

RESEARCH & REGULATORY ANALYSIS

The Detoxification Mirage

What a 2026 Isotope-Tracing Study Reveals About Mycotoxin Persistence, Processing Claims and the EU–UK–US Regulatory Divide

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Abstract

A September 2026 study used carbon-13 isotope tracing and high-resolution mass spectrometry to follow aflatoxin B1 and fumonisins through pilot-scale gluten-free pasta manufacture. It found no confirmed transformation products within the method's detection scope, challenging the assumption that ordinary thermal processing reliably destroys these contaminants. The broader problem is not simply toxin persistence since apparent reductions in measured parent compounds can reflect dilution, physical redistribution, incomplete extraction, chemical transformation or analytical blind spots, none of which alone establishes reduced toxicological risk. This article proposes a process-fate verification framework separating legal compliance, molecular transformation, exposure and biological hazard. It compares the EU's contaminant limits and prohibition on deliberate chemical detoxification of food with its distinct authorised assessment pathway for feed, the diverging Great Britain framework and the United States' guidance-based approach to fumonisins. It also identifies research priorities for modified mycotoxins, emerging plant-protein ingredients and evidence-based industrial validation.

KEYWORDS *Mycotoxins; aflatoxin B1; fumonisins; isotope tracing; modified mycotoxins; process validation; food law; animal feed*

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META DESCRIPTION: *New isotope-tracing research challenges mycotoxin detoxification claims and reveals major EU, UK and US differences in food and feed risk management today.*

INTERNAL TAGS: *Mycotoxins · Analytical Chemistry · Processing Technologies · Food Contaminants · EU Law · Feed Safety · Plant Proteins · Emerging Research*

1 | The overlooked signal in September 2026

On 11 September 2026, Rollo and colleagues published an unusually instructive study in the Journal of Mass Spectrometry. They followed aflatoxin B1 (AFB1) and fumonisins B1 and B2 (FB1 and FB2) during the manufacture of **gluten-free maize pasta**, combining controlled isotope-labelled tracers with liquid chromatography–high-resolution mass spectrometry (LC-HRMS). The question was not merely whether the measured parent toxin decreased. It was whether chemical descendants could be identified when the food underwent technologically realistic manufacturing steps. [1]

The investigators prepared pasta from experimentally spiked maize flour and from naturally contaminated material. Their process included hydration, heating, shaping, drying and cooking. Under the conditions examined, no AFB1 degradation or conversion product was detected above the analytical detection limit. A very low-intensity putative fumonisin-related signal appeared, but its isotope pattern failed the authors' confirmation criteria. Consequently, the study did not establish any confirmed fumonisin transformation product either. [1]

The correct interpretation is specific and restrained: these toxins appeared comparatively stable under the tested process conditions, within the sensitivity and scope of the methods used. The study does not prove that degradation is impossible in all processing conditions. It does not establish universal stability across extrusion, alkaline cooking, roasting, fermentation or chemical treatment. It also does not show that an undetected metabolite is necessarily absent. [1]

Why is this a timely industry story? Because ingredient and food-technology suppliers increasingly present processing as a route to contaminant reduction, while food regulators require results that are matrix-specific, analytically valid and legally meaningful. The distance between a lower chromatographic peak and a safer food remains one of the most consequential blind spots in modern food-processing innovation.

2 | What the experiment actually established

The pilot process matters. The researchers hydrated maize flour, heated dough so that its interior reached approximately 75 °C, dried pasta with temperatures up to 80 °C and cooked it in boiling water for seven minutes. The spiking approach included uniformly carbon-13-labelled AFB1 and fumonisins, which can be tracked by characteristic mass shifts. Small experimental batches and limited technical replicates constrained quantitative certainty; the authors expressly emphasised qualitative identification rather than a definitive process-wide destruction rate. [1]

A useful detail is that the experimental AFB1 spike of 65 µg/kg exceeded the ordinary EU maximum level for many cereal products. That high experimental loading was an analytical design choice, not an example of a lawful commercial ingredient. The naturally contaminated flour used for a separate confirmation exercise was also a research material, not a product demonstrated suitable for market placement. [1,4]

The principal scientific contribution is therefore methodological and can be depicted as such: isotope pairing offers a way to ask whether a signal derives from the target contaminant rather than from the surrounding food matrix. It is not a blanket certificate of detoxification. Nor does a negative untargeted screen prove that every conceivable reaction product has been ruled out.

