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Aquafeed Quality Assurance: Mycotoxin Control and Safe Storage Techniques for Shrimp Feed Mills

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Introduction:

Quality control is becoming a strategic need rather than an option in the shrimp feed sector. Mycotoxins are among the most pernicious of the dangers; they are imperceptible, persistent, and have the power to hinder shrimp growth, weaken the immune system, raise mortality, and undermine profitability. More than 90% of aquaculture compound-feed samples (fish + shrimp) contain at least one mycotoxin, according to recent worldwide surveys, underscoring the fact that contamination is nearly inevitable unless it is aggressively controlled (Dorninger et al., 2025). The risk is significantly greater for a shrimp-feed mill that operates in tropical or subtropical areas (like India, Southeast Asia, or Latin America), where the humidity and warmth are conducive to the growth of fungi (Lorusso et al., 2025).

Why mycotxin management needs to be a top priority for shrimp feed mills:

Molds like *Aspergillus, Fusarium*, and *Penicillium* species create secondary compounds called mycotoxins. Cereals, oilseed meals, and by-products used in feed formulation can all become contaminated by them. Reduced growth rate, decreased feed conversion efficiency, hepatopancreas damage, greater susceptibility to disease, and occasionally higher mortality are among the impacts seen in shrimp (Gonçalves et al., 2020). Due to their high feed intake and reliance on effective nutrient utilization, shrimp may experience significant production losses as a result of a "moderate" mycotoxin load. The consequences for the feed mill are clear: regulatory risk (particularly for export markets), reputational risk (farmer returns/complaints), raw-material risk, and finished-feed risk. Therefore, having a strong mycotoxin control strategy gives you a competitive edge.

Important mycotoxins of concern and their applicability to industry:

Aflatoxin B1 (AFB1), deoxynivalenol (DON), fumonisins (FB1/FB2), zearalenone (ZEA), and ochratoxin A (OTA) are some of the main mycotoxins included in shrimp-specific aquafeeds. Maize, maize-DDGS, wheat, and soybean by-products were found to contain detectable amounts of various mycotoxins in a comprehensive global study of aquafeed raw

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materials; maize and DDGS were especially susceptible to fumonisins and DON, 7.2% of fish-feed samples had AFB1 levels over EU standards (Dorninger et al.,2025).Co-contamination is frequent ; numerous samples included two or more mycotoxins, which increases risk by acting in concert or additively. This suggests that mycotoxin risk cannot be managed by mills as a stand-alone mycotoxin issue; rather, the combination is crucial from an operational perspective.

The feed-mill chain's entry point for contamination:

From the cultivation of raw materials (field fungi) to harvest and post-harvest (delayed drying, insect damage), transportation (mixed loads, broken kernels), storage (moisture ingress, insect/rodent damage, hot spots), and even feed manufacturing (moisture fluctuations, poor cleaning), contamination can be introduced at any point in time. According to integrated supply-chain assessments, significant control points include harvesting timing, grain drying, storage temperature and humidity, and handling and transit cleanliness (Calvet et al., 2015; Bryden et al., 2012). This indicates that a feed-mill manager should focus on monitoring the upstream chain rather than merely finished-feed testing because it is too late.

Preventive measures that can be implemented at the mill and ingredient levels:

Instead of depending only on post-contamination treatments, prevention at the raw material and processing stages is the first and most effective line of defense against mycotoxin contamination in aquafeeds. Feed producers should purchase ingredients from reputable suppliers who offer grains with less than 10% moisture content, little insect or mold damage, and verified quality control. For high-risk products including maize, distiller's dried grains with solubles (DDGS), wheat bran, and rice bran, vendors should also provide certificates of analysis (CoA) attesting to acceptable concentrations of important mycotoxins such aflatoxin B1 (AFB1) and deoxynivalenol (DON). Major toxins like AFB1 and DON should be detected upon arrival using strip kits or quick screening techniques like ELISA. To stop fungus from growing, all incoming grains must be dried to less than 13–14% moisture and promptly cooled. Since mold can grow in broken bins and leftover grain, silos and equipment inside the mill should be kept clean, pest-free, and well-maintained on a regular basis (Meenakshisundaram et al., 2025). HACCP (Hazard Analysis and Critical Control Point) principles should be incorporated into feed mills' quality management systems in order to improve control. This entails determining safe limits, identifying critical control points (CCPs) including ingredient moisture, temperature, and pest presence, and periodically checking and correcting compliance (Gonçalves et al., 2020).

