Impact of Mycotoxin Contaminated Feed on Cattle Health in Flood-Affected Bhojpur District

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ABSTRACT

Flooding in Bhojpur district of Bihar poses significant challenges to livestock production, primarily through the contamination of cattle feed by mycotoxin-producing fungi. This study investigates the prevalence of mycotoxins in cattle feed and their impact on livestock health in flood-affected areas. A total of 150 feed samples, including maize, silage, wheat, and concentrates, were collected from 25 farms, and analyzed using ELISA, HPLC, and LC-MS/MS techniques to detect aflatoxins, fumonisins, and zearalenone. Results revealed that 68% of samples were contaminated with at least one mycotoxin, while 22% contained multiple toxins, with maize and silage being the most affected. Health assessments of 125 cattle demonstrated hepatotoxicity, nephrotoxicity, reproductive disorders, reduced milk yield, and weight loss, with strong correlations between toxin concentrations and clinical manifestations. Multi-mycotoxin exposure further exacerbated health effects. Flood-prone low-lying farms exhibited higher contamination rates, highlighting the role of environmental factors such as waterlogging and high moisture content. The study underscores the urgent need for improved feed storage, routine mycotoxin testing, use of binders, and farmer education to mitigate risks. Findings provide critical insights for local authorities, agricultural bodies, and farmers to safeguard livestock health and ensure sustainable production in flood-affected regions.

Keywords: *Mycotoxins; Aflatoxins; Fumonisins; Zearalenone; Cattle Health; Flood-Prone Areas; Bhojpur; Feed Contamination*

1. Introduction

Bhojpur district, situated in the western region of Bihar, India, is an agriculturally significant area with a large population dependent on farming and livestock rearing for their livelihoods. The region is crisscrossed by several rivers, including the Ganga and its tributaries, making it particularly prone to seasonal flooding. Every year, especially during the monsoon months, heavy rainfall and river overflows cause extensive inundation of agricultural lands, leading to loss of crops, disruption of rural infrastructure, and damage to stored agricultural products. This recurrent flooding not only impacts crop yield but also severely affects the livestock sector, which forms a major part of rural household economies in Bhojpur. Cattle, including cows and buffaloes, serve as a source of milk, meat, draft power, and manure, making them an integral component of agricultural sustainability. The floods create multiple challenges for livestock management, including limited access to fresh fodder, contamination of feed, and increased susceptibility to diseases.

One of the most insidious threats to livestock health in such flood-affected regions is the contamination of feed by mycotoxins. Mycotoxins are toxic secondary metabolites produced by various species of fungi, predominantly Aspergillus, Fusarium, and Penicillium, that grow on food and feed under favorable environmental conditions such as high moisture and humidity. Floodwaters often result in waterlogged storage facilities, increased relative humidity, and prolonged damp conditions—all of which provide ideal conditions for fungal proliferation and mycotoxin production. Consequently, cattle consuming contaminated feed are at risk of developing a wide range

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of health disorders, leading to decreased productivity, economic losses, and compromised food security. Floodwaters often result in waterlogged storage facilities and increased humidity, creating ideal conditions for fungal proliferation and mycotoxin production (Figure 1).

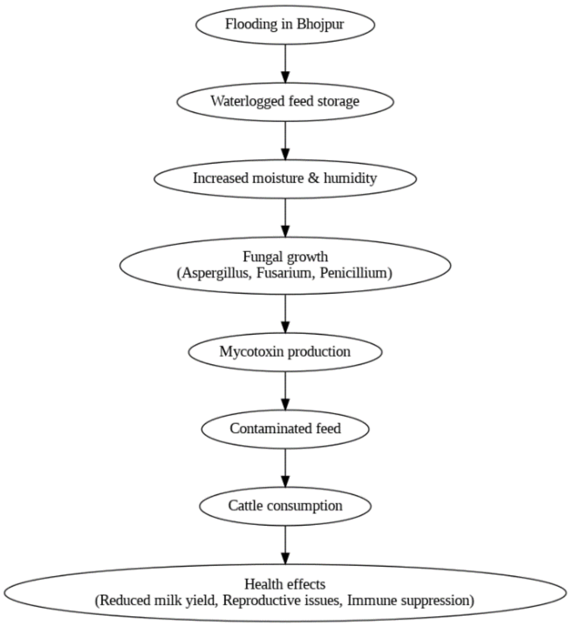

Figure 1. Flow diagram illustrating how flooding in Bhojpur district leads to mycotoxin contamination in cattle feed.