3 | The first category error: concentration is not contaminant mass

A toxin concentration is normally expressed as micrograms per kilogram of sampled food. Processing changes the denominator. Hydration adds water; drying removes it; cooking can transfer soluble constituents into discarded liquid and extrusion can alter extractability. A comparison of concentrations before and after processing is therefore not a complete mass balance.

Consider an illustrative, not experimental, example. One kilogram of raw material contains 100 µg of a toxin. If 0.5 kg of water is added and the toxin remains entirely in the dough, the concentration becomes about 66.7 µg/kg although the original 100 µg is still present. A nominal 33% concentration reduction has occurred

without any detoxification. Conversely, drying can raise concentration per kilogram while leaving the absolute toxin mass unchanged.

A defensible process study should report, where feasible, both concentration and the total amount of each analyte in each material stream. It should account for water and solids, product yield, fines, peel or bran fractions, wastewater and other losses. If toxin mass leaves the edible fraction, the process may reduce consumer exposure; whether that constitutes a legally permitted removal or a hazardous waste stream is a separate question.

The essential distinction is between reduction in measured concentration, reduction in recoverable parent molecule, reduction in total toxin-derived material and reduction in biological hazard. Those are **four different endpoints**.

4 | The second category error: parent loss is not demonstrated detoxification

A parent toxin can disappear from a targeted assay for at least five different reasons: it was physically removed; it partitioned into another phase; its extraction recovery changed; it reacted to form a modified compound; or the original analytical measurement was affected by matrix effects, sampling variability or censoring below the quantification limit.

Only some of these mechanisms reduce the hazard reaching the consumer. Physical removal can be effective when the contaminated fraction is securely segregated. Chemical transformation may or may not reduce toxicity. Binding to starch or protein can lower free-analyte recovery while retaining the potential for later release during digestion. Analytical suppression can create an apparent improvement that is not real.

The expression '**detoxification**' should therefore be reserved for evidence that a relevant toxicological hazard has been reduced, not merely for evidence that a selected analytical signal has decreased. The precise legal treatment of any intervention depends on whether it is food or feed, the substance and matrix concerned, and the intended mechanism. [4,6,8]

5 | Modified, hidden and matrix-bound mycotoxins are not synonyms

EFSA's assessment of fumonisins provides a useful taxonomy. Modified fumonisins have undergone a change in chemical structure: examples include hydrolysed, partially hydrolysed, N-carboxymethyl and N-deoxyfructosyl derivatives, as well as covalent adducts. Non-covalently matrix-associated forms, by contrast, can be described as hidden forms without necessarily being chemically modified. The distinction matters because extraction, hydrolysis and digestion can affect the analytical result differently. [2]

Some modified fumonisins have demonstrated lower potency than the parent compound in the studies assessed by EFSA, but the available data were not sufficient to incorporate the modified forms into the group tolerable daily intake for FB1–FB4. EFSA identified substantial uncertainties concerning occurrence, toxicokinetics and toxicity. It would therefore be inaccurate to claim that every modified fumonisin is equally toxic, or that every modified fumonisin is harmless. [2]

This is precisely where uncritical marketing becomes dangerous. '**No detectable parent fumonisin**' is an analytical statement. '**No relevant fumonisin hazard**' is a much broader toxicological conclusion requiring independent evidence.

6 | Aflatoxins and fumonisins are not interchangeable hazards

AFB1 is a potent genotoxic carcinogenic hazard and is regulated at very low concentrations in numerous foods. Fumonisins have a different toxicological profile, with ceramide-synthase inhibition central to their mechanism and important species-specific effects in animals. A universal 'mycotoxin detoxification' claim obscures these differences. [2,3,4]

Even within a toxin family, analytical scope varies by jurisdiction. EU maximum levels for fumonisins in relevant maize foods are generally framed as the sum of FB1 and FB2, whereas FDA's U.S. guidance uses the sum of FB1, FB2 and FB3 for the covered corn products. One result cannot automatically be presented as proof of conformity under both frameworks. [4,9]

Processing validation should begin with a target-analyte definition. Which molecules are included? Which species of fumonisin? Which modified forms? Which extraction protocol? Which analytical limits? Which intended market? Without those answers, a percentage reduction has little transferable meaning.

