Research Application Summary

The risk of feed and milk contamination by mycotoxins on smallholder dairy farmers in Kenya

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Abstract

Mycotoxins are toxic secondary metabolites produced by fungi in warm environments. Due to the warm climate highly favourable for growth of moulds, the threat of mycotoxin poisoning (livestock and human) is real and of major concern in Kenya. This is further compounded by the general preference for foods that are highly susceptible to mycotoxins contamination. This paper attempts to highlight the risk of mycotoxin contamination of dairy feeds and products' serious animal and human health implications. Available information clearly indicates that, aflatoxin is one of the most widely occurring and dangerous of all mycotoxins known. The term aflatoxin refers to a closely related group of metabolites produced by toxigenic strains of *Aspergillus flavus* and *A. parasiticus.* Aflatoxins are potent carcinogenic, mutagenic, teratogenic, and immunosuppressive agents. Four different aflatoxins, B1, B2, G1 and G2, have been identified with M1 (a metabolite of B1) being the most toxic. Their contamination of agricultural feed grains poses a serious threat worldwide. Although occurrence and magnitude of mycotoxin contamination varies with geographical and seasonal factors and also with the conditions under which a food or feed crop is grown, harvested, and stored, those grown under tropical and subtropical conditions are more prone to contamination than those in temperate regions due to favourable humidity and temperature levels for mould growth (10 – 40^{o}C, pH range of 4 – 8 and above 70% equilibrium relative humidity). Incidences of mycotoxin poisoning are more common on smallholder farms due to lack of appropriate control skills and knowledge. Dairy cattle on these farms often get poisoned as result of continuous exposure to contaminated feeds. Virtually all feeds are susceptible to mycotoxin contamination, so long as conditions permit mould colonisation. Poor storage and the general tendency to offer mouldy feed resources (protein supplements, poultry manure, cereal grains and crop residues) to livestock are the primary factors exacerbating mycotoxin related risks on smallholder farms in Kenya. Because of the greater role they play as milk producers, control of mycotoxins in dairy diets on smallholder farms would not only reduce the likelihood of livestock poisoning, but also significantly improve public health and consumer confidence, with positive impact on economic returns at household level.

Key words: Dairy, feeds, foods, moulds, Mycotoxins

Résumé

Les mycotoxines sont des métabolites secondaires toxiques produits par des champignons dans des environnements chauds. Suite au climat chaud très favorable à la croissance des moisissures, la menace d'intoxication par les mycotoxines (bétail et humain) est réelle et de préoccupation majeure au Kenya. Cette situation est davantage aggravée par la préférence générale pour les aliments qui sont très sensibles à la contamination des mycotoxines. Cet article tente de mettre en évidence le risque de contamination par les mycotoxines des produits laitiers et les sérieuses implications pour la santé humaine et animale de ces produits. Les informations disponibles indiquent clairement que, l'aflatoxine est l'une des plus largement répandue et dangereuse de toutes les mycotoxines connues. Le mot aflatoxine se réfère à un groupe étroitement lié de métabolites produits par des souches toxinogènes d'*Aspergillus flavus* et *A. parasiticus*. Les aflatoxines sont de puissants cancérogènes, mutagènes, tératogènes, et des agents immunosuppresseurs. Quatre aflatoxines différentes, B1, B2, G1 et G2 ont été identifiées avec M1 (un métabolite de B1) étant la plus toxique. Leur contamination des céréales fourragères agricoles constitue une grave menace dans le monde entier. Bien que la fréquence et l'ampleur de la contamination par les mycotoxines varient en fonction de facteurs géographiques et saisonniers, et aussi avec les conditions dans lesquelles une culture vivrière ou fourragère est cultivée, récoltée et stockée, celles qui sont cultivées dans des conditions tropicales et subtropicales sont plus sujettes à la contamination que celles des régions tempérées en raison de l'humidité et des niveaux de température favorables à la croissance de moisissure (10 - 40 ° C, gamme de pH de 4 à 8 et l'humidité relative d'équilibre au-dessus de 70%). Les incidences de l'intoxication par les mycotoxines sont plus fréquentes dans les petites exploitations agricoles suite au manque de capacités de contrôle et de connaissances appropriées. Les vaches laitières dans ces fermes sont souvent empoisonnées à la suite d'une exposition continue à des fourrages contaminés. Pratiquement tous les aliments sont sensibles à la contamination par les mycotoxines, tant que les conditions permettent la colonisation par la moisissure. Les mauvaises conditions de stockage et la tendance générale à offrir des ressources alimentaires moisies (des suppléments de protéines, du fumier de volaille, des céréales et les résidus de culture) au bétail sont les principaux facteurs aggravant les risques liés aux mycotoxines dans les petites exploitations agricoles au Kenya. En raison du plus grand rôle qu'elles jouent en tant que producteurs de lait, le contrôle des mycotoxines dans les aliments laitiers de petites exploitations agricoles permettrait non seulement de réduire le risque d'empoisonnement du bétail, mais aussi d'améliorer considérablement la santé publique et la confiance des consommateurs, avec un impact positif sur le rendement économique au niveau des ménages.

