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Aflatoxin B_1 in Cattle Feed and Aflatoxin M_1 in Milk in Northern Nigeria: Occurrence, Feed-to-Milk Carry-Over, Health Implications and Research Gaps

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ABSTRACT

Aflatoxins are toxic fungal metabolites of major food- and feed-safety concern. In dairy production, aflatoxin B_1 (AFB_1) ingested in contaminated feed is metabolised to aflatoxin M_1 (AFM_1), which is excreted in milk. This narrative review synthesises evidence on AFB_1 in cattle feed and AFM_1 in milk, with emphasis on Northern Nigeria and Katsina State. Literature published principally between 2007 and 2025 was identified through PubMed, Scopus, Google Scholar and African Journals Online and was critically interpreted with attention to analytical method, matrix, regulatory benchmark and study design. Northern Nigerian evidence demonstrates substantial contamination: Omeiza et al. (2021) detected AFB_1 in 89% of 180 cattle-feed samples and AFM_1 in 94% of 180 cow-milk samples, while a 2025 Katsina study by Olanrewaju and Okunola reported AFB_1 and AFM_1 in all sampled feed and milk, respectively. These studies establish that paired feed–milk investigation has already been undertaken; the remaining needs are larger and more representative Katsina datasets, repeated seasonal sampling, clearer animal- or herd-level pairing, harmonised analytical quality assurance and stronger characterisation of feed storage and management. Differences among ELISA, TLC and chromatographic methods, together with inconsistent reporting units in parts of the literature, limit direct comparison. Future work should integrate validated HPLC-FLD or LC-MS/MS methods, seasonal sampling, feed-management data and exposure assessment to support practical prevention and regulatory surveillance.

Keywords: Aflatoxin B_1, Aflatoxin M_1, Cattle feed, Milk, Carry-over, Dairy safety, Northern Nigeria, Katsina State

INTRODUCTION

Mycotoxin contamination remains an important challenge to food and feed safety because it affects crop quality, livestock productivity, human health and the economic value of agricultural commodities. Mycotoxins are naturally occurring secondary metabolites produced by several filamentous fungi, particularly species belonging to the genera Aspergillus, Fusarium and Penicillium. Among the different classes of mycotoxins, aflatoxins have received considerable attention because of their widespread occurrence, persistence in food and feed chains, and well-established toxicological significance (Kumar et al., 2017; Mahato et al., 2019; Nazhand et al., 2020). Although an estimate that approximately 25% of food crops worldwide are affected by mycotoxins has been widely cited, a critical reassessment by Eskola et al. (2020) showed that the proportion containing detectable mycotoxins may be considerably higher, depending on the commodity, toxin, geographical region and analytical threshold used.

Aflatoxins are produced mainly by toxigenic strains of Aspergillus flavus and Aspergillus parasiticus. The major naturally occurring forms are aflatoxins B_1 (AFB_1), B_2 (AFB_2), G_1 (AFG_1) and G_2 (AFG_2), of which AFB_1 is generally regarded as the most toxic and biologically significant (Kumar et al., 2017; Benkerroum, 2020). AFB_1 is of particular public-health concern because chronic exposure has been associated with hepatotoxicity, genotoxicity, immunotoxicity and hepatocellular carcinoma. The International Agency for Research on Cancer classifies naturally occurring aflatoxins, including AFB_1, as carcinogenic to humans, while AFM_1 has been classified as possibly carcinogenic to humans (IARC, 1993; Ostry et al., 2017). These toxicological properties make prevention of contamination preferable to reliance on corrective measures after contaminated commodities have entered the food chain.

The dairy production system provides an important pathway through which contamination of animal feed can subsequently become a human food-safety problem. When lactating cattle consume feed containing AFB_1, part of the ingested toxin is absorbed from the gastrointestinal tract and metabolised in the liver. Hydroxylation mediated by hepatic cytochrome P450 enzymes produces AFM_1, which enters the circulation and is subsequently excreted in milk. Thus, contamination of cattle feed with AFB_1 can indirectly expose milk consumers to AFM_1. The relationship between animal feeding and the safety of foods of animal origin has long been recognised as an important component of food-chain safety.

