Identity Preservation of Genetically Modified Organisms in the Food Chain: Requirements, Methods, and Costs

GRAHAM BROOKES
PG Economics, Wessex Barn, Frampton, Dorchester, Dorset DT2 9NB, UK

The use of the technology of genetic modification (GM) in European agriculture and the food supply chain is currently controversial. Because of strong anti-GM technology sentiments, the use of ingredients derived from plants containing GM have largely been eliminated from foods manufactured for direct human consumption by the food supply chain in much of the European Union (EU). During the past year, the attention of those opposed to the technology has turned to the use of GM ingredients in livestock production systems by incorporation of GM soy and maize in animal feed. A discussion is presented of the key issues relating to this subject, focusing on how supplies of GM or non-GM products are segregated or how their identities are preserved. The discussion is centered on GM maize and soybeans into which agronomic traits, such as herbicide tolerance and/or insect resistance, have been incorporated. These are currently the only crops into which some varieties containing GM have been approved for use in the EU.

Identity preservation (IP) refers to any system of raw material management that segregates or preserves the identity of the source or nature of the materials. IP relating to genetically modified organisms (GMOs) comes from the nature of GM technology which includes modifications that alter the nature of a crop or product or focuses on agronomic traits that aim to improve the profitability of primary agricultural production. The current controversy relating to GMOs focuses on the latter.

Identity Preservation and Its Application to GMOs

IP requires additional work and costs in handling, storage, transport, processing, cleaning-out of storage bins and processing machinery, and administration of GM crops to ensure that they and their derivatives can be identified and kept separate from nonmodified equivalent materials. These additional costs arise in connection with stages or functions through pre-farm, farm, transport, further storage, processing, manufacture of products, labeling, and distribution. They depend on the precise circumstances of the crop and the range of products derived from it, uses to which they are put, tolerances and the sophistication of the distribution system, the volume of material subject to IP, experience of operating IP systems, and whether dedicated plant/machinery and supply lines are used.

Empirical evidence to date relating to soy indicates the additional cost involved is within +10 to 150% of the farm-gate price of soy. Methods of initiating IP fall broadly into 2 main types: operation of an IP system that runs in parallel with conventional commodity trading systems or the use of a dedicated supply system that is exclusive to the material being subject to IP. IP costs tend to be highest in the first of these methods. Testing frequency requirements are likely to be heavily influenced by the tolerance levels set: the tighter these are, the greater the frequency of testing points likely to be required.

At a general level, segregation is synonymous with keeping crops and products apart, whereas IP applies when there is a positive desire to preserve the identity or source of a crop or product. In relation to agricultural products, this concept is not new; some degree of segregation or IP occurs for almost all farm products once they are traded beyond the farm gate.

Most traded agricultural products are subject to limited forms of grading into different classes and subclasses, with each class distinguishable by relatively simple and easy-to-follow criteria, often based on visual differences. Many products are typically graded or classified at their simplest level according to variety or type. Thus, there are different classes of wheat (hard or soft red, milling, and feed); maize (flint, dent, white, yellow); barley (feed, malting); and rice (round- or medium-grain japonica, long-grain indica, basmati).

These examples are based on varietal differences of the respective grains, although the grading may also include functional characteristics such as grain size or length, color, test weight, moisture content, and percentage of broken grains and impurities. Hence, grading can be viewed as a very basic form of segregation, or IP. Although some of these grading criteria can be determined simply by variety and visual criteria, others require the knowledge and expertise of a specialist or the use of special testing equipment.

The underlying rationale for any form of IP, and consequential segregation or grading of agricultural products, is to facilitate sales and trade of products from farms to the pur-
chokers at each stage in the food chain: first-stage processors (millers), food manufacturers, retailers, and final consumers. The segregation, IP, or grading allows purchasers to choose the appropriate grade or variety for their requirements. It enables buyers to obtain a grade of crop anywhere in the world and be assured or guaranteed of its characteristics without needing to examine the crop in detail. Thus, a limited system of widely accepted grade specifications has developed for most agricultural products and has been incorporated into standard contracts for the sale of each crop (the examples above illustrate some of the common and widely accepted grades for maize traded globally). Distribution systems have developed to facilitate the efficient storage, handling, and transportation of large volumes of products to these grades in what is often referred to as the “commodity-based” trading system.

