

# Grain Traceability and Its Role in Food Safety

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“To retain their comparative advantage in the global market and address domestic food safety and quality issues, the U.S. grain producers and handlers are implementing methods to produce, handle, and market trait specific grains, including documentation systems that trace raw materials back to the farm” (8). This statement captures one driver in the adoption of traceability systems over the past two decades by the cereal and oilseed industries. The importance of traceability in global trade and food safety was codified by both the European Commission (EC) and the United States in 2002 through EC regulation 178/2002 (2) and the U.S. Public Health Security and Bioterrorism Preparedness and Response Act (17), respectively.

EC regulation 178/2002 (2) lays out the general principles and requirements of food law and defines traceability as “The ability to trace and follow a food, feed, food-producing animal or substance intended to be or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.” Under article 18, the regulation further specifies that “Food and feed business operators shall be able to identify any person from whom they have been supplied with a food, a feed, a food-producing animal, or any substance intended to be, or expected to be, incorporated into a food or feed. To this end, such operators shall have in place systems and procedures which allow for this information to be made available to the competent authorities on demand.”

Grain traceability systems in the United States were initially developed based on

- New regulations stress the importance of traceability in global trade and food safety.
- An effective system must mark and rapidly identify the origins of commingled grain in a bulk shipment.
- Recent advances in the development of tracers offer new possibilities for improving tracking of grain through the supply chain.



economic incentives associated with genetically modified crops and value-enhanced marketing (7). Numerous patent applications filed around the turn of the 21st century involving grain markers employed a concept similar to one used during the 1970s, in which paper tags were inserted in grain to address the problem of grain theft. The promulgation of a rule for “Establishment and Maintenance of Records for Implementing,” section 306 of the U.S. Bioterrorism Act of 2002, requires a step forward and backward recordkeeping activity for tracing grain movement, effectively shifting the focus of traceability to recordkeeping within the grain industry (4).

Similar examples of recordkeeping requirements are included in the Canadian Can-Trace system (1) and International Standards Organization (ISO) food safety standard 22005 (11). Other private safety standard programs for feed include the American Feed Industry Association’s Safe Feed Safe Food, the EU Association of Specialty Feed Ingredients and Their Mixtures’ FAMI QS scheme, and the GMP+ International Feed Safety Assurance scheme. These programs facilitate adoption of national regulatory requirements that align with the Codex Alimentarius Code of Practice on Good Animal Feeding (CAC/RCP 54-2004), which includes traceability.

## U.S. Food Safety Modernization Act and Traceability

Until the U.S. Food Safety Modernization Act was signed by President Obama in 2011, federal regulatory officials in the United States lacked the authority to review company records to ensure conformance with traceability requirements. In the past, food safety recalls, which rely on traceability, have been voluntarily implemented by firms following guidance by the U.S. Food and Drug Administration (FDA) or the U.S. Department of Agriculture (USDA) (3,6). The first use of the authority granted to the FDA under section 306 of the Bioterrorism Act of 2002 involved the adulteration of pet food containing gluten meal and rice protein imported from China. The pet food was deliberately adulterated with melamine and cyanuric acid to boost the apparent level of protein. These two compounds formed crystals that were linked to acute renal failure in pets (14).

The deliberately introduced chemical adulterants (melamine and related compounds) ended up in more than 5,000 products from 12 companies, and waste streams from the manufacturing process ended up in feed intended for animals destined for the human food supply. The melamine incident served as a tipping point in the U.S. public’s alarm involving imported products and food safety and resulted in numerous actions, including the formation of an Interagency Working Group on Import Safety, which authored an Action Plan for Import Safety (10), and a Food Protection Plan authored by FDA personnel (5). The principles pertaining to traceability highlighted in these documents are summarized in Table I.

The U.S. Food Safety Modernization Act of 2011 (Public Law 111-353) incorporates many of the new authorities proposed in the Import Safety Action Plan and Food Protection Plan, including traceability (Table II). This statute provides FDA investigators with the authority “to have access to and copy all records relating to such article” for products deemed reasonably likely to cause serious adverse health consequences or death to humans or ani-

mals and includes distribution and importation (section 101). The requirement to perform hazard analysis and risk-based preventive controls (section 103), including corrective actions, implies the need for traceability associated with product recall, in addition to prohibiting the distribution of contaminated products. Section 110 2(f) of the act directs the secretary to make recommendations for enhanced surveillance, outbreak response, and traceability involving fruits and vegetables, while section 204 calls for enhanced tracking and tracing of foods and recordkeeping. Under this provision, the secretary shall establish pilot projects to explore traceability systems. The mandatory recall authority provision contained in section 206 directs the controller general of the U.S. Congress to identify state and local agencies with the authority to require the mandatory recall of food within 90 days of the date of enactment of the act. Many states possess mandatory recall authority, including Texas, which required pet food manufacturers to provide written recall strategies and collection points for melamine-contaminated products, which were shared, in turn, with other states and the FDA (18).