The transfer of AFB_1 from contaminated feed to AFM_1 in milk is commonly described as carry-over. However, the process is not governed by feed AFB_1 concentration alone. Zentai et al. (2023) showed that carry-over varies substantially with milk yield, amount of AFB_1 ingested, lactation stage, animal health, feed composition and individual animal variation. Consequently, measurement of AFM_1 in milk alone cannot reliably establish the level of AFB_1 contamination in the feed from which it originated. This limitation is particularly important when attempting to identify sources of contamination or quantify the relationship between feed quality and milk safety.

AFM_1 can appear in milk relatively soon after animals consume contaminated feed, while concentrations generally decline after the contaminated feed is withdrawn. This relatively rapid transfer makes the quality of feed offered to lactating cattle a direct determinant of milk-safety

management. Maize, groundnut products, cottonseed products, palm-kernel products and compound feeds are among materials susceptible to contamination by aflatoxigenic Aspergillus species, particularly under warm and humid conditions. These commodities or their by-products are relevant to livestock feeding systems in many tropical regions and therefore provide a potential route through which aflatoxins may enter dairy production.

Environmental and management conditions play important roles in determining contamination. Aflatoxin development can occur both before and after harvest. Drought stress, elevated temperature, insect damage and plant stress can increase susceptibility of crops to fungal invasion, whereas insufficient drying, high moisture content, poor ventilation and prolonged storage favour fungal proliferation and toxin production after harvest (Mahato et al., 2019; Nazhand et al., 2020). The interaction between climatic conditions and post-harvest handling is especially relevant in tropical and subtropical agricultural systems, where temperatures suitable for Aspergillus growth frequently coincide with limitations in controlled drying and storage facilities.

These conditions have particular relevance to dairy and pastoral production systems in Northern Nigeria. Livestock feeding may depend on combinations of crop residues, cereal grains, agro-industrial by-products, locally compounded feeds and other seasonally available materials. During periods of feed scarcity, stored materials may constitute a greater proportion of the animal diet. Prolonged storage under inadequately controlled moisture and temperature conditions can increase the probability of fungal growth and subsequent toxin formation. Nevertheless, the magnitude of this problem should not simply be assumed from climatic conditions; locally generated analytical data are required to establish the actual occurrence of AFB_1 in feeds used by dairy cattle and the resulting AFM_1 burden in milk.

Evidence already available from Nigeria demonstrates the importance of this problem. Akinyemi et al. (2021) examined 144 samples comprising camel milk, cow milk, goat milk and kindirmo collected across four states in Northern Nigeria. AFM_1 was detected in 74% of camel milk, 99% of cow milk and 100% of both goat milk and kindirmo samples. A substantial proportion exceeded the European regulatory limit, demonstrating that exposure through milk and traditional dairy products warrants attention. The study is especially relevant because its sampling area included Katsina State; however, it did not concurrently determine AFB_1 in the feeds consumed by the animals. Thus, although milk contamination was demonstrated, the relationship between individual feed contamination and the resulting AFM_1 concentration could not be quantified.

Similarly, Mukhtar et al. (2022) reported AFM_1 contamination in raw cow milk collected from several locations within Zaria metropolis. The study further demonstrated the occurrence of AFM_1 in dairy products within the north-western Nigerian production environment. However, as with much of the available literature, the feed supplied to the sampled animals was not concurrently analysed for AFB_1. In addition, some inconsistencies between reported concentration units and regulatory comparisons in that publication require caution when making quantitative comparisons. The limitation illustrates a broader methodological problem in the Nigerian literature: studies commonly investigate either contaminated feeds or contaminated milk rather than following the complete AFB_1-contaminated feed → animal exposure → AFM_1 in milk pathway.