Mots clés: Laiterie, fourrages, aliments, moisissures, mycotoxines

Background

Across the Eastern Africa sub-region, dairy production is an important part of national economies and more importantly, of the millions of resource – poor rural households who are the biggest contributors to the sector. In Kenya for instance, smallholder farmers own over 80% of the 3.5 million heads of dairy cattle, collectively producing about 80% of the total national milk output estimated at 4.2 billion litres per annum (Thorpe *et al.*, 2000) and contributing significantly to the national gross domestic product (GDP).

Despite of the big role it plays in the national economy, the sub-sector has several challenges. Of these, inability to produce high quality products that can compete well on the international market is the most critical. The issue of safety of dairy products is critical for consumer confidence throughout the supply chain and can indeed determine the success of the entire dairy sector. It therefore implies that, given the role they play in the sector, there is greater urgency in directing regional dairy products quality improvement efforts towards the smallholder resource – poor rural dairy households. This will not only provide a sound basis for increasing production of highly milk in Kenya and the region, but also a greater opportunity for improving animal and public health through production and utilisation of safe dairy feeds, milk and milk products. In addition, enforced adherence to the requisite safety standards will enable the regional dairy sector to take advantage of the emerging regional and international markets for milk and milk products.

Though there are many other hazards considered economically and health-wise important in dairy production (heavy metals, radionuclides, plant and animal related toxins, chemical residues and microbial pathogens), mycotoxins are the most prevalent. Mycotoxins have continued to wreck havoc along the entire agricultural product value chains. The situation is particularly perilous at farm level. This is primarily because majority of smallholder farm households neither have sufficient knowledge on the health risks posed by mycotoxins nor appropriate skills to control/prevent them. As such, many farm families and their livestock are, on daily basis, exposed to a wide range of mycotoxin related hazards. This underscores the need to examine in detail the whole subject of mycotoxins and the risk it poses to both human and animal health in the region. This paper attempts to provide an insight on the same. It further highlights salient predisposing factors and practical control/ prevention strategies to spur production of high quality dairy products in the region.

Literature Summary

Mycotoxins are those secondary metabolites of fungi (moulds) that have the capacity to impair animal health and productivity. Moulds, on the other hand, are filamentous fungi that occur universally in most feedstuffs, soil and plant debris. Among the thousands of species of fungi, only about 100 are known to produce mycotoxins during their growth process. This can occur at different stages of feed handling (at harvest, storage, processing, transportation and feeding). The genera of moulds specially known to produce mycotoxins detrimental to cattle include:

- Aspergillus (e.g. *Aspergillus flavus*; *Aspergillus nomis*; *Aspergillus parasiticus; Aspergillus fumigatus; Aspergillus niger*; *Aspergillus clavatus*; *Aspergillus glaucus*; *Aspergillus nidulans; Aspergillus oryzae; Aspergillus terreus; Aspergillus ustus* and *Aspergillus versicolor*);
- Fusarium (e.g. *Fusarium graminearum*; *Fusarium verticilloides*; *Fusarium proliferatum*);
- Penicillium (e.g. *Penicillium expansum*), and Alternaria