7 | The European food-law boundary is sharper than many innovators realise

In the European Union, Commission Regulation (EU) 2023/915 sets maximum levels for specified contaminants in specified food categories, including aflatoxins and fumonisins. The legal category, product destination, processing status and sometimes compositional conditions determine which maximum level applies. The regulation is directly applicable in Spain and other EU Member States; competent authorities enforce it through official controls. [4,5]

Article 4 is particularly important since food containing contaminants listed in Annex I **must not be deliberately detoxified by chemical treatments**. That prohibition should not be confused with a general ban on ordinary cooking, authorised food processing, lawful sorting or other physical measures. Nor should a food business infer that an unapproved chemical 'mycotoxin neutraliser' can make non-compliant material marketable simply because a laboratory reports a lower parent-toxin peak. [4]

Article 3 addresses the application of maximum levels to dried, diluted, processed and compound foods and the justification of concentration, dilution or processing factors. Article 5 sets conditions for certain products destined for sorting or other physical treatment before final marketing. These provisions make mass-balance evidence and correct categorisation matters of legal compliance, not just analytical preference. [4]

Commission Implementing Regulation (EU) 2023/2782 sets official-control sampling and analysis requirements for mycotoxins. The practical implication is that even a scientifically sophisticated in-house experiment does not replace representative sampling, suitable validation and the legally applicable compliance method. [7]

8 | The feed-law asymmetry: a controlled detoxification pathway exists

A striking distinction is that **EU feed law** contains a specific pathway for the assessment of detoxification processes. Directive 2002/32/EC governs undesirable substances in animal feed. Commission Regulation (EU) 2015/786 sets acceptability criteria for certain physical, chemical and microbiological detoxification processes applied to non-compliant feed, with scientific assessment by EFSA and competent-authority controls. [8]

For chemical processes, the regulation requires evidence of effectiveness and irreversibility, no harmful residues of the treatment substance, no hazardous contaminant reaction products and no adverse alteration of feed characteristics. Microbiological processes face corresponding requirements concerning metabolites, surviving organisms and the fate of the treatment agent. [8]

This is not permission to treat any contaminated feed with any reagent. It is a regulated, process-specific pathway with conditions and approval requirements. Equally, the existence of a feed pathway does not authorise the same process for food. The two regimes pursue related public-health goals but impose different legal conditions. [8]

For companies active in both human-food ingredients and animal nutrition, the product-use classification must therefore precede any experimental or commercial detoxification proposal.

9 | Great Britain is no longer a regulatory mirror of the EU

The United Kingdom must be analysed territorially. In Great Britain, the applicable contaminant framework is based on assimilated legislation, including the GB version of Regulation (EC) No 1831/2003 as amended domestically. Northern Ireland generally follows the relevant EU framework subject to the Windsor arrangements. A May 2026 Food Standards Scotland survey expressly compares the GB and EU/Northern Ireland positions. [10]

That survey reports that several maximum levels coincide for aflatoxins and fumonisins, while other areas differ, including deoxynivalenol, T-2/HT-2 toxins, ergot alkaloids and selected plant toxins. It would be misleading to say either that all UK limits have diverged or that the UK still applies the entire current EU Regulation 2023/915. The correct assessment is analyte-, food- and territory-specific. [10]

The commercial implication is straightforward, as an EU technical dossier cannot simply be relabelled 'UK compliant'. For GB, the relevant assimilated and domestic provisions must be checked; for Northern Ireland, the EU position must be examined separately.

