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Mycotoxins: Toxigenic Fungal Compounds – A Review

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ABSTRACT

The toxigenic fungal compounds called mycotoxin are poisonous substances produced by different species of fungus. Basically three major genera of fungus are identified to produce mycotoxins: they include *Aspergillus, Fusarium and Penicillum*. Although other genera also produces these toxigenic compounds. The presence of mytotoxins in food poses health risk ranging from mild to severe damage to the liver and kidney. Chronic damage may be induced in animals or human after ingestion of small quantity of the toxin present in contaminated foods. For example Aflatoxin produced by *Aspergillus flavus*, if ingested from contaminated food could pose serious and severe health risk to man and animals. Foods like rice, corn, barley, wheat, sorghum, peanut, cotton seeds, soya bean, silages and by products feeds which have been mishandled are the major sources of mycotoxins. Different species of fungus produce different types of mycotoxins. The disease caused by ingestion of mycotoxins is called mycotoxicosis. Mycotoxin contamination of foods could be prevented by controlling the environmental condition that influence fungal growth, which is by controlling the physical conditions of the grains, cleaning the storage systems regularly and by the use of mold inhibitors and anti cracking additives. The control of the toxigenic compounds could also be by removing the suspected feed contaminated with mycotoxins or by addition of toxin binder to the ration of the feed.

Keywords: *fungus, mycotoxins, severe, chronic, mycotoxicosis*

1. INTRODUCTION

"Myco" means fungus "Toxin" means poison [3].Mycotoxins are toxic secondary metabolite of low molecular weight produced by naturally occurring fungi [5]. Mycotoxins are neither infectious nor contagious, but can occur on a herd – wide basis [23]. Many fungi produce poisonous substances called mycotoxins that can cause acute or chronic intoxication and damage. Ingestion of poisonous mushrooms (e.g. *Amanita phallides*) may cause severe damage to the liver and the kidney. Chronic damage or neoplasms may be induced in animals or humans following ingestion of small quantities of toxin present in contaminated food (e.g. Aflatoxin from *Aspergillus flavus*). Derivative of fungal products (e.g. LSD) may cause profound metal derangement. [10] in contrast, some mycotoxins directly inhibit the growth of other microorganisms. To elaborate more on mycotoxins, the term mycotoxin literally means poison from a fungus. Mycotoxins are substances produced from fungal secondary metabolic processes, which impair animal health, thereby causing great economic loses of livestock through diseases. They are usually named on the basis of the fungus that produces them. For instance, Aflatoxin uses the A for *Aspergillus*, fla for the species *flavus* along with the word toxin [17].

There are three (3) major genera of fungi that produce mycotoxins: they *include Aspergillus, Fusarium and Penicillum*. Mycotoxin producing fungi grow on a wide spectrum of feed that include cereal grains, groundnuts, beans and peas. They can invade the food supply at any time during production, processing, transporting or storage. These organisms are aerobic and can both be pathogenic to plants or saprophytic with them. Several factors influence the degree of fungal growth plants products and the production levels of mycotoxins. These factors include: substrate characteristics, climate, physical interference and stress [17].Ambient temperature (12 - 47^{o}C) and moisture levels of about >70% are optimal for proper fungal development and mycotoxin production. Other factors that might contribute to the growth of mycotoxin – producting fungi are insect and mechanical damage which destroy some of the plants physical barriers thereby allowing fungal colonization. Poor fertilization and drought can also cause some levels of stress in the plant which weaken the plant's natural defense since fungal growth is often associated with a particular climatic event such as drought, outbreaks characteristically occur during seasonal weather. Mycotoxins affect specific tissues or organs depending on the particular toxin involved. Some affects the nervous system, some cause liver and kidney damages and others even cause vomiting in some species – clinical syndromes in farm animals range from acute death to chronic diseases, from reproductive deficiencies to just an overall debilitations.

In general, mycotoxins are specifically associated with a particular feed and are not transmissible from organism to organisms (except when special circumstances are considered like milk production for later human consumption) and are usually not responsive to any kind of direct treatment. Some ruminant disease proven to be directly related to mycotoxins consumption are: facial eczema in New Zealand's sheep, salivation factor I cattle, death of cattle from T-2 toxin, stachybotryotoxicosis in Eastern Europe's sheep and goats, lupinosis in sheep in South Africa, and maltoryxine poisoning in cattle [1]. Among the most common mycotoxins implicated as health problems for ruminants

are aflatoxins, Zearalenone, trichothecenes and achratoxins;