Techniques for safely storing raw materials and completed feed :

Mills frequently fall short when it comes to safe storage. Effective design and well-run

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operations yield significant benefits. Important guidelines for the industry: Elevated floors, pallets to keep bags off the ground, and dry, well-ventilated interiors are all essential features for warehouses. It is not advisable to stack bags next to walls or in moist, condensation-prone regions. Since low temperatures greatly limit the possibility of fungal growth, the storage environment should be kept at or below 13°C and the relative humidity should be kept below 70%. Aeration and cooling systems reduce mycotoxin risks and lower internal stack temperatures, even in tropical areas. Regular monitoring (daily or weekly basis) of the temperature, moisture content, and insect activity of the stack is essential. Early warning and continuous tracking are currently supported by contemporary automated sensor systems (Bashorun et al., 2023). To avoid cross-contamination, mills should adhere to the first-in, first-out (FIFO) concept, mark all storage lots with arrival dates, and refrain from combining old and new batches (Gonçalves et al., 2020). Maintaining proper housekeeping is essential; clear away dust, broken bags, and spilled grain, and make sure that rodents and pests are controlled. To prevent contamination from spreading, trucks and containers need to be washed clean. To maintain feed quality and safety during long-term or export storage, moisture-resistant or hermetic packing with desiccants is advised.

Detection and routine testing: making it operational:

The operationalization of detection and routine testing in feed mills is essential for ensuring feed safety and quality. Rapid screening tests for key mycotoxins like AFB1 and DON should be performed on every new lot of high-risk raw materials. Any "flagged" results should be verified by complete LC-MS/MS **(Liquid Chromatography–Tandem Mass Spectrometry**) laboratory analysis. Since storage conditions have a significant impact on mycotoxin levels, composite sampling should be carried out monthly or at least quarterly for finished feed or stored batches to test for multiple mycotoxins, including AFB1, DON, FB1/FB2, ZEA, and OTA. This is especially important when ingredient sources or climatic conditions change (Amin et al., 2023). Since mycotoxins frequently occur in localized "hot-spots" within lots, proper sampling is essential to preventing mistakes from tiny or non-representative samples. Standard protocols, such as those described in the United States Department of Agriculture (USDA) Mycotoxin Handbook, should be followed (Meenakshisundaram et al., 2025). According to regulatory agencies like the FDA, testing should be conducted in validated labs using multi-mycotoxin LC-MS/MS techniques (Dorninger et al., 2025). Trend analysis, the identification of high-risk suppliers, and the optimization of storage procedures are made possible by accurate documentation of lot details, test results, storage location, duration, and usage. In order to identify high-risk lots based on

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historical data, modern feed mills are progressively using predictive analytics and machine-learning techniques, which reinforces regular monitoring and preventive control measures (Gonçalves et al., 2020).

Strategies for mitigation what actually works:

Practical mitigation techniques will be required in real-world mills, even though preventive and storage control are crucial. Options beneficial to the industry include: Activated carbons, yeast-derived compounds, and clays (bentonite, zeolite) are examples of mycotoxin binders and adsorbents. These lessen the mycotoxin's bioavailability in the animal stomach but do not completely eradicate it. For instance, adding propionic acid (0.1–0.5%) or clays can limit mold growth and mitigate risk, according to studies on completed feed preservation (Čolović et al., 2019). Dietary antioxidants (selenium, vitamins A, C, and E) and glutathione-based detoxification substrates (glutamate, cysteine, and glycine) have been shown in recent studies to improve animals' ability to withstand low-level mycotoxin exposure (Lorusso et al., 2025). Aquaculture feed mills that produce higher-value species (like shrimp) can benefit from the approach, even when a large portion of the effort is in terrestrial animals. New approaches to detoxification and biocontrol: microbial detoxifiers, enzymes, and storage treatments for volatile bioactive compounds are being developed (Bashorun et al., 2023; Abraham et al., 2022). The majority of mills currently handle them as future-proofing instead of main control. Formulation buffer: Mills may decide to increase binder inclusion, decrease target inclusion of high-risk ingredients, or incorporate "insurance" feed formulations for high-value clients during high-risk seasons or ingredient batches. Although it costs more, this could guard against production and reputational losses.