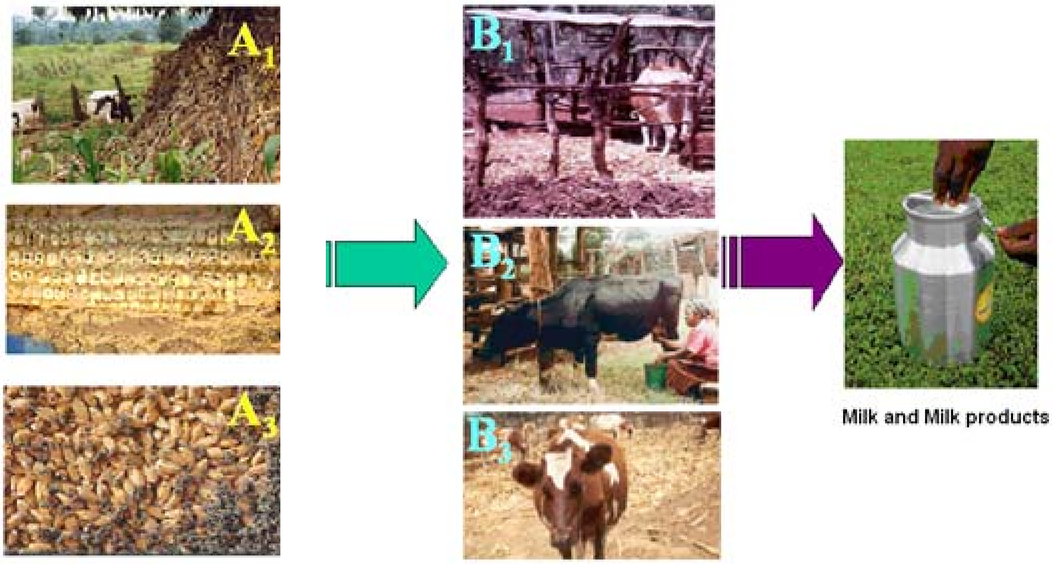
Of these general, *Aspergillus flavus* and *Aspergillus parasiticus* are the most important species because they are the primary producers of carcinogenic aflatoxin in foods and feeds. Aflatoxins are one of the most potent toxic substances that occur naturally under suitable conditions. Aflatoxicosis is poisoning that result from ingestion of aflatoxins in contaminated food or feed. Aflatoxin poisoning is often reported in various parts of Kenya. In other parts of the world aflatoxin poisoning is reported in almost all domestic and non domestic animals (cattle, horses, rabbits, and other non-human primates) and humans. The most widely reported are aflatoxin B_1 and B_2 produced by *Aspergillus flavus* and G_1 and G_2 produced only by *Aspergillus parasiticus*, and found in feeds of plant origin (forages, silages, grains, crop residues, etc). Of this group of toxins (B_1, B_2, G_1 and G_2), B_1 is the most the most toxic, carcinogenic, hepatotoxic and potentially mutagenic as it increases the apparent protein requirement of cattle and it is known to cause cancer. If a significant amount of aflatoxin B_1 is consumed by a dairy cow, a metabolite M_1 appears in the milk within 12 hours. Though studies have shown that M_1 is not as carcinogenic as B_1, it does pose significant health risk to consumers of contaminated milk. Other mycotoxins of less importance include: Diacetoxyscirpanol; Neosolaniol; Ochratoxin; Fumigaclavine (A and B – common in silages); Rubratoxin; citrinin; Patulin; Cyclopiazonic acid; Sterigmatocystin; Ergot alkaloids, etc.

Health Implications

The effect of aflatoxins and other mycotoxin related toxins on livestock include severe damage of the liver, kidneys, central nervous system, reduce natural immunity, hence increasing the severity of secondary diseases and also have estrogenic effects. Mycosis is a dairy cattle disease caused by molds. It is particularly pronounced when the immune system of a cow is severely suppressed during stressful periods. Mycosis can occur in various locations such as the lungs, mammary gland, uterus or intestine. An intestinal infection may result in hemorrhagic bowel. Molds also cause mycotoxicosis in cattle and other farm animals when they consume contaminated feeds**.** Mycotoxins can increase the incidence of disease and reduce production efficiency in cattle (Joffe, 1986; Pier, 1992; Coulombe, 1993).

Clinical Signs

Due to effects of rumen microbes, dairy cattle are more resistant to mycotoxins than are monogastrics. However, because of greater feed consumption and production stresses, they may be more susceptible to than beef cattle. Irrespective of the animal species, symptoms exhibited by affected animals are non-specific and difficult to diagnose. However, for dairy cattle, some general observable signs can be helpful. These include: 1) Reduced feed intake due to either damage of the internal organs (including ulceration of the gut), alteration of the feed composition or reduced palatability due to bad odour; 2) Loss in milk production; 3) Unthriftness and rough hair coat; 4) Under nourished appearance; 5) intermittent diarrhoea sometimes with dark or bloody manure; 6) increased abortions/still births; 7) silent heat and irregular estrus cycles; 8) Expression of estrus in pregnant cows and 9) increased incidences of diseases such as metritis, ketosis, retained placenta, etc. Figure 3 summarises the general clinical signs displayed by the affected cattle.