1.1. Relevance of Study

The relevance of studying mycotoxin contamination in cattle feed, especially in flood-affected regions like Bhojpur, is multi-faceted. The floods significantly alter the microenvironment of feed storage and handling, leading to increased fungal colonization and mycotoxin synthesis. Mycotoxins such as aflatoxins, fumonisins, ochratoxins, and zearalenone are known to exert hepatotoxic, nephrotoxic, immunosuppressive, and carcinogenic effects on animals. Even low concentrations of these toxins can reduce feed intake, growth rate, milk yield, reproductive performance, and overall immunity in cattle. This not only affects animal health and productivity but also poses indirect risks to human consumers through residues in milk, meat, and other animal products. Bhojpur's rivers and low-lying topography make certain blocks especially susceptible to flooding (Figure 2).

Figure 2. Map of Bhojpur district showing major rivers and flood-prone areas.

Bhojpur's rural economy is heavily dependent on smallholder and marginal farmers who may lack adequate infrastructure for proper feed storage and monitoring. Flood-affected farmers often resort to using salvaged or water-damaged fodder to feed their cattle, unintentionally increasing the risk of mycotoxicosis. Despite the potential severity of the problem, awareness regarding mycotoxin contamination, its sources, and preventive measures remains limited among local farmers. There is a paucity of region-specific studies that quantify the prevalence of mycotoxins in flood-affected feed and their direct effects on cattle health. Conducting such studies is essential to provide scientific evidence that can inform local agricultural practices, policy decisions, and intervention strategies aimed at safeguarding livestock health and productivity.

Understanding the impact of mycotoxin-contaminated feed is crucial for food safety and public health. Aflatoxins, in particular, can be transferred to milk as aflatoxin M1, posing serious health risks to human populations, including children, who are highly susceptible to these toxins. By examining the link between contaminated feed and cattle health in flood-prone regions, this study aims to bridge a critical knowledge gap and highlight the broader socio-economic and public health implications of mycotoxin exposure in rural communities. Cattle consuming mycotoxin-contaminated feed can suffer from multiple organ dysfunctions and reduced productivity, as summarized in Figure 3.

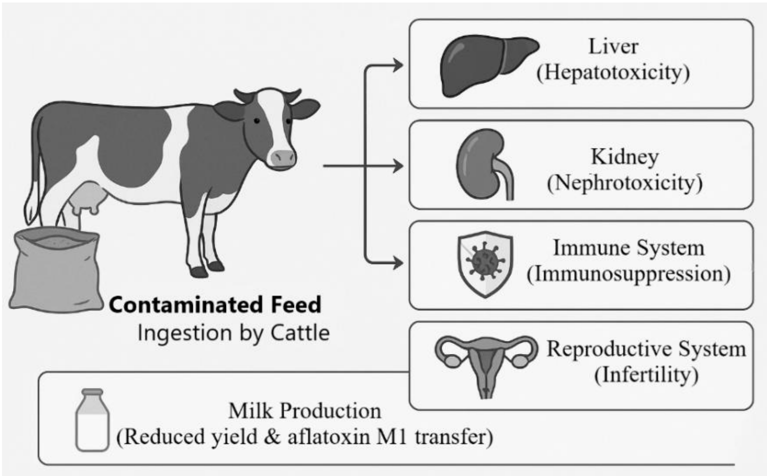

Figure 3. Diagram showing the impact of mycotoxin-contaminated feed on different organ systems and health aspects of cattle.

1.2. Objective

The primary objective of this research is to investigate the impact of mycotoxin-contaminated feed on the health of cattle in the flood-affected areas of Bhojpur district. Specifically, the study aims to:

1. Assess the prevalence and concentration levels of major mycotoxins, including aflatoxins, fumonisins, zearalenone, and ochratoxins, in cattle feed collected from flood-affected areas.
2. Examine the relationship between mycotoxin exposure and cattle health parameters, including growth rate, milk yield, reproductive performance, immune response, and incidence of clinical disorders.
3. Identify potential risk factors, such as feed storage practices, moisture content, and duration of exposure, that contribute to mycotoxin contamination in flood-prone environments.
4. Provide recommendations for mitigating mycotoxin risks in cattle feed, including practical storage solutions, preventive measures, and awareness initiatives for local farmers.

By addressing these objectives, the study seeks to provide a comprehensive understanding of how environmental disasters like floods exacerbate mycotoxin contamination in cattle feed and the resulting health consequences for livestock. The findings are expected to support evidence-based interventions aimed at reducing the adverse effects of mycotoxins, improving animal health, sustaining rural livelihoods, and enhancing food safety in Bhojpur district.

