differed between GM potatoes and non-GM potatoes, after they were exposed to a variety of stresses in the field and at the store.¹⁴⁰

GM cotton has greater susceptibility to nematodes¹⁴¹ and other pests, and in various conditions, dropped their cotton bolls, died on contact with the herbicide they were engineered to tolerate, succumbed to disease or drought, failed to germinate, or had smaller cotton bolls and poorer cotton quality. Monsanto paid millions in settlements with farmers.¹⁴²

Yields of GM Roundup Ready soy have been on average 7%–10% less than equivalent conventional varieties.¹⁴³

Furthermore, a study consisting of side-by-side field trials over a two-year period at four different locations of GM and equivalent non-GM varieties of glyphosate-resistant (GR) soybean cultivars concluded that, “Yields were suppressed with GR soybean cultivars. . . . The work reported here demonstrates that a **5% yield suppression was related to the gene or its insertion process** and another 5% suppression was due to cultivar genetic differential.”¹⁴⁴ Given that yield is dependent on the overall physiological condition of the plants and not just on the function of a single gene, the results from these controlled studies demonstrate the general disruptive effect that the GM transformation process has on the genome and consequent biochemical functioning as a whole.

In spite of the overwhelming evidence of substantial compositional changes in GM crops, advocates continue to deny the presence of these unpredictable, potentially harmful changes. In a 2002 article, for example, the authors claimed that “transgenic varieties expressing a single agronomic trait (are) not expected to (have an) altered nutrient composition.”¹⁴⁵ According to Pusztai and Bardocz, “It would be helpful in the interests of science to generally recognize and accept that views such as that . . . fly in the face of the facts and published data.”¹⁴⁶

New studies reveal more unknowns

Modern techniques can provide data on a full range of RNA transcripts, proteins, and metabolites (transcriptome, proteome, and metabolome) that are produced by an organism. Scientists have been calling for GM foods to be submitted to these analyses for some time. A 2005 UK government-funded study concluded that “a combination of proteomic, metabolomic, and genomic approaches would seem to be necessary for any safety assessment to be as comprehensive as possible.”¹⁴⁷

Recent studies using these techniques demonstrated that the impacts of the GM transformation process vary considerably from one “event” to another, producing both intended and unintended effects. In one study, the expression of “up to 58 genes” was increased or decreased “more than fivefold.”¹⁴⁸ Another study concluded that “the unintended effects” of GM transformation were greater than the natural biological variation of the plant, when comparing plants grown under a specific experimental condition.¹⁴⁹

Using these techniques to quantify how many proteins change and by how much, is limited by our lack of understanding of biochemical pathways. In a study of GM potatoes for example, researchers found that only 9 of the 730 proteins they analyzed showed significant differences. But

they were at a loss to explain how such small differences could result in some potato lines being extremely stunted with low tuber yield.¹⁵⁰

Scientists have been cataloging various enzymes and their effects in their native organism for years. But according to Richard Finn, this “is only partly useful because it is the properties of the enzyme in its new biochemical environment that will determine which chemicals it transforms and at what rate.”¹⁵¹ Similarly, the European Commission says that “Even if a given protein per se does not represent an allergen, its expression in another host organism may indirectly upregulate the expression of potential allergens.”¹⁵²

Our lack of understanding of the effects of transporting material between species is compounded by our inability to grasp the holistic complexity at work inside plants and animals. “If a biologist is shown a map of all known biochemical pathways,” says Finn, “they are unlikely to see any patterns—to most biologists it is just a collection of names and arrows. There is much knowledge, and some understanding, of many individual enzymes and most biochemical pathways, but how and why has evolution shaped biochemistry as an entity? If we cannot answer that question how can we confidently predict the outcomes of attempts to change an organism’s biochemical repertoire by genetic manipulation?”¹⁵³

The quest to understand these mechanics at work in plants is made more complicated by the finding that patterns of gene expression vary considerably due to changing environmental conditions. Variations in response to the environment, according to recent studies, were “generally greater than the effect of the genetic transformation.”¹⁵⁴ This doesn’t minimize the potential harm that can arise from the GM transformation process. Quite the contrary; changes due to genetic engineering would be added onto—and possibly interfere with—changes caused by the environment. For example, suppose that a gene or gene cluster designed to protect the plant from a specific infestation is disabled. If an infestation occurs, the plant may compensate by producing compounds that are toxic to humans. Safety assessments of GM crops grown only under a narrow range of conditions would overlook this risk and might not even identify that the genes were impaired.

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PART 1, SECTION 3: THE PROTEIN MAY CREATE PROBLEMS

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