Regulation is another important aspect of aflatoxin control. Maximum permitted concentrations differ according to toxin, commodity and jurisdiction. This distinction is critical because regulatory limits established for AFB_1 in animal feed cannot be directly compared with those established for AFM_1 in milk. Differences among international regulatory limits also mean that a sample considered compliant under one regulatory framework may not necessarily meet another. Consequently, studies should clearly identify the toxin measured, analytical units, sample matrix and regulatory benchmark applied rather than referring generally to a single 'permissible aflatoxin limit'.

The public-health importance of AFM_1 contamination is amplified by the nutritional importance and regular consumption of milk. Milk and dairy products provide proteins, minerals and other nutrients and may form an important component of the diets of children and other population groups. Preventing AFM_1 contamination therefore requires intervention earlier in the production chain, particularly through appropriate feed sourcing, drying, storage, monitoring and withdrawal of highly contaminated feed. Because AFM_1 formation originates from AFB_1 exposure in the animal, an integrated feed-and-milk surveillance strategy provides more useful information than monitoring milk alone.

Despite growing evidence of aflatoxin contamination in Nigeria, important knowledge gaps remain. Omeiza et al. (2021) concurrently analysed 180 cattle-feed samples and 180 cow-milk samples in Northern Nigeria and found AFB_1 and AFM_1 in 89% and 94% of samples, respectively. More recently, Olanrewaju and Okunola (2025) reported a Katsina State investigation in which feed and milk were sampled from selected cattle farms and analysed by HPLC. These studies demonstrate that concurrent feed–milk investigation has been undertaken both regionally and in Katsina State. The remaining gap is therefore not the absence of paired evidence, but the limited number, scale and temporal coverage of such studies and the need for stronger animal- or herd-level linkage, seasonal replication, analytical quality assurance and detailed feed-management data.

For Katsina State, the 2025 study provides important local evidence but should be regarded as an initial dataset rather than a complete characterisation of the State. Its relatively small sample base and cross-sectional design leave important questions about seasonal variation, representativeness across production systems, feed-source differences, storage conditions and the quantitative relationship between AFB_1 intake and AFM_1 excretion. Larger multi-season studies across additional farms and production systems are therefore needed to test the consistency and generalisability of the observed contamination pattern.

Accordingly, this review critically synthesises available literature on the occurrence of AFB_1 in cattle feed and AFM_1 in milk, their toxicological and public-health implications, factors controlling feed-to-milk carry-over, analytical approaches, prevention strategies and regulatory considerations, with particular emphasis on Northern Nigeria and Katsina State. It also distinguishes what has already been demonstrated from what remains uncertain, thereby defining priorities for larger, seasonal and methodologically harmonised dairy-safety studies.

Review Methodology

Because the review was designed as a narrative synthesis rather than a systematic review, no PRISMA-style pooled selection count or meta-analysis is reported. Comparisons therefore emphasise study design, sample matrix, analytical

technique, reporting units, quality-control information and regulatory benchmark. The review was refined with reference to the SANRA domains for narrative reviews, particularly justification of importance, statement of aims, description of the literature search, appropriate referencing, scientific reasoning and presentation of relevant endpoint data (Baethge et al., 2019).

Priority was given to peer-reviewed studies reporting measured AFB_1 or AFM_1 concentrations, analytical methods, dairy-feed or milk matrices, feed-to-milk carry-over, health effects, regulatory comparisons or production conditions relevant to tropical dairy systems. General food-commodity studies were retained only when they provided contextual evidence of aflatoxin pressure in the Nigerian food chain; they were not treated as direct evidence of contamination in cattle feed. Studies with unclear units or internally inconsistent regulatory comparisons were retained only with explicit caution in interpretation.

This article is a narrative review. Literature published principally between 2007 and 2025 was identified through PubMed, Scopus, Google Scholar and African Journals Online (AJOL). Searches were last checked on 24 September 2026 to verify key publications and bibliographic details. Search terms were used singly and in combination and included "aflatoxin", "AFB_1", "AFM_1", "cattle feed", "dairy feed", "raw milk", "dairy", "Nigeria", "Northern Nigeria", "Katsina", "carry-over", "ELISA", "HPLC" and "LC-MS/MS". Reference lists of relevant papers were also examined for additional studies.