A_1 – Poorly conserved maize stover (susceptible to moulding); A_2 – Heavily pest infested un-shelled maize cob; A_3 – Mould colonized wheat grain; B_1 – Dump (dairy cow) feeding environment; B_2 – Smallholder farmer milking and grass hay on dirty ground; B_3 – Dairy cows scavenging on maize stover on dirty yard .

Figure 1. Potential sources of aflatoxin poisoning of dairy cows and pathway for contamination of milk on smallholder farms in Kenya.

Figure 2. Rotten grain and wet feeding environment as pre-disposing factors for mycotoxin poisoning in dairy cows.

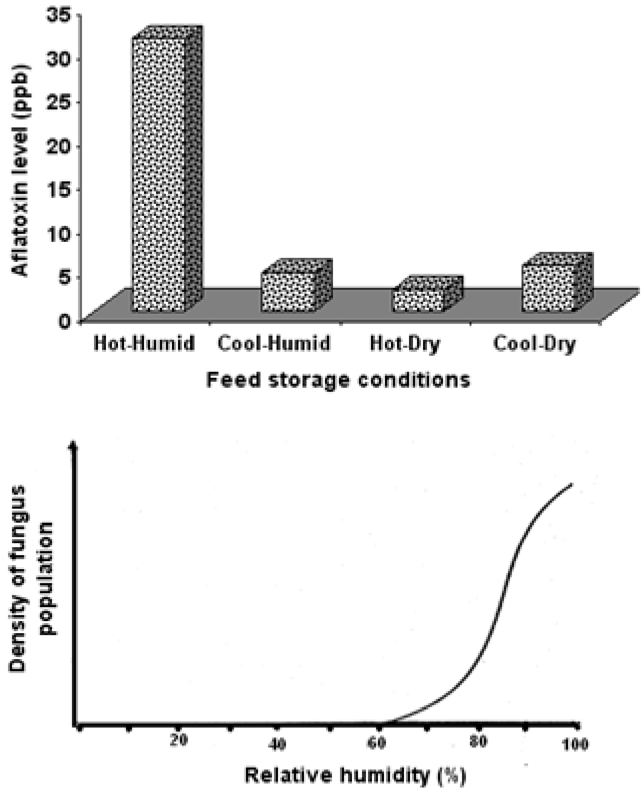


Figure 3. Influence of temperature and relative humidity of fungal colonization and aflatoxin production in animal feeds (Thomson and Henke, 2000).

Pre-disposing Factors

Mold growth and the production of mycotoxins are usually associated with extremes in weather conditions and poor management of feed and food stuffs. Conditions known to exacerbate mould colonisation and therefore mycotoxin production include: 1) presence of fungal spores; 2) warm environment (range of 10 – 40^{o}C); 3) high moisture and oxygen (hydration of feedstuff above 20% dry matter and above 70% equilibrium relative humidity; 4) static feed heaping (spurring rhizoid formation); 5) poor air circulation); 6) physical feed damage (i.e. by pests); 7) plant stress such as drought, low soil fertility or insect infestation (Figs. 1, 2 and 3); 8) presence of suitable organic substrate and 9) suitable pH (range of 4 – 8).

In Kenya majority of smallholder dairy herds are kept in either total (zero-grazing) or semi-confinement (semi-zero-grazing) in highly moist environments. Their respiration, defecation, water spillages and rainfall make the environments where these animals are kept highly laden with moisture (Fig. 2). This therefore means that, feed that was initially very low in moisture content will rapidly gain moisture when placed into this kind of environment, hence spurring the growth of mould and production of mycotoxin.

Economic Implications

In many parts of the world, mycotoxins have been reported to negatively affect feed intake in dairy animals which directly impairs the herd production potential, not to mention the loss of the finished product. High disease incidences and non response to treatments has more often increased the dairy herd's overhead costs. Cystic ovaries accompanied by uterine infections have been reported contribute heavily to reproductive wastage. The existence of other toxins, unbalanced nutrition, poor hygiene, hard weather conditions and/or pathological problems in the herd at the same time as mycotoxin exposure, are likely to amplify their negative effects. The importance of quality feedstuffs to producers can mean the difference between profit and loss. Figure 4 summarises the impact of mycotoxins in dairy animals.