### Grain-Traceability Technology Update

A tracing and recall system that relies on current recordkeeping methods is inadequate for common grain quality and food safety problems such as aflatoxin contami-

nation in corn. Many types of foods can be traced from the field at the bin level, but this is not possible with grain, since it is stored and moved in bulk.

Recent advances in the development of a grain-traceability system by Texas A&M research scientists and engineers will help address some of the complex challenges involved. The system entails at-harvest application of information-carrying devices, called tracers, that are conveyed in and with the grain (Fig. 1) throughout transport. Investigations into the durability of these tracers and their flow properties in grain have been performed by research engineers at the USDA Agricultural Research Service (ARS) Center for Grain and Animal Health Research in Manhattan, KS. The two teams of scientists partnered to develop a system for marking and rapidly identifying the origin of grain in a bulk shipment, enabling back tracing to individual fields. Insertion of the tracers into the grain, movement with the grain through the supply chain, and an associated sampling scheme to identify multiple lots of commingled grain (Fig. 2) based on binomial and multinomial probability estimates have been demonstrated (13).

The key objectives for the tracers are as follows:

- Composed of food-grade material that will not adulterate grain.
- Mechanically deliverable into grain during harvesting.

- Not easily segregated from grain during handling and storage.
- Carry information about the grain's origin to the individual field level.

There are many engineering challenges associated with meeting these objectives, not the least of which is developing a tracer particle that is durable and does not adulterate the grain. Research into this objective has produced two potential types of tracers made with a pharmaceutical-grade tablet press: one composed of a particular starch and sugar combination, and the other composed of a particular sugar-based material. Both types are food grade and contain no protein, minimizing concerns about allergic reactions and meeting European maize product threshold requirements for genetically modified organisms.

A dispensing system that inserts tracers into the grain during harvest has been developed and tested by a team of research engineers and scientists from Kansas State University who collaborated on the traceability project (9). Tests showed that the tracers remained with the grain during repeated transport and handling and did not become segregated. Research on the hardness of the tracers showed that they resisted breakage that might occur during mechanical delivery of the tracers into the grain and as they flow along with the grain (12). The surface texture of the tracers enables them to be marked with identifica-

**Table I. Traceability recommendations by the Import Safety Working Group and the FDA**

Document	Section	Recommendation
Import Safety	1.2	The FDA would take into consideration industry best practices, such as hazard analysis and critical control (HACCP) requirements.
Import Safety	7.1	Departments and agencies, in partnership with the importing community, should develop a coding system for imported products and participants in the import life cycle, as well as draft any regulations necessary for implementation.
Import Safety	8.1	The importing community has a great deal of information about the product life cycle that would assist the federal government in its enforcement and compliance actions. Use of this data could allow federal departments and agencies to make early determinations of import risk based on data already being collected.
Import Safety	11.4	Authorize the FDA to issue mandatory recalls of food products.
Import Safety	13.1	Develop best practices for the use of technologies to expedite consumer notification of recalls.
Import Safety	14.1	Work with foreign and domestic industry to encourage the development of best practices for the use of electronic track-and-trace technologies.
Food Protection Plan	3.1	Work with stakeholders to develop an action plan for implementing more effective trace-back process improvements and technologies to more rapidly and precisely track the origin and destination of contaminated foods, feed, and ingredients.

**Table II. Food Safety Modernization Act sections, key provisions, and actions**

Section	Title	Key Provision	Action
101	Inspections of records	Reasonable probability of adverse health effects	Access to and copy all records
103	Hazard analysis and risk-based preventive controls	Corrective actions may be taken if preventive controls are ineffective	All affected food is prevented from entering commerce
204	Enhancing tracking and tracing of food and recordkeeping	Pilot projects Product-tracing system Additional recordkeeping	Develop methods for rapid and effective tracking and tracing of foods
206	Mandatory recall authority	Secretary may require a recall	Establishment immediately ceases distribution of article

tion codes that can be read by optoelectronic scanning devices.