Aflatoxins and the AFB_1–AFM_1 Pathway

The principal naturally occurring aflatoxins are AFB_1, AFB_2, AFG_1 and AFG_2. AFB_1 is the most toxicologically important because of its potent hepatotoxic, genotoxic and carcinogenic properties (Kumar et al., 2017; Benkerroum, 2020). When lactating cattle ingest AFB_1, hepatic metabolism produces the hydroxylated metabolite AFM_1, which enters the circulation and is excreted in milk. The appearance of AFM_1 in milk therefore reflects prior dietary exposure, but the concentration is modified by feed intake, milk yield, stage of lactation, animal health, timing of sampling and individual metabolic variation (Zentai et al., 2023).

Carry-over is commonly expressed as the percentage of ingested AFB_1 that is recovered as AFM_1 in milk. Because carry-over is variable, AFM_1 concentration cannot be inferred reliably from a single feed concentration without information on intake and animal productivity. This is why paired feed–milk sampling and farm-level production data are important for causal interpretation (Figure 1).

AFB_1 contamination of feed/feed ingredients
↓
Cattle ingestion and gastrointestinal absorption
↓
Hepatic biotransformation of AFB_1 to AFM_1
↓
AFM_1 transfer into milk → human dietary exposure

Figure 1: Conceptual Pathway Linking AFB_1-Contaminated Feed with AFM_1 in Milk and Human Exposure

Key modifiers: AFB_1 dose, feed intake, feed composition, storage conditions, milk yield, lactation stage, animal health, sampling interval and season

Occurrence of AFB_1 in Cattle Feeds and Feed Ingredients

The risk of AFB_1 in dairy production is strongly linked to feed ingredients susceptible to fungal invasion, particularly cereals, oilseed products and compounded concentrates. Warm temperatures, drought stress before harvest, delayed drying, elevated moisture during storage, insect damage and prolonged storage can promote contamination (Mahato et al., 2019; Nazhand et al., 2020). These conditions are relevant to many smallholder and pastoral systems in Northern Nigeria, where feed availability and storage practices vary seasonally.

Direct Nigerian dairy-feed evidence is provided by Omeiza et al. (2021), who concurrently collected 180 feed samples and 180 cow-milk samples from commercial, institutional and traditional dairy settings in Northern Nigeria. Using immunoaffinity clean-up and HPLC, AFB_1 was detected in 160 of 180 feed samples (89%). Among the AFB_1-positive samples, 35 (21.9%) contained concentrations at or above 20 µg/kg. Concentrate- and grain-based feeds showed a greater proportion of highly contaminated samples than pasture-based feed, and traditional Fulani herd groups had more feed samples at critical concentrations than institutional farms. These findings make the study particularly relevant to the present review because it directly evaluates cattle feed rather than using unrelated food commodities as proxies.

Evidence from other African dairy systems supports the importance of concentrate feeds. A recent Tanzanian investigation reported widespread aflatoxin contamination of cattle concentrate feed and estimated potential transfer into milk. Such studies strengthen the biological plausibility of the feed-to-milk pathway under tropical conditions, but differences in feed formulation, climate and husbandry mean that their quantitative results should not be transferred directly to Katsina State.

Studies of Nigerian foods such as chilli pepper and egusi remain useful as indicators of broader aflatoxin pressure in the food chain (Ezekiel et al., 2019; Obani et al., 2019). However, unless these materials are documented as livestock-feed ingredients, their contamination levels should not be interpreted as measurements of dairy-cattle exposure.

Katsina-specific evidence is now available from Olanrewaju and Okunola (2025), who collected feed and milk from selected cattle farms in Katsina State and quantified AFB_1 and AFM_1 using HPLC. The study reported AFB_1 in all feed samples, with concentrations above the benchmark applied by the authors. This local evidence is important because it moves the literature beyond extrapolation from Zaria and broader Northern Nigerian datasets. However, its small cross-sectional sample base means that State-wide prevalence, seasonal variability and production-system differences remain uncertain.