10 | The United States uses a different fumonisin control instrument

The U.S. Food and Drug Administration publish guidance levels for total fumonisins in specified human corn foods and animal feeds. The 2001 guidance remains listed as FDA's current thinking and expressly states that it is non-binding guidance rather than a regulation. For example, it recommends 2 ppm total fumonisins (FB1+FB2+FB3) for certain degermed dry-milled corn products and 4 ppm for certain whole or partially degermed dry-milled products. [9]

Those figures should not be confused with the EU's legally binding, product-specific maximum levels, nor should they be applied indiscriminately to every corn-derived food. FDA's broader mycotoxin control programme also addresses aflatoxins, deoxynivalenol, ochratoxin A and other hazards. [9,11]

A cross-border certificate must therefore specify analyte definition, units, matrix, product category, applicable regulatory instrument and whether the quoted value is a mandatory maximum or agency guidance.

11 | Why the 2026 plant-protein survey widens the question

A second 2026 source makes the issue relevant beyond maize pasta. In May, Food Standards Scotland published a survey of chemical contaminants in plant-based protein products, covering products containing pea, soy and wheat proteins and using a broad analytical panel. The survey explicitly identifies gaps in commodity-specific maximum levels for some plant-protein matrices and distinguishes those gaps from the continuing general duty to market safe food. [10]

This matters for high-protein powders, textured proteins, meat analogues and nutrition formulations. New ingredient categories can concentrate raw-material constituents, change extraction efficiency and combine contaminants from several agricultural sources. A legal maximum established for a cereal commodity may not map mechanically onto a composite protein formulation; applicable rules and general food-safety duties must be assessed on the actual product. [4,10]

The strategic implication is not that plant proteins are inherently unsafe. It is that expanding protein innovation must be accompanied by proportionate contaminant characterisation rather than an assumption that novel processing automatically reduces agricultural hazards.

12 | Sampling error can dominate analytical sophistication

Mycotoxins are often distributed heterogeneously within a lot. A handful of contaminated kernels or localized fungal growth can produce high between-sample variability. An ultra-high-resolution instrument cannot rescue a non-representative sample.

The hierarchy is therefore: lot definition; sampling design; sample homogenisation; extraction validation; analytical specificity; uncertainty estimation; and decision rule. Official-control sampling under EU Regulation 2023/2782 is designed to address such representativeness issues. [7]

A pilot processing trial should document whether the same original material was partitioned into treatment and control groups, whether sample masses were sufficient, whether processing stages were replicated and whether moisture was corrected. Without those details, an apparent 20% or 40% reduction can fall within ordinary experimental variability.

13 | Four complementary analytical windows

Targeted LC–MS/MS is indispensable for routine quantification of specified regulated parent toxins, with validated recoveries and limits of quantification in the relevant matrix. It answers a bounded compliance question.

Untargeted or suspect-screening LC–HRMS can search for unexpected products, although signal detection does not by itself establish chemical identity. Stable-isotope tracer experiments can provide stronger evidence that a new signal originated from a particular toxin precursor, but interpretation still depends on isotopic purity, background contaminants, detection thresholds and confirmation criteria. [1]

Hydrolysis or digestion experiments may reveal matrix-associated forms that routine extraction underestimates. Yet hydrolysis can also create analytical artefacts or convert species during preparation; methods require independent controls. [2]

Finally, toxicological testing must address the hazard actually claimed to have been reduced. An analytical decrease is not a substitute for an appropriately designed biological endpoint. No single assay provides all four answers.

14 | Research & Innovation Opportunity: Process-Fate Verification

UNRESOLVED PROBLEM. Food-processing studies frequently report changes in parent-mycotoxin concentration without a complete account of where toxin-derived material went or whether the hazard was reduced. The September 2026 study shows both the promise and the limits of isotope-based tracking. [1]

WHY IT MATTERS. A misleading reduction claim can alter supplier acceptance, product release, consumer exposure and regulatory decisions. Conversely, scientifically valid physical removal or process optimisation may be undervalued if investigators report concentration alone.

WHAT IS ALREADY KNOWN. Stable-isotope LC–HRMS has been applied to mycotoxin fate; EFSA has reviewed modified and hidden fumonisins; EU law already requires justification of processing factors in relevant contexts. These elements are not new inventions. [1,2,4]

WHAT REMAINS UNKNOWN. For many matrices and industrial processes, validated toxin-specific fate maps and toxicological data for low-level transformation products remain incomplete. Existing public evidence does not establish a universal quantitative mass-balance method suitable for every process and contaminant.