Although most agricultural products are traded through a commodity-based system according to limited grading or very basic IP of the respective crops, there are numerous examples of more sophisticated IP, where segregation or IP steps reflect additional specifications or requirements requested by purchasers of the product, such as greater sophistication: the content or composition of products, for example, protein content or starch level; or requirements not related to content or composition, such as region or country of origin, or method of production (e.g., organic).

The rationale for the segregation or IP in both of these forms is the same as that for the commodity-based system, namely, to give customers what they want in terms of quality and consistency. The main difference is that the volumes traded tend to be significantly smaller than those traded via the commodity system.

The classification of IP and segregation into these forms also highlights 2 important concepts in IP and segregation developments: testing and tolerances.

Testing

For many crops, segregation or IP offers purchasers guarantees and confidence that the product supplied is the one specified. An important part of the IP system is the testing of samples for physical or chemical (protein) content. However, for some crops it is not possible to test or measure whether the purchaser’s specifications or requirements have been met. This applies to most cases of IP relating to production process; in such cases, confidence in the IP (e.g., organic) relies on the integrity of the supplier, the level of confidence that purchasers have in suppliers, and the robustness of the segregation or IP system.

Tolerances

The issue of tolerance arises because of the impossibility of ensuring absolute purity of products. The principle of tolerances in purity standards is long-established throughout the food industry. Thus a specified maize variety may contain up to a threshold level of other grains. European Union (EU) intervention standards for most grains have a 3% maximum admixture of impurities. A particularly relevant use of such tolerances is that applied to organic crops. Because of the difficulty of eliminating all comingling throughout the harvesting, storage, transport, and processing chains, a 5% tolerance of nonorganic material is allowed in some processed foods derived from and labeled as being made from organic ingredients.

In recent years, there has been significant development of more sophisticated segregation or IP systems for agricultural products. Currently many more systems aim to trace produce back through the food chain to the point of production (farm level) and to provide purchasers with increasing levels of assurance as to content, composition, and method of production. Notable examples include the growth in the development and demand for organic products and quality-assured supplies of cereals, e.g., the combinable crops scheme in the United Kingdom.

The motives here have been consumer health concerns, loss of confidence in product content and quality, consumer protection, concern for the environment, and ethical concerns for welfare standards in livestock production. The IP or segregation principle is that the consumer is concerned with process, how crops are grown and how animals have been fed and raised. In the beef example, the driving force has been the problem of bovine spongiform encephalopathy (BSE) and its link to contaminated feed. In the cereals combinable-crops scheme, the driving force is primarily associated with issues such as pesticide residues and other possible contamination of crops through the supply chain, e.g., cleaning, storage, and transport.

An underlying feature of most agricultural product and derivative markets is the drive to add value to products by improving or altering the inherent characteristics of a product for which price premia may be charged and the desire to obtain greater consistency and uniformity of the crops and products supplied to markets or as raw materials used in the manufacture of final consumer products. These features strengthen the competitive position of the value-added product versus its substitutable alternatives by differentiating it and potentially reducing the cost of processing, e.g., developing a maize with a higher starch or protein content. Such technical developments may involve the use of both conventional and GM technology. The main implication of the development of more value-adding is the segmentation of markets and a decreasing importance for non-IP or segregated, commodity traded products.