Occurrence of AFM_1 in Milk and Dairy Products

Atanda et al. (2007) demonstrated AFM_1 contamination in milk and selected dairy products in Ogun State using two-dimensional thin-layer chromatography. Although

historically important, the study did not concurrently analyse cattle feed and therefore could not establish the feed source of AFM_1.

Akinyemi et al. (2021) analysed 144 samples comprising camel milk, cow milk, goat milk and kindirmo from four Northern Nigerian states using ELISA. AFM_1 was detected in 74% of camel milk, 99% of cow milk, and 100% of goat milk and kindirmo samples. The published data report mean concentrations of approximately 38.1 ng/L in camel milk, 68.4 ng/L in cow milk, 112 ng/L in goat milk and 145 ng/L in kindirmo, with substantial proportions exceeding the European limit. The study included Katsina State samples, but individual milk samples were not linked to corresponding feed samples.

Omeiza et al. (2021) provides stronger feed–milk linkage at the production-system level. AFM_1 was detected in 170 of 180 cow-milk samples (94%), and 46 of the positive samples (27.1%) were at or above 0.5 µg/L. Traditional dairy herd groups showed comparatively greater contamination than institutional systems. The concurrent collection of feed and milk is a major strength, although the study does not remove the need for Katsina-specific work because local feed sources, storage, seasonality and management may differ.

Mukhtar et al. (2022) also reported AFM_1 in raw cow milk from five locations in Zaria metropolis. However, the numerical values, units and regulatory comparisons in the publication are difficult to reconcile consistently. The study is therefore useful evidence of occurrence, but its quantitative values should be interpreted cautiously unless the original analytical records and units are confirmed.

In the same Katsina investigation, Olanrewaju and Okunola (2025) reported AFM_1 in all milk samples analysed by HPLC. The reported concentrations were high relative to international milk limits used in the study. Because the sample set was limited and cross-sectional, the results are best interpreted as evidence of occurrence and a signal for broader surveillance rather than as a definitive estimate of contamination prevalence across Katsina State.

Comparative Summary of Key Studies

Some selected comparative studies are showed in Table 1.

Table 1: Selected Comparative Summary of Key Studies

Study	Location	Matrix / n	Method	AFB_1 finding	AFM_1 finding	Regulatory comparison	Main limitation
Atanda et al. (2007)	Ogun State	Milk/dairy products	2-D TLC	Not analysed	AFM_1 detected	Compared with contemporary milk limits	No paired feed analysis
Akinyemi et al. (2021)	Northern Nigeria incl. Katsina	144 milk/product samples	ELISA	Not analysed	74–100% detection across matrices	EU limit used	No corresponding feed samples
Omeiza et al. (2021)	Northern Nigeria	180 feed + 180 cow milk	IAC-HPLC	89% positive; 21.9% of positives ≥20 µg/kg	94% positive; 27.1% of positives ≥0.5 µg/L	Multiple critical thresholds discussed	Broad regional design; not Katsina-specific
Mukhtar et al. (2022)	Zaria	Raw cow milk	Chromatographic analysis as reported	Not analysed	AFM_1 detected at all locations	EU limit cited	Published units/limit interpretation need verification

Factors Influencing AFB_1-to-AFM_1 Carry-Over

Carry-over is influenced by both exposure and animal-level factors. Higher AFB_1 intake generally increases the amount available for metabolism, while milk yield can alter the concentration through dilution. Early lactation, individual metabolic differences, animal health and the interval between exposure and milk sampling can also affect AFM_1 concentration (Zentai et al., 2023). Consequently, a cross-sectional milk result should not be interpreted as a direct numerical surrogate for feed AFB_1.