One of the challenges to overcome has been the imprinting of a code that is readable, durable, and carries adequate information onto the tracers. Various types of code, printing techniques, food-grade inks, and application methods are being studied. An example of the current state of the research is shown in Figure 3. Readability levels with off-the-shelf bar-code scanners are currently very high, but readability must be maintained after handling, so code durability tests are being planned. The re-



**Fig. 1.** Tracers for insertion into grain can be marked with an information-carrying code such as a bar code.

sulting tracers will have great potential for application in a comprehensive grain-tracing system. It has been proposed that tracers would be inserted into grain at a rate of roughly one tracer per kilogram of grain; the fractional weight of the tracers in grain would be infinitesimal. Ultimately, the tracers and associated system for dispensing, sampling and scanning, and database management are expected to add roughly US\$0.05 to the cost of a bushel of grain.

Tests to validate the ability to identify grain in expected sample sizes using the newly designed tracers also need to be conducted at a grain-handling facility. Tracers would be dispensed at a specified rate either onboard a harvest combine or into flowing grain at a grain elevator. To simulate tracer movement and behavior during grain handling and storage throughout the system, grain blended with tracers would repeatedly go through a loading truck and grain elevator bins with different capacities. Representative samples from elevator bins and a loading truck would be collected and screened with appropriate aperture-size sieves to separate the tracers. The tracers then would be scanned for readability.

The development of this technology has been supported, in part, by the USDA Na-

tional Research Initiative's Plant Bio-security Program in a project titled "Global Tracing and Recall System for US Grains: Proof-of-Concept."

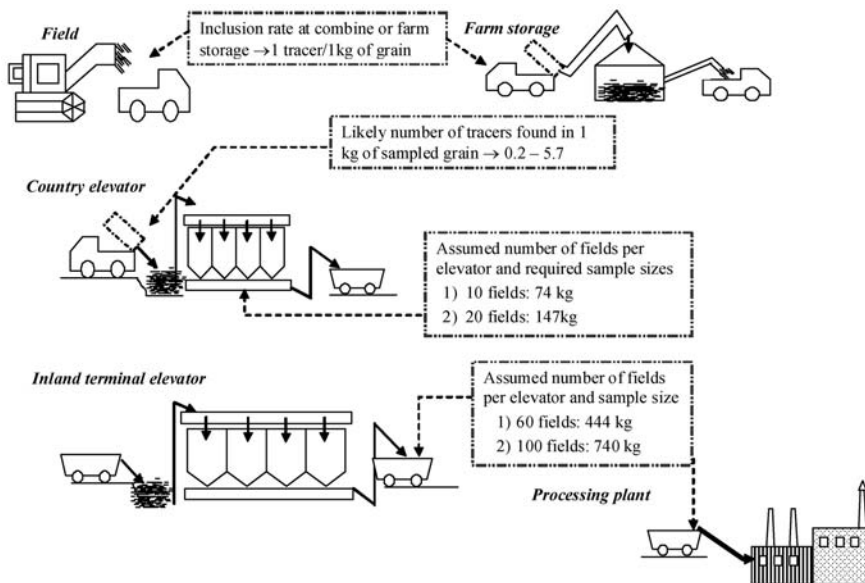
### Traceability and Aflatoxin Risk Management

In Texas, aflatoxin continues to present a food safety challenge for the grain and feed industries (Table III). In 2010, the Office of the Texas State Chemist (OTSC) identified more than 3.2 million bu of corn containing >300 ppb aflatoxin at 24 locations in the state. Aflatoxin is a group 1 carcinogen, as defined by the International Agency for Research on Cancer (15). Aflatoxin contamination is both a food safety and public health issue and at high doses can lead to serious illness, including acute liver cirrhosis and death in both humans and animals. At sublethal doses, aflatoxin exposure can increase the risk of liver cancer.

Tracing aflatoxin-contaminated corn from its point of origin through the market channels to its end-use remains a challenge. High levels of aflatoxin contamination not only pose a risk to animal and human health, the high prevalence of this group I carcinogen also suppresses the price for Texas grown corn containing aflatoxin concentrations below the 20 ppb action level prescribed by state and federal regulations.

In Texas, aflatoxin-contaminated cereals and oilseeds exceeding 20 ppb aflatoxin must be labeled as feed and channeled to the appropriate end-use. Aflatoxin contamination exceeding 300 ppb is managed through blending and disposition plans that involve regulatory oversight by OTSC. To better manage the risk of aflatoxin-contaminated corn, OTSC has initiated several risk management activities to ensure food safety and preserve market confidence.

In 2010, OTSC required that all grain elevators handling aflatoxin-contaminated



**Fig. 2.** Traceability scheme, including sample size estimates, to identify commingled grain lots (e.g., farms) in the market system.