The Rationale for IP for GM Crops

The subject of segregation or IP in GM crops is a complex web of interrelating interests and issues, which themselves are changing over time. The underlying driving forces for segregation or IP comes from the nature of GM technology, which can be distinguished according to 2 main categories of intended, immediate beneficiary of the technology: modifications that focus on quality traits that alter the nature of a crop or product; and modifications that focus on agronomic traits that aim at improving the profitability of primary agricultural production through reducing costs and increasing yields.
Genetic Modifications for Quality Crops

These modifications bring about changes in the crop or product compositional, quality traits, and hence may make possible various industrial and pharmaceutical applications of crops, for example, altering the starch or protein content of a cereal. They may also stimulate the host plant to produce some vitamin or enzyme, or they might alter the physical characteristics of the fruits or seeds of the plant, changing its shape or color. Other modifications can alter physiological processes in the plant, for example, slowing down the process of ripening or decomposition of certain tissues, which improves some aspect of quality, extends shelf life, and reduces waste. In all such cases, the point of the modification is to provide the consumer with a new product or one with improved attributes. The direct beneficiary in these cited cases is plainly the purchaser of the product, who may be the final consumer or a food manufacturer.

The scope for developing new value-added crops derived from GM seed will depend on the traits offering real value to users, who may then be prepared to pay price premia to farmers to grow crops containing such traits. Once such opportunities are created, it is in the interests of all participants to segregate or use IP methods to maintain the integrity of the new or modified product throughout the supply chain. In this case, the underlying driving force for segregation or IP in this category of GM product comes from the supply side (the provider of the technology, farmer, processor, manufacturer). It is the only way that the desirable properties of the new GM can be identified and paid for and becomes a crucial vehicle in demonstrating or advertising to the consumer the desirable new features or traits of the GM-derived material. This category of GM crop is relatively uncontroversial. There is agreement among all parties in the supply chain, including final consumers, that segregation or IP is desirable and practicable.

Crops modified for various quality traits are, however, more likely to be specialist; minor crops do not occupy as large an area of crop land as do conventional crops. In the conventional crop setting, many specialist crops contain specific characteristics for limited “niche” markets.

A GM quality trait currently available on the market is the tomato modified to slow the post-picking ripening process and thus to produce tomatoes with less postharvest spoilage and provide thicker tomato paste. This was until mid-1999 regarded as a technical and marketing success, although in the wake of increased media coverage and opposition to GM technology both purchases and availability in retail outlets in the United Kingdom fell off. Numerous other GM for quality traits are under development, and a second wave of products is expected to gather momentum in the coming years. Indeed the first ones are already beginning to be commercially grown (or about to be planted) in North America. Nevertheless, GM for agronomic traits in crops is the topic on which most discussion has taken place and where most of the intense public debate in Europe is focused.

Genetic Modifications for Agronomic Traits

These modifications comprise mainly agronomic resistance and growth traits, such as herbicide, insect, nematode, and virus resistance, and the development of hybrid seeds, which are higher-yielding. They offer the farmer who plants the modified seeds the opportunity to reduce labor or machinery use, or to make less use of pesticides, which in turn, may result in some cost savings. Alternatively, the modification (notably hybrid seed development) might enable an improved yield of the crop, thereby providing benefit to the adopter by increasing revenue associated with higher levels of production.

For these essentially cost-reducing modifications, there is no intention or desire of the GM provider to change the nature or composition of a crop, only to make it easier, cheaper, and more profitable to grow. Compared with the non-GM crop alternatives, the GM crop and its derivatives are the same as, or substantially equivalent to, the non-GM crop. From the supplier perspective, that is, the farmer and those further down the food distribution chain, this substantial equivalence of non-GM and GM product has been the basis for arguing that segregation or IP of either form of product is unnecessary. Certainly this has been the prevailing line taken in North America, where GM crops have developed most significantly in recent years, and there is no direct economic incentive to initiate segregation or IP of such crops from the supplier or supply-side perspective as there clearly is for value-adding, quality trait GM crops.

The driving force for segregation or IP of GM crops (containing agronomic or cost-saving traits) that are targeted at farmers therefore comes from consumers. This arises when people express a desire to have the opportunity to avoid support for, or consumption of, GM crops and their derivatives, and raises several complex issues for segregation or IP of GM crops containing agronomic traits. The main issue currently confronting European society is the extent to which consumers should have the right and means to exercise choice about whether to consume foods derived from crops containing “cost-saving” GM technology. This issue has implications for segregation or IP of crops that do or do not contain modified genetic material and any consequential labeling of food products. European consumers’ concerns about GM crops are a mix of ethical, health, and environmental issues. To fully accommodate these concerns by offering choice must mean that the segregation or IP and consequential labeling must embrace not only foods that contain GM material but also those that have been made from GM crops. This distinction is important, as the focus of concern is on the process of production (i.e., the process of using GM technology) as well as the content of food products derived from the crops grown from GM seed.