A good example of a well known mycotoxin is aflatoxin. Aflatoxins are produced by *Aspegillus flavus* and *Aspegillus parasiticus* and often cause liver damage and cancer, decreased milk production and immune suppression. The members of the species are usually more susceptible to the effects of aflatoxins, which may be express as gastrointestinal disturbance, anaemia, reduced feed consumption and overall retarded growth and development. Lactating mothers excrete <5% of ingested mycotoxins in the milk thereby directly affecting the nursing animal. Since the discovery in the early 1960's, aflatoxins (BBGG) have been a significant problem in the feed industries. A. *flavus* outbreaks can occur in the field during preharvest or on crops in storage at substrate moisture content of 14% and a temperature of 25 – 40^{o}C. Some signs of aflatoxins production in ruminants include reduction in feed intake, weight loss and rapid death [1]. For mold growth to occur, four (4) conditions must exits:

a. There must be an adequate food source e.g. grains.
b. The temperature must be maintained between 12 and 31^{o}C.
c. There must be sufficient oxygen to allow mold growth and
d. There must be sufficient moisture, at least in some parts of feed, for mold growth.

Thus, if the farmer can control the availability of oxygen and moisture, he can go a long way to prevent mycotoxins from being produced on the farm [14.4].
Molds produce mycotoxins in response to stress. For example, molds growing on corn, either in the field or in storage, will produce no mycotoxin until subjected to freezen temperatures or until subjected to moisture deprivation. Mycotoxin problems are more pronounced in crops growing under cool, moist conditions and under drought stressed condition. Unfortunately both of these conditions occur annually in large portions of the world. Mycotoxin production will be in direct proportion to the duration of this stress. Conversely it is possible that feeds heavily contaminated with molds can be mixed, ground or treated so that obvious mold is not evident. Yet, feed can be completely contaminated with mycotoxins thus, a feed can have molds and still not contain mycotoxins and have mycotoxins without mold. The only way to properly evaluate these situations is the reaction of the cows. Even if mycotoxins are present it may be difficult to demonstrate their presence or their relative severity .Although there have been about 400 mycotoxins identified, there are probably as many that have not been fully characterized. Also, pure mycotoxin may have little animal impact. However, the same mycotoxin, given at lower dose, but in conjunction will another mycotoxin, may have a devastating effect on the health and productive ability of the animal. Apparently different mycotoxins can potentiate the effect of other mycotoxins [14,4].This study is therefore aimed at enlightening the populace/farmers on the effects of mycotoxins and to suggest/provide possible solutions to how these mycotoxin's production can be prevented, control/manage most especially when present in foods/feeds.

2. MAJOR SOURCES OF MYCOTOXINS

The primary sources of mycotoxin tend to be corn, barely, wheat, cotton seed, sorghum, by products feeds which have been mishandled and silages. Silage continues to be the major source of mycotoxin problem. In many countries, this can be traced to the dependence on hand labour to empty trucks from the field, to distribute the silage in the bunk and to remove silage from the bunk. This is further complicated by improper sixing of silo stacks for the size of the herd. Silage usually contains molds of the *Fusarium* type and are contaminated by the Zearalenone, deoxynivalenol acid (Don), *Fusarium* toxin and T – 2 toxin [18,17].

3. COMMON MEMBERS OF MYCOTOXIN FAMILY

3.1 Aflatoxins

Aflatoxin is a group of mycotoxins produced mainly by *Aspergillus flavus, A. parasiticus and A. nomius.* Aflatoxin, especially AFB1 is the most potent toxic metabolite, which shows hepatotoxic teratogenic and mutagenic properties, causing such diseases to mammals as toxic hepatitis, hemorrhage, edema, immunosuppression and hepatic carcinoma [8,12].

[13] reported that Aflatoxins are polyketide-derived furanocoumarins and basically have a central 5 ring core. The differences in the different types include types of side chains or degree of saturation of carbon – carbon bond. Aflatoxin B_1 and B_2,G_1 and G_2 and M_1 and M_2 are typical examples. Aflatoxins are best recognized and best characterized. It is produced by molds of the *Aspergillus* species and is a potent carcinogen. This is the reason why aflatoxin levels are regulated in raw milk in the United States. Symptoms include: decrease appetite, decreased production, weight loss, high liver enzymes, loss of liver function, abortion and ultimately death. Although aflatoxin is perhaps the most dangerous of the mycotoxins, it really does little practical damage. This is because its effects are severe and dramatic which makes the change to aflatoxin contaminated feeds noticeable. It is quickly associated with feed changes, and the offending feed can either be reduced in quantity or removed. Also feed companies readily appreciate the damage that aflatoxin can do and regularly screen for it presence. Thus, aflatoxin is really not the severe problem that it could be left unscreened. If liver damage is not severe, animals usually recover in 4-10 days after the offending feed has been removed on practical best, 20 ppb can probably be well tolerated by mature milking cows, but only about ppb in growing cattle and 4 ppb for calves. For chronic feeding these levels should be reduced by one half. *(A. flavus* outbreak can occur in the field during pre

harvest or on crops in storage at a substrate moisture content of 14% and temperature of 25 - 40^{o}C [2, 20, 17].