Management Strategies

Aflatoxins and other mycotoxins can only be prevented through good feed handling. The first step in preventing Aflatoxins and other mycotoxins is to prevent moulding of feedstuffs. This can be done trough elimination of pre-disposing factors

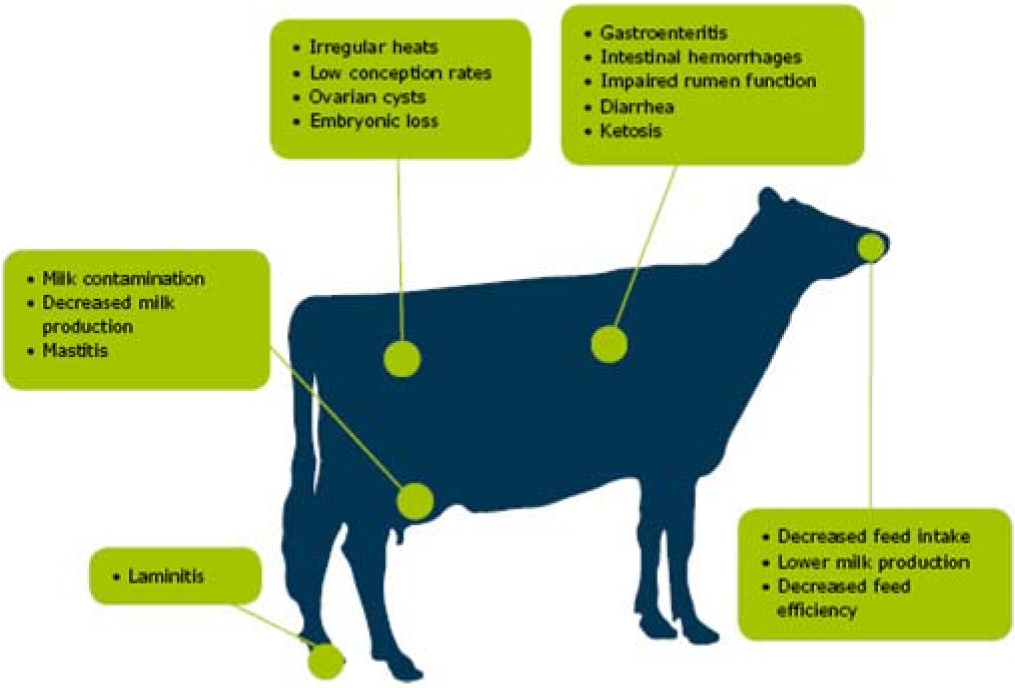


Figure 4. Clinical signs of mycotoxin poisoning in dairy cattle (Adapted from: Biomin GmbH: Mycotoxins in Dairy Cows).

(aforementioned). Appropriate mould control measures would include a deliberate effort to ensure that feedstuffs (primarily crop residues, concentrates and supplements) are sufficiently dried and stored and/or fed in a clean dry environment. It is however, important to note that, although drying of feed has been shown to reduce mould counts, many mould spores remain in the feed or feed material after it has been dried. After drying, the remaining spores can grow if conditions are right. Under stall feeding environment provision of good and easy to clean feed troughs will greatly reduce growth of mould and therefore production of mycotoxin on the feed being offered. Management of crop production in the field is also known to reduce (but not totally prevent), the occurrence and concentrations of mycotoxins. Maintenance of high soil fertility can reduce nutrient deficiency stress known to exacerbate mycotoxin contamination. If the herbage is grown for silage making, it is important that recommended procedures are followed keenly. Excellent silage management can reduce the incidence of mycotoxins. Of these, hybrid selection, reduction of field and harvest stress, rapid filling of the silo, use of an effective silage additive, tight packing, covering, rapid feed out and discarding the spoilage are the most critical.In addition, it is worth noting that, introduction of mould-contaminated feedstuffs, could contribute in seeding fungal spores into otherwise clean feed materials. As such, farmers are strongly advised to avoid using feed ingredients from questionable sources. Where possible, regular laboratory feed test can also be an important tool in ensuring high fed safety. For grains, sufficient air-drying, mixing of pesticides to reduce pest damage and thorough cleaning of storage facilities will greatly reduce the chances of mycotoxin contamination.