For the GM crops containing modifications aimed at the food industry and final consumers (quality or value-adding traits), it is clearly in the interests of the supplier to initiate segregation or IP and incur any associated, additional costs that may arise. However, for the GM crops containing modifications aimed at farmers (agronomic cost-saving and yield-enhancing traits), there is no direct supplier incentive to segre-
gate or IP and label. The issue then becomes one of assessing the obligation and cost imposed on suppliers via the regulatory authorities. What are the practicalities of doing this? What are the economic consequences?

**Identity Preservation: Requirements and Costs**

IP requires additional work and cost involved in handling, storage, transport, processing, cleaning-out of storage bins and processing machinery, and administration of GM crops to ensure that they and all their derivatives can be identified and kept separate from nonmodified equivalent materials. These real, additional costs arise in connection with a number of stages or functions through pre-farm, farm, transport, further storage, processing, manufacture of products, labeling, and distribution.

**Requirements**

**Pre-Farm**

*Plant (seed) breeding:* The development of new crop varieties currently takes place under very controlled conditions. Distances of about 300 m are maintained between crops to minimize chances of cross-pollination (aeolian or through bees). Although some crops are less likely than others to exhibit cross-pollination (e.g., maize compared with oilseed rape), this 300 m distance is enforced regardless of the crop varieties planted in trials. As a result, the 300 m *cordon sanitaire* is universally accepted as reasonable for maintaining purity levels at 99%, that is, allowing a 1% tolerance level. It is impossible to ensure 100% purity unless production takes place within a hermetically sealed unit. Provided this level of purity and tolerance is considered acceptable in respect of GM varieties, no changes to current practices would arise and no additional costs would be incurred. However, objection to this level of cordon for GM test crops is being voiced, most notably from those with organic interests (e.g., the Soil Association in the United Kingdom says a 6 mile or 10 km cordon should be set to maintain the purity of organic crops that might be grown in the vicinity of GM trial crops). The recent incidence of adventitious contamination of non-GM seed for oilseed rape, maize, and cotton sold to farmers in the EU highlights the concern.

*Seed multiplication:* As with plant breeding, conventional systems of multiplication are closely monitored. Multiplication usually takes place with a 200–300 m distance between crops, depending on the crop and the risk of cross-pollination. This *cordon sanitaire* is universally accepted as reasonable for maintaining purity levels at 98% (a 2% tolerance level). Provided this level of purity and tolerance is considered acceptable in respect of GM varieties, no changes to current practices would arise and no additional costs would be incurred. Adopting a 1% tolerance threshold (consistent with end-product labeling) would, however, inevitably result in higher costs associated with seed production.

*Seed distribution:* Under conventional systems, different varieties are separately bagged and labeled. For GM varieties, no differences would be likely to occur and hence no extra costs would occur.

**Farm Level**

IP requirements at the farm level can be considered in 3 stages: planting, harvest, and storage.

**Planting**

*Plant the specific seed product:* To enter produce into a segregated or IP chain, the farmer first must ensure that the correct seed is planted. This means that different seed bags should not be mixed together. This should be fairly simple to do as seed is usually bagged and labeled according to contents, and farmers are currently used to dealing with multiple varieties of particular crops and are unlikely to mix seed accidentally at this stage. Where the intention is to segregate a crop for which distinct husbandry practices are required (e.g., a herbicide-tolerant GM crop), then clearly the result of mistakes at this stage would become apparent to the farmer, for example, after herbicide application. Additional care and double-checking is therefore likely to occur in such a case, although the additional costs involved would be negligible.