For Katsina State, future paired studies should record feed type and quantity, estimated dry-matter intake, milk yield, lactation stage, storage duration, moisture conditions and sampling interval. Repeated sampling across wet and dry seasons would allow the influence of seasonal feed scarcity and storage to be tested rather than assumed.

Health and Production Implications

Animal Health and Dairy Productivity

Aflatoxin exposure in livestock can impair liver function, suppress immunity, reduce feed intake, growth and reproductive performance, and decrease milk production. Clinical severity depends on dose, duration, age, nutritional status and co-exposure to other mycotoxins (Council for Agricultural Science and Technology, 2003; Unnevehr & Grace, 2020). Even where exposure does not produce overt disease, reduced productivity and rejected feed or milk can create economic losses for dairy households.

Human Health and Consumer Risk

AFB_1 is a well-established human carcinogen, with chronic exposure strongly associated with hepatocellular carcinoma, particularly in populations with concurrent hepatitis B infection. AFM_1 is less potent than AFB_1 but remains a food-safety concern because milk is widely consumed and can be important in the diets of children. Prevention therefore requires control of AFB_1 before it enters the dairy animal as well as monitoring AFM_1 in milk (IARC, 1993; Ostry et al., 2017; Marchese et al., 2018).

Analytical Methods for AFB_1 and AFM_1 Determination

Analytical method strongly affects comparability among studies. TLC is relatively inexpensive and historically important but generally offers lower sensitivity and less precise quantification than modern chromatographic

approaches. ELISA is rapid, comparatively affordable and suitable for screening large numbers of samples, but matrix effects and antibody cross-reactivity can influence results. HPLC with fluorescence detection, especially after immunoaffinity clean-up and appropriate derivatisation, provides stronger quantitative specificity. LC-MS/MS offers high selectivity and the possibility of multi-mycotoxin determination, although equipment and operating costs may limit routine use in some laboratories.

Future studies should report sample preparation, extraction and clean-up procedures, calibration range, limit of detection, limit of quantification, recovery, precision and quality-control materials. Screening-positive samples obtained by ELISA should ideally be confirmed in a representative subset by a validated chromatographic method. The HPLC approach used by Omeiza et al. (2021) illustrates the value of analysing feed and milk with a consistent analytical framework.

Regulatory Standards and Food-Safety Interpretation

Regulatory limits differ by toxin, matrix and jurisdiction and should not be used interchangeably. Under European Union rules, the maximum AFB_1 content is 0.02 mg/kg (20 µg/kg) for feed materials and 0.005 mg/kg (5 µg/kg) for compound feed intended for dairy cattle and calves. In the United States, FDA guidance applies a 20 ppb action level for aflatoxins in feed ingredients intended for dairy animals. For AFM_1 in milk, the U.S. action level is 0.5 ppb, whereas the European maximum is substantially lower. These differences explain why the same analytical result may be classified differently under different regulatory systems.

A review should therefore state clearly whether a reported threshold applies to AFB_1 alone or total aflatoxins, whether it concerns feed or milk, and which jurisdiction established it. This is particularly important when comparing Nigerian studies that have used different benchmarks (See Table 2).

Table 2: Selected Regulatory Benchmarks Relevant to AFB_1 in Feed and AFM_1 in Milk

Analyte	Matrix	Jurisdiction	Benchmark	Interpretive note
AFB_1	Feed materials	European Union	20 µg/kg	General feed-material maximum; lower limits apply to some complete/compound feeds.
AFB_1	Compound feed for dairy cattle	European Union	5 µg/kg	Dairy-specific compound-feed maximum.
Aflatoxins	Feed for dairy animals	United States FDA	20 ppb	Action level for feed ingredients intended for dairy animals.
AFM_1	Milk	European Union	0.05 µg/kg (50 ng/kg)	Maximum level for milk; matrix-based comparison.
AFM_1	Milk	United States FDA	0.5 ppb	Action level for milk.