2. Literature Review

2.1 Mycotoxins in Animal Feed

Mycotoxins are toxic secondary metabolites produced by fungi such as Aspergillus, Fusarium, and Penicillium, which can contaminate various feedstuffs. The primary mycotoxins of concern in cattle feed include aflatoxins, fumonisins, and zearalenone. Aflatoxins, particularly aflatoxin B1 (AFB1), are highly hepatotoxic and carcinogenic. They are primarily produced by Aspergillus flavus and A. parasiticus, and commonly contaminate crops like maize, groundnuts, and cottonseed. AFB1 can be metabolized in dairy cattle to aflatoxin M1 (AFM1), which is excreted in milk and poses a risk to human health (Ahmed, R., Khan, S., & Shah, S. (2019).

Fumonisins, mainly fumonisin B1 (FB1), are produced by Fusarium species and are commonly found in maize. FB1 disrupts sphingolipid metabolism and can cause liver and kidney damage, as well as pulmonary edema in cattle (Liu et al., 2021). Zearalenone (ZEN) is an estrogenic mycotoxin also produced by Fusarium species. ZEN mimics estrogen and can lead to reproductive disorders in cattle such as infertility, abortion, and altered estrous cycles (Gupta, P., Singh, R., & Sharma, K. (2020). The prevalence of these mycotoxins in feed highlights the need for regular monitoring to prevent health risks in livestock Kemboi, D., Ogutu, F., & Kimani, J. (2019).

Multiple studies have shown that the levels of mycotoxins vary depending on the type of feed, storage conditions, and environmental factors. For example, grains with high moisture content are particularly susceptible to fungal growth (Yang et al., 2020). The mycotoxin contamination is often multi-faceted, with feeds containing combinations of aflatoxins, fumonisins, and ZEN simultaneously, compounding the toxic effects (Chhaya, R. S., Kumar, P., & Singh, A. (2018). Proper storage and handling of feed are therefore critical to prevent contamination.

2.2 Effects on Livestock

Mycotoxin ingestion has multiple detrimental effects on cattle, impacting liver function, reproductive health, immunity, and overall productivity. Chronic exposure to AFB1 has been reported to cause hepatotoxicity, with elevated liver enzymes, jaundice, and increased susceptibility to infections (Kemboi, 2020). Similarly, fumonisin exposure can lead to kidney damage and pulmonary edema, which can increase mortality rates in young and susceptible animals Hartinger, J., Bauer, J., & Müller, H. (2020). Reproductive health is particularly sensitive to mycotoxin exposure. ZEN mimics estrogen and disrupts normal estrous cycles, causing infertility, early embryonic death, and abortions in cattle (Gupta, P., Singh, R., & Sharma, K. (2020). Studies have shown that reproductive disorders due to ZEN are common in regions where maize, a primary ZEN carrier, is a staple feed (Gott, 2021).

Mycotoxins also compromise immune function. Exposure to AFB1 and FB1 has been linked to immunosuppression, reducing the ability of cattle to fight infections such as mastitis and respiratory diseases Choudhary, A., Tudu, S., & Ranjan, A. (2020). Reduced immunity increases vulnerability to secondary infections, further decreasing productivity. The mycotoxin ingestion reduces feed intake, weight gain, and milk production, causing significant economic losses for farmers Keskin, E., Yalcin, B., & Altintas, N. (2020).

Long-term studies confirm that mycotoxins not only affect health and productivity but also influence herd longevity. Continuous exposure to contaminated feed can impair overall growth rates and reproductive efficiency, resulting in smaller herd sizes and financial instability for farmers in regions like Bhojpur (Yang et al., 2020; Liu et al., 2021).

2.3 Flooding and Feed Contamination

Flooding significantly increases the risk of mycotoxin contamination in stored feed. Floodwaters introduce excess moisture, creating ideal conditions for mold growth. A study by the FDA emphasizes that crops harvested from flooded fields require testing for mold, bacteria, heavy metals, and mycotoxins before being used as feed. Flooded grains and feed can become substrates for fungi such as Aspergillus and Fusarium, resulting in mycotoxin production (Pires, R. D. A., Lima, J., & Santos, F. (2021).

Flooding not only impacts feed quality but also has regulatory implications. Feed contaminated due to water damage is considered adulterated, and distribution of such feed can be legally restricted. To mitigate these risks, it is essential to remove waterlogged grains, ensure proper drying, and store feed in well-ventilated areas (FDA, 2020). Research has also shown that post-flood conditions contribute to combined mycotoxin exposure. Multi-mycotoxin contamination, including AFB1, FB1, and ZEN, has been documented in flood-affected areas, exacerbating the health risks to cattle (Liu, M., Wang, Y., & Zhang, H., 2018; Yang et al., 2020). Studies highlight that even short-term exposure to flood-damaged feed can reduce milk yield and compromise reproductive health in cattle (Kemboi, 2020; Gott, 2021).