PROPOSED HYPOTHESIS. A tiered verification protocol that combines moisture-corrected material balances, parent-toxin LC–MS/MS, isotope-assisted transformation screening, targeted analysis of known modified forms and relevant toxicological endpoints could discriminate genuine risk reduction from analytical disappearance more reliably than parent-only testing.

DEVELOPMENT PATHWAY. Select one commodity and toxin family; establish baseline sampling variance; map every material stream; perform controlled pilot runs with realistic conditions; quantify recovery and partitioning; identify plausible modified species; test whether digestion releases parent toxin; compare toxicological endpoints where scientifically justified; repeat in independent batches and laboratories.

REGULATORY CONSTRAINTS. The protocol is an R&D tool, not a substitute for legal maximum levels. In EU food, deliberate chemical detoxification of Annex I contaminants remains prohibited under Article 4 of Regulation 2023/915. In feed, the separate approval regime under Regulation 2015/786 applies when its scope is met. [4,8]

INDUSTRIAL RELEVANCE. A successful framework could improve process validation, supplier qualification, technical dossiers and the credibility of contaminant-reduction claims. It should initially be treated as a proposed evidence standard, not as a patented or uniquely novel technology.

15 | A second opportunity: the matrix-release test

One important unresolved question is whether a decrease in solvent-extractable fumonisin is accompanied by a decrease in the amount released under physiologically relevant gastrointestinal conditions. A matrix-associated contaminant can be less extractable in the laboratory yet still contribute to exposure after digestion. EFSA has recognised the distinction between modified and hidden fumonisins and the uncertainty of their toxicology. [2,3]

A focused study could compare conventional extraction, enzymatic digestion, controlled hydrolysis and targeted metabolite quantification on the same processed sample, using isotope-labelled standards and appropriate blanks. The hypothesis would be that some processes alter apparent extractability more than actual bioaccessible burden. This remains a hypothesis for any particular ingredient until experimentally tested.

For cereal and legume protein systems, the question is especially relevant because thermal aggregation, protein–starch interactions and fibre-rich matrices may alter extraction and digestive release. No generic quantitative conclusion should be inferred without matrix-specific evidence.

16 | Feed is not a lower-standard destination for contaminated food

A common commercial temptation is to redirect food material that fails a contaminant specification into animal feed. That is not automatically lawful or safe. Feed has its own undesirable-substance limits, species-specific vulnerabilities and restrictions on the marketing and use of non-compliant materials. [3,8]

EFSA's assessment of fumonisins in feed found particular concern for pigs under relevant exposure scenarios, illustrating that animal species differ substantially in susceptibility. The United Kingdom's June 2026 feed guidance recommends reviewing testing programmes and widening surveillance of lesser-known trichothecenes, while distinguishing binding legal limits for AFB1 from guidance values for several other mycotoxins. [3,12]

The feed route therefore requires independent legal and toxicological qualification. It must never be described as a generic disposal solution for a failed human-food batch.

17 | The innovation trap: “detoxifying ingredient” is a claim, not a mechanism

Commercial literature often groups adsorbents, binders, enzymes, mineral systems, organic acids, microorganisms and thermal technologies under a single detoxification label. Their mechanisms can be fundamentally different.

An adsorbent may reduce bioaccessibility without lowering the contaminant concentration in the bulk feed. A microbial process may transform a toxin but leave metabolites that require evaluation. A separation process may remove a contaminated fraction while producing hazardous by-products. A process-water treatment may control microbes yet have no demonstrated effect on pre-existing mycotoxins in an ingredient.

The relevant technical dossier should therefore define intended food/feed use; target toxin and species; mechanism; matrix; treatment conditions; measured endpoint; fate of by-products; safety of residues;

independent reproducibility; and legal route. Broad claims such as 'neutralises all mycotoxins' should be treated as scientifically suspect without extensive toxin-specific evidence.