Prevention and Control Strategies

Control is most effective when contamination is addressed before contaminated feed reaches lactating cattle. At farm level, priority measures include timely harvesting, adequate drying, protection of feed from moisture ingress, clean and ventilated storage, stock rotation, segregation of visibly deteriorated material and routine screening of high-risk feed ingredients. These measures should be adapted to local feed types and storage systems rather than applied as generic recommendations.

Where screening indicates elevated AFB_1, contaminated feed should not be diluted informally into dairy rations as a substitute for regulatory compliance. Feed-management decisions should follow applicable veterinary and feed-safety guidance. Validated mycotoxin-control products may have a role in some production systems, but their effectiveness is product- and toxin-specific and should not replace prevention, monitoring or good storage practice.

At the milk-safety level, surveillance should combine feed testing with milk testing, particularly during periods when stored feed is heavily relied upon. Farmer education, extension support, traceable feed sourcing and laboratory capacity for confirmatory analysis are important complementary measures. Intervention studies in Katsina should measure contamination before and after practical improvements in drying, storage and feed selection so that recommendations are supported by local evidence.

Limitations of the Review

This review is narrative rather than systematic and therefore does not claim exhaustive retrieval of every publication or provide a pooled meta-analysis. The available studies also differ substantially in sampling design, sample size, matrix, analytical method, reporting units and regulatory benchmark, which limits direct quantitative comparison.

Geographical coverage is uneven, and some conclusions for Northern Nigeria rely on relatively small or cross-sectional datasets. In addition, inconsistencies in units or regulatory interpretation occur in parts of the published literature. These limitations were handled by qualifying uncertain values rather than silently converting or reconciling them. The review should therefore be interpreted as a critical synthesis of the available evidence and research priorities, not as a formal prevalence meta-analysis.

Research Gaps and Future Priorities in Northern Nigeria and Katsina State

i. Independent replication and intervention studies: the 2025 Katsina findings should be tested in larger independent datasets, followed by studies evaluating whether improved drying, storage, feed screening and farmer education measurably reduce contamination.

ii. Exposure and risk characterisation: locally relevant milk-consumption data and clearly justified

toxicological reference points are needed for transparent dietary exposure and risk estimates.

iii. Analytical harmonisation: studies should report extraction and clean-up procedures, calibration, LOD, LOQ, recovery, precision, matrix effects and quality-control materials; screening methods should be confirmed chromatographically where feasible.

iv. Feed-source characterisation: commercial concentrates, grains, crop residues, oilseed cakes and locally formulated rations should be identified and analysed separately, together with moisture content and storage conditions.

v. Strength of pairing: future work should link feed and milk at defined herd or animal level and record the interval between exposure and milk sampling, rather than relying only on contemporaneous farm-level sampling.

vi. Seasonality: repeated wet- and dry-season sampling is required to determine whether feed scarcity, storage duration and climatic conditions produce consistent seasonal changes in AFB_1 and AFM_1.

vii. Evidence breadth and representativeness: paired feed–milk studies now exist in Northern Nigeria and Katsina State, but the number of studies remains small relative to the diversity of production systems. Larger multi-farm datasets are needed before State-wide prevalence can be estimated confidently.

CONCLUSION

Available evidence establishes that AFB_1 contamination of dairy feed and AFM_1 contamination of milk are important food-chain concerns in Northern Nigeria. Concurrent feed–milk investigations have already been conducted regionally (Omeiza et al., 2021) and in Katsina State (Olanrewaju & Okunola, 2025); therefore, the remaining research need is not a complete absence of paired evidence. Rather, current evidence is limited by small numbers of studies, heterogeneous methods, cross-sectional designs and insufficient seasonal and production-system coverage. Future research should emphasise larger representative sampling, stronger herd- or animal-level pairing, wet- and dry-season follow-up, validated analytical quality assurance, detailed feed-storage data and transparent exposure assessment. Prevention should focus on feed quality, drying and storage, targeted screening, farmer education and coordinated feed-and-milk surveillance. These priorities would provide a stronger basis for practical dairy-safety interventions in Katsina State and comparable agroecological settings.

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