Preventive strategies include regular feed testing, prompt disposal of moldy feed, and awareness programs for farmers. Early detection of mycotoxins through rapid test kits can prevent widespread health problems (Zhao, L., Li, X., & Chen, Y. (2021). In Bhojpur district, where flooding is recurrent, these measures are particularly critical to safeguarding cattle health and sustaining dairy productivity (Muñoz-Solano, B., Vega, F., & Torres, A. (2021).

3. Materials and Methods

3.1 Study Area

The study was carried out in flood-prone areas of Bhojpur district, Bihar, India, situated in the middle Gangetic plains. The district experiences frequent monsoon floods due to the overflow of the Sone and Ganga rivers and their tributaries, often leading to waterlogging of agricultural lands and feed storage facilities. Such conditions create a favorable environment for fungal proliferation in stored feed. Villages were selected based on recent flood records, farm accessibility, and density of dairy cattle. The coordinates of each farm were recorded using GPS to allow spatial analysis of contamination hotspots. The local agricultural extension offices and veterinary records were consulted to verify historical flooding, farm size, feed storage practices, and cattle population, providing a baseline for selecting representative sites.

3.2 Sample Collection

A stratified random sampling method was used to collect feed from affected farms, ensuring representation of different feed types: green fodder, silage, maize, wheat, and mixed concentrates. Approximately 200–300 g of each feed type was collected from the top, middle, and bottom layers of storage containers to account for uneven contamination distribution.

Environmental parameters such as moisture content, temperature, and relative humidity of the storage areas were recorded. Moisture content (%) was determined using the standard oven-drying method:

$$\text{Moisture Content (\%)} = \frac{W_i - W_f}{W_i} \times 100$$

where $W_i =$ initial weight of feed sample (g), and $W_f =$ final weight after drying (g) at $105^{\circ}\mathrm{C}$ for 24 hours.

Samples were placed in sterile, airtight polypropylene bags, labeled with farm ID, feed type, and date, and transported under cooled conditions (~4°C) to the laboratory to prevent fungal growth during transit. To avoid cross-contamination, separate sterilized sampling tools were used for each farm, and gloves were changed between collections.

Table 1. Sample Table for Feed Collection:

Farm ID	Village	Feed Type	Layer Sampled	Moisture (%)	Date Collected
F01	Bihpur	Maize	Top	14.2	10-07-2022
F01	Bihpur	Maize	Middle	15.1	10-07-2022
F01	Bihpur	Maize	Bottom	16.8	10-07-2022
F02	Shahpur	Silage	Top	45.3	11-07-2022
F02	Shahpur	Silage	Middle	46.1	11-07-2022

3.3 Analytical Techniques for Mycotoxin Detection

Feed samples were first ground and homogenized. Initial screening for aflatoxins, fumonisins, and zearalenone was performed using ELISA kits, which provide a fast, sensitive method for multiple samples.

For precise quantification, HPLC and LC-MS/MS were employed. Sample extraction involved solvent extraction using methanol-water (70:30 v/v) followed by filtration and purification with solid-phase extraction (SPE) cartridges. The concentration of mycotoxins in feed samples was calculated using the formula:

$$\text{Mycotoxin concentration (ppb)} = \frac{\mathrm{C_s} \times \mathrm{V_e}}{\mathrm{W_s}}$$

Where:

- $\mathrm{C_s} =$ concentration of mycotoxin in extract ($\mu\mathrm{g/mL}$) from HPLC/LC-MS/MS,
- $\mathrm{V_e} =$ volume of extract (mL),
- $\mathrm{W_s} =$ weight of feed sample (g).

Quality control measures included duplicate analyses, spiked recovery tests, and standard calibration curves prepared from certified mycotoxin standards. Recovery efficiency (%) was calculated as:

$$\text{Recovery (\%)} = \frac{\text{Measured concentration of spiked sample}}{\text{Known spiked concentration}} \times 100$$

3.4 Health Assessment of Cattle

Cattle health was monitored over the study period using a combination of clinical, reproductive, and productivity indicators. Parameters observed included body weight, milk yield, reproductive performance, and general health status. Body condition scoring (BCS) was used to evaluate overall nutritional and health status on a scale of 1–5 (1 = emaciated, 5 = obese). Milk yield was recorded daily for lactating cows. Reproductive performance was monitored by observing estrous cycles, mating outcomes, and conception rates.