*Clean planting equipment:* To avoid comingling via a seed drill, these implements must be cleaned thoroughly before use. The amount of time spent cleaning would depend to some extent on the IP tolerance levels and whether the IP tolerance level was extremely tight (0.01%); this might necessitate the use of separate machinery for each crop to be segregated.

*Avoid cross-pollination:* This depends to some degree on the ability of the crop to cross-pollinate with other non-IP varieties. Research performed on herbicide-tolerant oilseed rape suggests that cross-pollination is technically possible. However, the (already small) likelihood of cross-pollination diminishes as the distance between modified and nonmodified crop increases. To minimize the possibility of cross-pollination, careful planting of crops is likely to be required (i.e., use of a *cordon sanitaire* between GM and non-GM crops). Production without a reasonable *cordon* (growing a GM variety immediately adjacent to a non-GM variety) could lead to purity levels as low as 70–75% with a tolerance level of up to 30%. This is clearly unacceptable and farmers typically growing specific varieties, usually under contract to a processor, maintain a distance between varieties that they wish to preserve and other crops of a similar nature. Clearly, the larger the *cordon* the higher the costs associated with segregation are likely to be in terms of checking on surrounding crop planting before planting a GM crop, and with the disincentive of having to consider possible impact on adjacent farmland outside the control of a landowner.

*Keep accurate records of plantings:* This is essential to avoid confusion after harvest and to ensure segregation or IP. Although this practice will increase the time and cost involved for farmers, it has become an increasing feature of farming in recent years, especially as quality assurance schemes requiring traceability have become more prominent. As indicated above, the extent to which this increases costs to the farmer will depend on the level of tolerances set.
Harvest

Clean combine before harvest: This step is essential in order to avoid inadvertently mixing other crops with those requiring segregation. Tolerance levels will dictate the degree of cleaning required, and the more restrictive the level of tolerance the greater the cleaning costs will be. There may also be an additional cost associated with a reduction in the timeliness for use of machinery; more time spent cleaning means less time harvesting, which increases costs. If tolerance levels were set at very low levels (0.001%) separate machinery might be needed for crops subject to segregation, although in such a case, it is unlikely that a farmer would choose to grow both IP and non-IP varieties of the same crop.

Storage

Clean on-farm storage bins: Storage bins must be cleaned out or new, dedicated facilities must be built if tolerance levels are set at very low levels to ensure that the postharvest mixing of crops could not take place. The degree of cleaning required, and hence the cost, would depend on the tolerance levels used. In the event that IP and non-IP varieties were grown, careful management would be required to ensure that crops are not stored in the wrong storage bins or stored together.

Transport

Clean trucks/wagons/tools before transporting IP crops: Again, the costs incurred will depend on the tolerance levels set. IP would require transport companies to keep careful records of which trucks and wagons had been used for which IP crop and variety. Given the range of other uses to which trucks and wagons may be put, this level of administration and control could be difficult to achieve and costly in a sector that is widely recognized as operating on low margins. Additionally, the issue of liability for contamination during transit would have to be clarified and could restrict the number of operators prepared to transport IP produce.

Clean storage bins before accepting delivery of IP crops: The amount of cleaning required and thus the cost would depend on the stipulated tolerance level. IP would require dedicated and possibly purpose-built storage facilities.

Eliminate comingling during loading or unloading: This would require cleaning any equipment used in the loading/unloading process and would entail both a labor and a downtime cost (i.e., dead time for cleaning when machinery might otherwise be in use). Very low levels of tolerance might necessitate dedicated loading/unloading equipment.

Sample and test each load: For GM crops containing quality traits, testing would be required to ensure that traits such as higher protein content matched specifications (tolerances). For GM crops with agronomic traits, the testing would be limited to DNA/protein to determine the presence (or absence) of GMOs up to the tolerance level set, which might be no detectable residue. In both cases the cost of testing would depend on the level of tolerance; the lower the tolerance the more sophisticated the testing equipment and procedures would likely be required. Current test costs for herbicide-resistant soybeans range from U.S. $15–20 dollars to several hundred dollars, depending on the tolerance and degree of sophistication of the test.