18 | Practical implications for Industry and operators

For an ingredient and food-technology business company working across cereals, cocoa, spices, protein ingredients, pet food and processing technologies, the **central opportunity is stronger contaminant-risk intelligence**—not the indiscriminate addition of a new detoxification claim.

First, raw-material specifications should define the correct toxin panel by commodity and destination market. Maize-derived materials may require fumonisin and aflatoxin controls; other cereals, spices and cocoa have different relevant hazards and legal categories. The presence of a named contaminant in one commodity should not be extrapolated automatically to another. [4,11]

Second, a technical file should distinguish microbial-control efficacy from mycotoxin reduction. For example, evidence that a product affects insects, bacteria or process-water microbiology would not, without separate testing, establish degradation of AFB1 or fumonisins. This distinction protects both scientific credibility and regulatory position.

Third, if any company explores a genuine contaminant-removal or mitigation technology, the development should proceed in separate stages: analytical feasibility; mechanism; process validation; legal classification; industrial implementation; and only then economic analysis. No efficacy percentage or commercial claim should precede reproducible matrix-specific evidence.

Fourth, supplier dossiers can include a 'processing-fate statement' specifying whether any claimed reduction arises from sorting, separation, dilution, transformation or another mechanism, with a clear description of what was measured. This is a modest but practical differentiation opportunity.

19 | A decision framework for procurement, R&D and regulatory affairs

Before accepting a proposed **mycotoxin-mitigation technology**, a multidisciplinary review should answer seven questions.

IDENTITY — What parent toxin and modified forms are included? **ANALYTICS** — Is the method validated for the actual food or feed matrix? **MASS BALANCE** — Is the reduction in concentration or in toxin-derived mass? **MECHANISM** — Where did the material go, and are reaction products characterised? **TOXICOLOGY** — Has reduced hazard been demonstrated, rather than assumed? **LEGALITY** — Is the intended intervention permissible in the destination jurisdiction and product category? **REPRODUCIBILITY** — Do independent batches and realistic industrial conditions support the result?

A negative answer does not always invalidate exploratory R&D. It does invalidate an unqualified commercial conclusion. The decision framework is intended to prevent a promising laboratory observation from being mistaken for a regulatory-ready technology.

20 | Conclusions: from “less detectable” to “demonstrably safer”

The September 2026 isotope-tracing study is important precisely because it did not produce a dramatic detoxification claim. Under realistic pilot pasta conditions, it found no confirmed transformation products of AFB1, FB1 or FB2 within the analytical scope employed. That negative result is scientifically useful: it constrains assumptions about what routine processing achieves. [1]

The wider lesson is methodological and legal. Concentration is not mass. Parent disappearance is not necessarily transformation. Transformation is not necessarily detoxification. Compliance with one jurisdiction's analyte definition is not compliance with every market. And the EU's regulated pathway for feed detoxification must not be confused with its prohibition on deliberate chemical detoxification of food containing listed contaminants. [2,4,8,9]

For industry, the next advance will not be the most persuasive percentage-reduction claim. It will be the most defensible chain of evidence linking material fate, molecular identity, consumer or animal exposure, toxicological relevance and legal authorisation.

A food process should not be called safer merely because the toxin has become harder to measure. It should be called safer when the relevant hazard has been demonstrably and lawfully reduced.

Related Knowledge Areas

Food Safety · Processing Technologies · Functional Ingredients · Animal Nutrition · Regulatory Affairs · Biotechnology · Emerging Research. Internal links should distinguish validated contaminant control from proposed process-fate research; no product-specific mycotoxin efficacy is asserted here.

Evidence and Editorial Status

Established evidence: primary 2026 processing study; EFSA toxicological opinions; enacted EU legislation; official GB, EU and U.S. regulatory materials. **Emerging evidence:** application of isotope-tracing to realistic industrial matrices and broader 2026 plant-protein contaminant surveillance. **Expert interpretation:** need to separate concentration, molecular fate, exposure and legal status. **Hypotheses and proposals:** tiered Process-Fate Verification and matrix-release testing; neither is claimed as a novel patented invention or validated industry standard.

Scope note: Scientific and legal status assessed as of October 2026. Product-specific limits and national amendments should be checked against the latest official consolidated texts before making a compliance determination.

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