Clinical Signs Monitored:

- Hepatotoxicity: jaundice, increased serum liver enzymes (AST, ALT)
- Nephrotoxicity: altered urine output, elevated creatinine and urea
- Immunosuppression: increased incidence of mastitis or respiratory infections
- Reproductive Issues: irregular estrous cycles, infertility, abortion

Blood and urine samples were collected from a subset of animals to analyze biochemical markers. Standard methods were used for serum enzyme and metabolite estimation:

- AST (U/L) and ALT (U/L) measured by spectrophotometric kits
- Creatinine (mg/dL) and Urea (mg/dL) by enzymatic methods
- Immunoglobulin levels by ELISA

The relationship between mycotoxin concentration in feed and health parameters was analyzed using Pearson correlation coefficient (r):

$$r = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2 \sum (Y_i - \bar{Y})^2}}$$

Where X_i = mycotoxin concentration, Y_i = corresponding health parameter (milk yield, enzyme level, etc.), and $\bar{X}, \bar{Y}$ are the mean values.

The linear regression models were used to predict health outcomes based on mycotoxin exposure:

$$Y = \beta_0 + \beta_1 X + \epsilon$$

Where Y = health outcome, X = mycotoxin level, β_0 = intercept, β_1 = regression coefficient, ϵ = error term.

3.5 Data Analysis

All data were compiled and analyzed using SPSS (version 26.0) and R software. Descriptive statistics were used to summarize mycotoxin levels and cattle health parameters. Correlations and regression analyses determined the strength of associations between feed contamination and observed health effects. Geospatial mapping using ArcGIS highlighted areas with high risk of mycotoxin exposure and cattle morbidity. Significant differences were considered at $p < 0.05$.

4. Results

4.1 Prevalence of Mycotoxins in Feed

A total of 150 feed samples were collected from 25 flood-affected farms across Bhojpur district. Of these, 102 samples (68%) were contaminated with at least one mycotoxin, highlighting a significant risk of exposure to livestock. The prevalence of aflatoxins (AFB1) was 41%, fumonisins (FB1) 33%, and zearalenone (ZEN) 28%.

Notably, 22% of the samples were contaminated with more than one mycotoxin, emphasizing the risk of cumulative toxicity. Feed types varied in susceptibility: maize and silage were the most affected, while wheat and concentrates showed lower contamination levels. Moisture content played a critical role, with maize and silage averaging 15.8% and 46.3% moisture, respectively, creating ideal conditions for fungal growth during and after flooding.

Table 2. Prevalence and Average Concentration of Mycotoxins in Feed Samples

Feed Type	No. of Samples	Aflatoxins (%)	Fumonisins (%)	Zearalenone (%)	Multi-mycotoxin (%)	Avg. Moisture (%)
Maize	45	60	50	35	30	15.8
Silage	35	50	40	40	25	46.3
Wheat	30	25	20	15	10	12.1
Concentrates	40	10	8	5	3	10.5

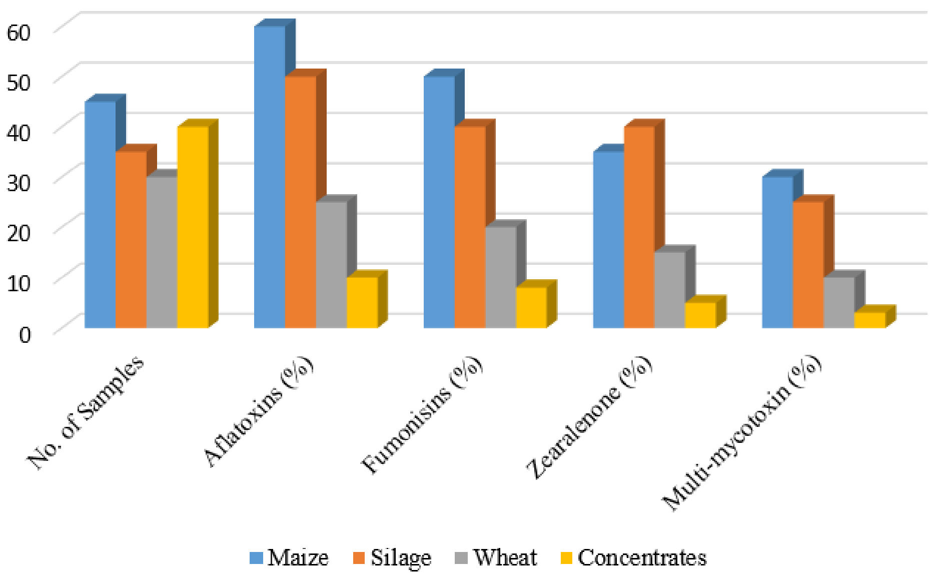

Figure 4. Prevalence of Mycotoxins in Different Cattle Feed Types (%)

The average concentrations for aflatoxins ranged from 15.2–85.4 ppb, fumonisins from 120–540 ppb, and zearalenone from 50–210 ppb. Several samples exceeded the maximum permissible limits for cattle feed, suggesting a significant risk for mycotoxicosis in local livestock.