Additional strategies that are attractive to the sector :

- Shrimp-feed mills can implement value-added tactics to differentiate themselves in a crowded market: Offer “mycotoxin-safe guarantee” packages to customers: e.g., periodical testing reports, guarantee of <10 µg/kg AFB1, etc. This makes quality feed standout.

  Employ traceability by labelling each batch with the lot numbers of the source ingredients, test results, and storage history. Feed mills with proven quality assurance receive greater payments from many shrimp farms.
- Invest in “smart warehouse” analytics: employing IoT (Internet of Things) sensors for temperature/humidity stacks, cloud analytics to visualize risk heat-maps, automated alarms when stack temperature climbs above threshold. These solutions offer real-time actionable insight and are becoming more and more affordable (Gonçalves et al., 2020).

- Seasonal risk management: increase the frequency of inspections, reduce storage times, and apply more desiccants or aeration during the monsoon or hot seasons. Mills can lower insurance-type expenses (e.g., fewer rejections, fewer farmer complaints) by recognizing seasonal risk.
- Training and culture: provide mycotoxin awareness training to warehouse employees, unloading teams, and maintenance crews to empower them and explain the role that filthy vehicles, broken bags, and inadequate maintenance play. Human mistake can be decreased by fostering a culture that believes that ***"clean storage = safer feed = happier farmers."***

Detailed explanation of the mill's operational SOP:

A shrimp-feed mill's operational Standard Operating Procedure (SOP) offers a systematic, step-by-step framework to ensure feed safety, quality, and traceability. Each lot of raw ingredients should be physically inspected upon receipt, with supplier and batch details recorded, moisture content measured, and rapid screening for high-risk mycotoxins like AFB1 and DON, if applicable; ingredients should then be stored appropriately, dry, cool, and in designated silos or pallets, with storage dates and locations clearly documented; warehouse management should adhere to the FIFO (First In, First Out) principle, with weekly temperature and humidity readings recorded; and composite testing of ingredient blends should be carried out prior to production, especially when ingredient sources change seasonally or when substitutions occur. The **final feed** should be labeled with the production date, stacked properly on pallets, and not stored beyond the recommended period (typically 10 weeks, depending on climatic conditions), with routine environmental monitoring in place. **Periodic testing** includes monthly composite samples of completed feed and archiving trace samples from every batch. If testing identifies mycotoxin levels exceeding thresholds, appropriate **mitigation measures** should be implemented, including use of binders, formulation adjustments, quarantining affected batches, and timely recording and notification of the issue. Comprehensive **documentation and traceability** require recording all testing, storage conditions, and corrective actions, in addition to trend analysis and a quarterly assessment of supplier performance. Customer assistance is also essential, offering farm-level advising help, test certifications, and directions for storing feed. Key performance indicators (KPIs) include pre-dispatch screening batch pass rates, supplier lot rejection rates, feed conversion improvements, and farmer complaints should be routinely examined for ongoing improvement in order to maximize feed safety and operational efficiency.

Final remarks for the sector:

Mills that view mycotoxin control as just another expense rather than a strategic investment run the risk of losing market share in the present shrimp-feed industry. Shrimp growth, health, survival, and overall farm profitability are all strongly impacted by feed quality, which also has an impact on the mill's reputation, client retention, and export standard compliance. Feed mills may cut waste, improve product reliability, and reach premium markets by putting in place a thorough mycotoxin management system that covers ingredient sourcing, storage design and monitoring, routine testing, formulation modifications, and proactive customer communication. The long-term advantages of investing in sensors, employee training, and traceability systems are significant and include enhanced farm performance, increased consumer trust, and a decrease in complaints, all of which strengthen the mill's position in the market and profitability.

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