Recommended Farm Practices

Employment of good farm practices can significantly reduce the incidences of mycotoxin poisoning. Somme of the recommended farm practices include:

a) Use of seed materials resistant to fungal and insect damage. Drought and insect damage are most important in instigating mold growth and mycotoxin formation in the field. Therefore, varieties adapted to the area and resistant to fungal disease or to insect damage (Bt hybrids) have fewer field produced mycotoxins. Irrigation can reduce mycotoxin formation in the field.

b) Good forage and grain harvesting practices. When harvesting, avoid lodged or fallen material, because contact with soil can increase mycotoxins. Mycotoxins increase with delayed harvest, and with late season rain and cool periods. Damaged grains have increased mycotoxin levels, thus for dry grain storage, harvesting equipment should be maintained to avoid kernel damage. Mycotoxin concentrations are greatest in the fines, and in broken and damaged kernels, thus Cleaning can greatly reduce mycotoxin concentrations in the feedstuff.

c) Proper Drying and storage of grains and forages. After harvest, grains should not be allowed to remain at moisture levels greater than 15 to 18%. While there is little mold growth in grain below 15% moisture, drying to levels below 14% and preferably to <13% help to compensate for non uniform moisture concentrations throughout the grain mass. High temperatures increase the amount of free (water activity) in the grain which is the primary cause of mold growth in storage. Storage should be sufficient to eliminate moisture migration, moisture condensation or leaks. Grain stored for more than two weeks should be kept aerated and cool. Commodity sheds should protect feedstuffs from rain or other water sources. They should be constructed with a vapor barrier in the floor to reduce moisture. If wet feeds are stored in commodity sheds near dry feeds, a method must be devised to prevent moisture contamination of the dry feed.

d) Proper Management of storage facilities. Bins, silos and other storage facilities should be cleaned to eliminate source of inoculation. Check stored feed at intervals to determine if heating and molding are occurring. Organic acids can be used as preservatives for feeds too high in moisture for proper storage. Mold will grow in hay at moisture levels above 12 to 15%. Hay harvested at high moistures will tend to equilibrate to moisture contents of 12 to 14%, but rate of moisture loss is dependent on moisture at harvest, air movement, humidity, air temperature, bale density and the storage facility. Rate of dry down is enhanced by ventilation, creation of air spaces between bales, reduced size of stacks, alternated direction of stacking and avoidance of other wet products in the same area.

e) Proper Ensiling and Silo Management. Prevention of mycotoxins in silage includes following accepted silage making practices aimed at preventing deterioration primarily by quickly reducing pH and eliminating the oxygen. Accepted silage making practices emphasize: 1) harvesting at the proper moisture content~ 2) Chopping uniformly at the proper length; 3) filling the silo rapidly~ 4) Packing the silage sufficiently to exclude air~ 5) using an effective fermentation aide, and 6) covering completely and well. *Penicillium* molds are acid tolerant and may grow if any air is present. Microbial or other additives that reduce pH rapidly can reduce mold growth and mycotoxin formation. Ammonia, propionic acid, sorbic acid and microbial or enzymatic silage additives are shown to be at least partially effective at inhibiting mold growth. Added ammonia may prevent silage from reaching a low pH, but it can reduce mold growth through direct inhibition. Organic acids provide some of the acidity needed for preservation without sole reliance on microbial produced acids. Organic acids may be used to treat the entire silage mass, or to selectively treat the outer layers of the silo. Organic acids are sometimes used during feedlot to treat the silo feeding face and/or the TMR (total mixed ration) in an effort to reduce deterioration of the feeding face and to reduce heating in the feed bunk. Silo size should be matched to herd size to insure daily removal of silage at a rate faster than deterioration. In warm weather, it is best to remove a foot of silage daily from the feeding face. The feeding face of silos should be cleanly cut and disturbed as little as possible to prevent aeration into the silage mass. Silage (or other wet feeds) should be fed immediately after removal from storage. Feed bunks should be cleaned regularly. As with silage, high moisture grains or byproduct feeds must be stored at proper moisture content to exclude air and stored in a well maintained and managed structure. Wet feeds must be handled in quantities which allow them to be fed out within 7 to 10 days. Organic acids are very helpful in preventing mold in wet commodity feeds and can extend storage life. Discard any spoilage.

Conclusion

Mycotoxins pose a serious health risk to both livestock and human. Other than the direct health implications, economic losses arising from mycotoxicoses are equally enormous. Controlling mould growth and mycotoxin production is therefore very important. Solutions to mycotoxin menace can be based only on application of recommended preventive measures and research focusing on detoxification/decontamination of mycotoxin-contaminated foods and feeds.

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