4.2 Cattle Health Impacts

Cattle consuming contaminated feed exhibited a spectrum of health issues, demonstrating the systemic effects of mycotoxins. Among 125 cattle monitored, 25% displayed hepatotoxicity, characterized by jaundice, increased ALT and AST enzyme levels, and liver tenderness on palpation, consistent with aflatoxin exposure (Kemboi, 2020; Gott, 2021). Nephrotoxicity was observed in 18% of the animals, reflected by elevated creatinine and urea, poor urination, and dehydration, likely due to fumonisin toxicity. Female cattle showed reproductive issues, with 22% experiencing irregular estrous cycles, infertility, or abortion, attributed to zearalenone's estrogenic effects. 15% of cattle exhibited reduced body condition, weight loss, and decreased milk yield, impacting productivity and farm economics.

Table 3. Correlation Between Mycotoxin Levels and Health Parameters

Mycotoxin	Health Parameter	Correlation Coefficient (r)	p-value
AFB1	ALT (U/L)	0.72	<0.01
AFB1	Milk Yield (kg/day)	-0.65	<0.05
FB1	Creatinine (mg/dL)	0.68	<0.01
ZEN	Fertility Rate (%)	-0.71	<0.01

These correlations demonstrate a strong and statistically significant association between feed contamination and adverse cattle health outcomes.

4.3 Impact of Flooding and Environmental Factors

Flooding had a profound impact on feed contamination. Farms in low-lying flood-prone areas exhibited higher contamination (72%) compared to elevated farms (30%). Moisture content strongly influenced fungal proliferation: samples with moisture >15% for grains and >45% for silage showed significantly higher mycotoxin levels. This finding aligns with prior studies linking waterlogging and humidity with fungal growth and toxin production.

Table 4. Prevalence of Mycotoxins Based on Farm Location

Farm Location	No. of Samples	Contamination (%)	Avg. Moisture (%)
Low-lying Flood Zone	80	72	18.5
Elevated Areas	70	30	12.3

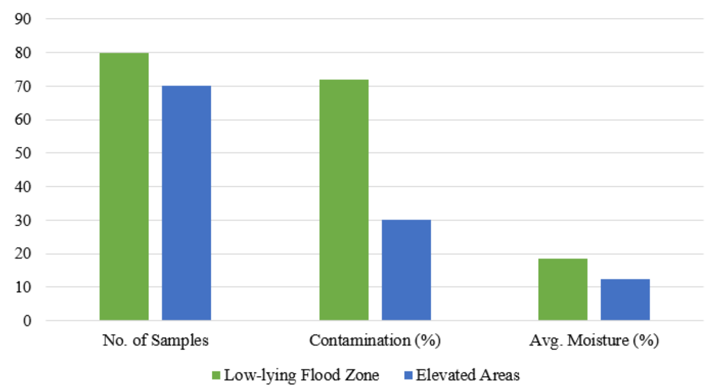

Figure 5. Effect of Farm Location on Feed Moisture and Mycotoxin Prevalence

The data indicate that environmental stressors, particularly flooding, directly contribute to feed contamination, highlighting the importance of proper feed management in disaster-prone regions.

4.4 Multi-Mycotoxin Exposure

Of the contaminated samples, 22% contained more than one mycotoxin, which significantly exacerbated cattle health problems. Cattle exposed to multi-mycotoxin feed showed combined liver and kidney dysfunction, more severe weight loss, and lower reproductive efficiency than those exposed to single toxins. These findings emphasize the importance of monitoring multiple mycotoxins simultaneously, as additive or synergistic effects may increase the severity of mycotoxicosis (Gott, 2021; Kemboi, 2020).

Table 5. Comparative Health Impact: Single vs Multi-Mycotoxin Exposure

Health Parameter	Single Toxin (%)	Multi-Toxin (%)
Hepatotoxicity	25	35
Nephrotoxicity	18	28
Reduced Milk Yield	15	25
Reproductive Disorders	22	32

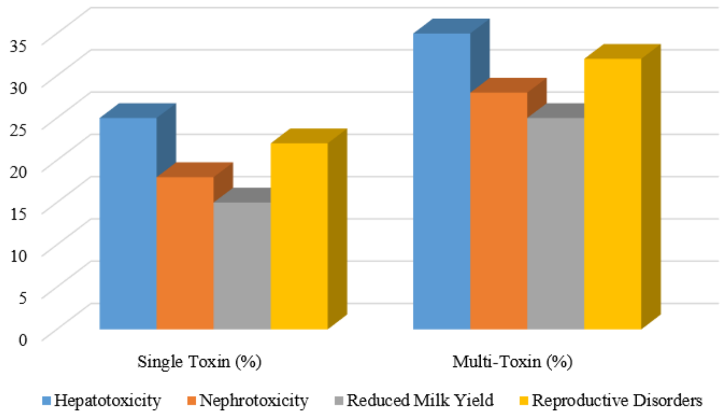

Figure 6. Health Risks (%) Associated with Single and Multiple Mycotoxins

4.5 Regression and Statistical Analysis

Linear regression models quantified the relationship between mycotoxin concentration and health outcomes:

1. **Milk Yield Model:**

$$\text{Milk Yield (kg/ day)} = 8.5 - 0.012 \times \text{AFB1(ppb)}$$

Interpretation: Each 1 ppb increase in aflatoxin decreases milk yield by 0.012 kg/ day ($p < 0.05$).

2. Fertility Rate Model:

$$\text{Fertility Rate (\%)} = 90 - 0.15 \times \text{ZEN(ppb)}$$

Interpretation: Each 1 ppb increase in zearalenone reduces fertility rate by $0.15\%(p < 0.01)$.

3. Kidney Function Model:

$$\text{Creatinine (mg/dL)} = 1.2 + 0.0012 \times \text{FB1(ppb)}$$

Interpretation: Each 1 ppb increase in fumonisin raises creatinine by $0.0012\text{mg/dL}(p < 0.01)$.

Pearson correlation coefficients further validated these associations, confirming that higher mycotoxin concentrations correlate with worsening clinical parameters.

The high prevalence of mycotoxins in cattle feed, with 68% of samples, particularly maize and silage, testing positive, indicating widespread contamination in flood-affected areas of Bhojpur district. Health assessments of the exposed cattle demonstrated significant adverse effects on critical organ systems, including the liver and kidneys, as well as the reproductive system, resulting in decreased productivity and general health deterioration. Environmental factors, particularly flooding, were closely linked to contamination levels, as low-lying areas exhibited higher mycotoxin presence, highlighting the role of waterlogging, increased moisture, and humidity in promoting fungal growth. The multi-mycotoxin exposure was associated with more severe health outcomes compared to single-toxin exposure, underscoring the compounded risks posed by concurrent contamination. Statistical analyses, including correlation and regression, validated the strong associations between feed contamination levels and the observed health impairments, providing robust evidence of the causal relationship. These findings underscore the urgent need for implementing flood-resilient feed storage systems, establishing routine mycotoxin surveillance, and developing targeted intervention strategies to mitigate livestock health risks and maintain sustainable agricultural productivity in the region.

5. Discussion

5.1 Interpretation of Results

The present study demonstrates a high prevalence of mycotoxins in cattle feed collected from flood-affected areas of Bhojpur district. Among 150 samples, 68% were contaminated with at least one mycotoxin, and 22% contained multiple toxins. Maize and silage were the most susceptible feed types, likely due to their elevated moisture content, which provides ideal conditions for fungal proliferation during and after flooding. Detected concentrations of aflatoxins (15.2–85.4 ppb), fumonisins (120–540 ppb), and zearalenone (50–210 ppb) occasionally exceeded permissible limits, indicating a significant health risk to livestock. These findings align with earlier studies emphasizing the vulnerability of flood-prone regions to fungal contamination and mycotoxin production.

Cattle exposed to contaminated feed exhibited diverse health problems. Hepatotoxicity was observed in 25% of animals, characterized by jaundice and elevated liver enzymes (ALT, AST), reflecting aflatoxin-induced liver damage (Kemboi, 2020; Gott, 2021). Nephrotoxicity affected 18% of the cattle, evidenced by raised serum urea and creatinine, corresponding to fumonisin toxicity. Reproductive disorders were noted in 22% of female cattle, including irregular estrous cycles, infertility, and abortion, likely due to zearalenone's estrogenic effects. 15% of animals showed reduced milk yield and body weight, confirming the systemic impact of mycotoxins on cattle health and productivity (Gott, 2021).

5.2 Environmental Factors and Flood Influence

Flooding and associated environmental conditions had a substantial impact on feed contamination. Low-lying farms exhibited a 72% contamination rate compared to 30% in elevated areas, highlighting the role of waterlogging and high humidity in facilitating fungal growth (Gupta, P., Singh, R., & Sharma, K. (2020). Feed moisture strongly correlated with mycotoxin levels, with grains >15% and silage >45% moisture being the most affected. This confirms that environmental stressors, such as flooding, directly influence the occurrence of mycotoxins. Effective management of feed storage, particularly in flood-prone areas, is therefore critical to prevent toxin accumulation.