Ensure correct delivery of the segregated produce: There is the potential for mistakes to be made and produce to be delivered to the wrong processor, export terminal, or user. However, this potential already exists for conventional crops and products and should not pose an insurmountable problem, but it may involve some small, additional management costs.

Further Storage

Any additional storage requirements would lead to the same problems and associated costs discussed above with respect to on-farm storage.

Processing

Ensure storage tanks are clean before use: The degree (and cost) of cleanliness would depend on the level of tolerance. Very low tolerance levels would probably require dedicated storage facilities.

Sample and test each processing batch: This would ensure that the quality specifications of quality trait GM products have been preserved, or for agronomic traits that the required level of tolerance for presence of DNA or protein have been met. The costs here would depend on the level of tolerances set and the extent to which confidence exists in the IP previously undertaken to this point from the farm.

Clean the processing machinery: This would eliminate comingling during processing. The extent and cost of cleaning required would depend on the tolerance levels used. In addition to the labor costs of cleaning, there would also be costs associated with shutting down processing lines, especially where continuous rather than batch processing systems are used. Very low levels of tolerance would probably require dedicated processing facilities.

Distribution

Ensure that IP products go to the correct end-user: This may necessitate use of separate storage and transportation to conventional products. Additional costs might also arise from a loss of economies of size in transportation (e.g., the cost per ton of transporting produce in a 50 000 ton ship is significantly lower than for shipping in a 5000 ton capacity ship). The magnitude of these latter costs would depend on the size of the market for the IP product relative to conventional product markets.

Labeling

Ensure correct labeling: Additional costs relating to labeling include additional time for checks and the associated cost of ensuring that IP products are separately and correctly labeled; the capital cost of resetting, redesigning, and printing labels to meet the new requirements; costs of policing the new requirements to ensure compliance; and the avoidance of fraudulent labeling, e.g., of products purporting to GM-free that are not, or products containing a GM quality trait that it does not possess.
Costs and Methods

The magnitude of additional segregation or IP costs will depend on a number of factors, including the precise circumstances of the crop and the range of products derived from it; the uses to which they are put; tolerances and specifications set; and the sophistication of the distribution system. It also varies with time according to factors such as the volume of material subject to IP; experience of operating IP systems; and whether dedicated plant/machinery and supply lines are used.

Empirical evidence to date relating to soy suggests the additional cost involved is within a range of +10 to +150% of the farm-gate price of soy. Also, because of the value-added nature of almost all supply chains, which invariably involve further processing, the costs of IP relative to the base price of a raw material tend to be highest at the beginning of the supply chain and lowest at the end of the chain. In other words, the cost of IP is more significant, relative to the price of crop or raw material to a farmer or first-stage processor than to a retailer.

Methods of Initiating IP

(a) The initiation and operation of an IP system that runs in parallel with conventional commodity trading systems.—These tend to result in higher overall costs of IP because of the requirements throughout the supply chain to separate material and to clean plant, machinery, transport facilities, and storage depots. Inevitably the scope for adventitious contamination occurring in such an IP system tends to be higher than in (b) below; hence, there are likely to be greater requirements for testing to be initiated at various stages in the supply chain, if only to facilitate tracing of the point of any adventitious contamination.

(b) The use of a dedicated supply system that is exclusive to the material being subject to IP.—This approach tends to result in lower levels of overall cost associated with IP. Only material derived from the target crop (non-GM) is permitted into the supply chain. For example, farms only grow non-GM varieties and the transport, storage, and processing facilities used are dedicated to the non-GM version of a crop. In this way, the likelihood of adventitious contamination occurring tends to be less than (a) above, and pressure to test at each stage in the supply line may also be less than in (a) above.

Testing frequency is likely to be influenced heavily by the tolerance levels set. The tighter these are, the greater the risk of adventitious contamination being identified relative to the tolerance level set. Hence the frequency of testing points in the supply chain is likely to be greater with tighter tolerance levels.