**Table III.** Aflatoxin incidence in Texas corn by year

Aflatoxin Level	Percentage of Corn by Year				
	2006	2007	2008	2009	2010
≤20 ppb	63.6	87.0	62.9	63.2	61.6
21–300 ppb	30.2	12.7	35.0	31.4	32.5
301–500 ppb	2.1	0.2	0.7	2.6	3.9
≥500 ppb	4.1	0.1	1.4	2.8	2.0



**Fig. 3.** Two-dimensional data-matrix code printed on tracers.

grain hold a license with OTSC and report the amount of aflatoxin-contaminated grain received and its disposition. This action was implemented to ensure compliance with the Food and Drug Administration Amendment Act (FDAAA) of 2007 that requires firms to report shipment of contaminated product using an online porthole called the Reportable Food Registry. Grain containing >20 ppb aflatoxin and shipped without the appropriate label designating the amount of aflatoxin and the product end-use is adulterated and falls under the FDAAA reporting requirement. OTSC implemented the new licensing requirement to enable the grain industry to achieve full compliance with FDAAA, thereby minimizing reportable incidents.

In 2011, OTSC implemented a one-sample strategy (16) as a second step to achieve full compliance with FDAAA, fulfill pending requirements of the U.S. Food Safety Modernization Act, and minimize market risk. Each truckload of corn delivered to a commercial grain elevator may be sampled and tested for aflatoxin three or more times for grain purchasing, crop insurance, and regulatory oversight. Multiple tests yield different aflatoxin results and create uncertainty in the market. Aflatoxin is not uniformly distributed in corn, and it is measured in parts per billion. Consequently, a 30% variation between aflatoxin samples is common when a truckload of corn is tested multiple times using official procedures. When official procedures are not followed, a 60% variation between aflatoxin sample measurements has been documented by OTSC field investigators.

To minimize the negative market impact of multiple aflatoxin measurements and nonuniform adoption of official procedures, the one-sample strategy utilizes a single corn sample for purchasing, regulatory, and crop insurance decisions. This voluntary program administered by OTSC incorporates USDA-approved sampling methodology outlined in the Risk Management Agency *Loss Adjustment Manual*. Program participants must use Federal Grain Inspection Service-approved test kits validated by OTSC to measure aflatoxin up to 1,000 ppb. OTSC field investigators conduct onsite training of grain industry personnel on how to perform grain sampling and aflatoxin testing using official procedures and serve as the competent authority to ensure that official procedures are followed during harvest. The one-sample strategy includes proficiency testing to ensure accurate aflatoxin measurement by program participants and adoption of quality control techniques, including the daily

use of control samples and scale calibration coupled with unannounced inspections, record reviews, and verification of aflatoxin test results using retained samples.

The adoption of improved tracking and tracing technology for Texas grown corn will augment steps taken by feed control officials, grain producers, and commercial grain handlers to manage the risk associated with aflatoxin and help reverse the negative price impact encountered in many grain markets in the state.

### Reduction to Practice

A need exists to extend the tracing work performed by Texas A&M in collaboration with USDA ARS in Manhattan, KS, into the reduction to practice phase of technology development. Section 204 of the U.S. Food Safety Modernization Act, "Enhancing Tracking and Tracing of Food and Recordkeeping," directs the secretary to establish pilot projects involving tracing systems for high-risk products. One possible pilot project would involve the use of grain tracers in aflatoxin-contaminated grain. Such a project would involve the following steps:

- 1) Insert tracers designating the toxin level and grain origin into loads of aflatoxin-contaminated grain.
- 2) Sample outbound shipment of grain to confirm the presence of tracers and verify the aflatoxin level of the corn.
- 3) Sample grain at the point of destination, scan tracers to identify the source of grain and level of aflatoxin, and evaluate the level of aflatoxin in the contaminated grain.

The proposed project would be repeated at multiple grain elevators that segregate grain based on aflatoxin level and at grain elevators that commingle grain containing different levels of aflatoxin. Performance indices would include measuring the presence of tracers, the ability to read the code on the tracer, and aflatoxin level measurement.

Additionally, a time and cost analysis of the pilot project should be performed and compared with the market discount for Texas corn compared with corn that originates from the Midwestern United States via rail. The use of tracers would provide additional verification of recordkeeping tracing requirements contained within the Food Safety Modernization Act.

### Summary

Significant advances in tracing grain have resulted from regulatory requirements and market forces. Most tracing

systems rely on recordkeeping, which lacks precision when applied to bulk commodities such as grain in which commingling is common. Recent advances in the development of coded caplets made of food-grade material offer new possibilities for improving tracking and tracing of grain. Proposed use of grain tracers in aflatoxin-contaminated corn will augment existing practices to manage risk, provide greater market confidence, and may lead to future commercialization opportunities.

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