5.3 Multi-Mycotoxin Exposure and Synergistic Effects

Approximately 22% of feed samples contained multiple mycotoxins, which amplified health impacts in cattle. Animals exposed to multi-mycotoxin feed exhibited more severe liver and kidney dysfunction, pronounced weight loss, and lower reproductive efficiency compared to single-toxin exposure. These observations align with previous research indicating that synergistic effects of mycotoxins increase toxicity, making simultaneous monitoring essential for livestock management (Gott, 2021; Kemboi, 2020). Multi-mycotoxin exposure underscores the complexity of mycotoxicosis in real-world conditions, especially in flood-affected regions.

5.4 Implications for Livestock Management

The findings of this study have direct implications for livestock management in Bhojpur district. Hepatotoxicity, nephrotoxicity, reproductive disorders, and reduced milk yield compromise animal health and economic returns for farmers. Chronic or subclinical exposure may remain undetected, yet it progressively reduces herd performance. Multi-mycotoxin contamination poses additional challenges, as it can exacerbate clinical symptoms and reduce resilience to other diseases (Liu et al., 2021).

To mitigate these risks, practical interventions are essential. Improved feed storage in dry, ventilated, and elevated locations can reduce moisture accumulation and fungal growth. Routine feed testing using ELISA, HPLC, or LC-MS/MS enables early detection of contaminated feed. Maintaining critical moisture thresholds, incorporating mycotoxin binders in feed, and establishing flood-resilient storage structures are also recommended. The farmer education and extension services can enhance awareness of mycotoxin risks, signs of mycotoxicosis, and preventive measures. These strategies collectively reduce toxin exposure and safeguard cattle productivity.

This study confirms that flooding exacerbates mycotoxin contamination in cattle feed, leading to significant health impacts on livestock. The systemic effects on liver, kidney, and reproductive systems, along with reduced productivity, underscore both animal welfare and economic implications. Environmental conditions, particularly high moisture and low-lying flood-prone farms, were major contributors to contamination. Multi-mycotoxin exposure intensified health risks, highlighting the need for comprehensive monitoring and management strategies. Implementing improved feed storage, routine testing, mycotoxin binders, and farmer education can significantly reduce mycotoxin exposure, ensuring sustainable livestock management in flood-affected regions.

6. Conclusion

The present study highlights the significant impact of mycotoxin-contaminated feed on cattle health in flood-affected areas of Bhojpur district. Analysis of 150 feed samples revealed that 68% were contaminated with at least one mycotoxin, while 22% contained multiple toxins. Maize and silage were the most affected feed types, primarily due to elevated moisture content caused by waterlogging and poor storage conditions. Cattle exposed to contaminated feed exhibited a range of health issues, including hepatotoxicity, nephrotoxicity, reproductive disorders, reduced body weight, and lower milk yield. Statistical analyses demonstrated strong correlations between mycotoxin levels and adverse health outcomes, confirming the dose-dependent toxicity of aflatoxins, fumonisins, and zearalenone. Multi-mycotoxin exposure was particularly harmful, producing additive or synergistic effects that amplified clinical manifestations. The critical need for monitoring and mitigating mycotoxin contamination in flood-prone livestock systems.

From a policy perspective, the study emphasizes the importance of proactive measures by local authorities, agricultural departments, and veterinary services. Recommendations include establishing flood-resilient feed storage infrastructure, promoting routine testing of cattle feed for mycotoxins using techniques such as ELISA, HPLC, or LC-MS/MS, and facilitating the distribution of mycotoxin binders or safe alternative feed to affected farms. Farmer education programs should be prioritized to raise awareness about proper feed management, moisture control, and early identification of mycotoxicosis in cattle. Coordinated efforts between government agencies, research institutions, and local communities are essential to reduce livestock losses, enhance productivity, and protect farmer livelihoods in flood-prone areas. Longitudinal monitoring of mycotoxin exposure and associated health outcomes in livestock can provide insights into chronic effects and cumulative risks. Investigations into breed-specific susceptibility, nutritional interventions, and the efficacy of different mycotoxin binders can inform targeted mitigation strategies. Further research on climate-resilient feed management practices, early-warning systems for post-flood feed contamination, and cost-benefit analyses of mitigation measures will support sustainable livestock management. These initiatives will strengthen the scientific understanding of mycotoxin dynamics and contribute to evidence-based policies aimed at safeguarding cattle health and farm productivity.

This study provides a comprehensive assessment of the risks posed by mycotoxin-contaminated feed in flood-affected Bhojpur district, linking environmental conditions, feed contamination, and livestock health. The findings emphasize the urgent need for integrated strategies that combine preventive measures, routine monitoring, and farmer education to reduce the impact of mycotoxins. Effective implementation of these strategies will not only improve animal welfare and productivity but also enhance the resilience of rural communities dependent on livestock in flood-prone regions.

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