3.2 Deoxynivalenol (DON)

DON is produced by molds of the *Fusarium* species. Much of the data in dairy cattle concerning the effects of DON are conflicting. High doses of pure DON have caused no noticeable problems; however, lower doses of DON in associate with other mycotoxins have resulted in lower milk production with increased morbidity. In addition nervous symptoms, diarrhoea and intestinal hemorrhage have been reported. For this reason DON is often referred to as a "marker" mycotoxin, i.e., presence of DON is usually associated with other mycotoxins that may not be easily identified. Levels of DON below 500 ppb are probably safe for consumption by dairy cattle [19]. Different assays for DON have been developed for the substrate which is found but the newest technology for DON assays is the ELISA screening procedure [18].

3.3 Zearalenone

Zearalenone is mycotoxin with estrogenic activity which is produced by molds of the *Fusarium* species [19]. Similarly**,** [13] reported that Zearalenone is a toxin produced in stored grain contaminated by *Fusarium sp*. Many of these toxins have being used as antimicrobials agents Lowered milk production, abortion, short heat cycle, nymphomania, and feminization of bulls have been reported when feeding Zearalenone infected silages. Zearalenol is a compound similar to Zealenone but it is reported to provoke 5-10 times the estrogen response levels of Zearalenone. Below 250 ppb are probably safe to feed adult dairy cattle if no other molds are contaminating the feed [19,18].

3.4 T-2 Toxin (One of the Trichothecenes)

T-2 toxin is produced by several molds of the *Fusarium* species. T-2 is found not only in com-silage but in some haylages, symptoms in cattle include lowered milk production, diarrhea, hemorrhagic bowel, sterility and lesions in the intestine, ovaries and uterus. Immune function is severely depressed. Consumption of large quantities can cause acute death. Consumption of greater than 100 ppb are probably dangerous. Diacetoxyscirpenol (DAS) is a closely related compound that produces many of the same effects. Fifty (50) ppb is the safe suggested limit for this toxin [1,7]. T-2 toxin has been detected in agricultural crops and products [18].

3.5 Fumonisin

Fumonisin has been reported relatively recently, and the effects are still relatively unknown. It has been implicated in liver and kidney damage, decreased immune function and high mortality rates in cattle. It is tumorgenic in swine and horses, but this has not been demonstrated in cattle. Fumonism is thought to potentiate the toxicity of other trichothecene toxins. Safe levels has been estimated to be below 50,000 ppb. 5, 000 ppb is the maximum safe level for horses [1,20].

3.6 Ergot Alkaloids

Ergot Alkaloids are amides of the terpenoid indole derivative D-lysergic acid, and are produced by wide range of fungi, predominantly *Clavicipitaceae*, but are also present in members of plant family *Convolaceae* eg.*Ipomea Violaceae and Turbina corymbosa* [13].Ergot Alkaloids are mold mycotoxins that infects the flowering portion of many grains and grasses. Arbortion storms and lowered fertility are associated with consumption of ergot infected feeds/foods. Although dramatic in its effects, ergot is probably not an industry wide problem. Cattle fed at 1% (10,000 ppb) had increased abortion rates with calves that were born alive being weak and debilitated [1,7].

3.7 Ochratoxin

Ochratoxin is a Mycotoxin produced almost always on grains and almost always as a result of poor storage conditions by molds of the *Penicillium* family and by *Aspergillus ochraceus*. Constrolled studies in dairy animals are lacking, although cattle feed with achratoxin contaminated feed has enlarged lowers and kidneys at slaughter. Safe levels are assumed to be less than 10, 000 ppb [1,4].

4. MYCOTOXICOSIS AND SYMPTOMS OF MYCOTOXICOSIS

The manifestation of mycotoxin poisoning has long been appreciated as an acute cause of poor animal performance; it is only recently that chronic, subclinical mycotoxin load has been appreciated as a cause of poor animal performance and increased disease susceptibility. The adverse effects of mycotoxins are thought to be due to both a direct effect on the animal and indirect by suppression of the immune system [20].

Molds and mycotoxins are widely distributed in nature. In general, it is difficult to make a confirmed diagnosis of mycotoxicosis. There are several general symptoms that may make one suspicious that a mycotoxin problem may exist. Many of these symptoms are general and can be symptomatic of other problems. For example.

a. Consumption of dry matter is much less (-2.0kg or 5Ib) or much more (+2.0 kg to 5Ib) than would be predicted for the present production. Less dry matter is generally a symptom of aflatoxin or other serious mycotoxins. More intake than production warrants can indicate problem with DON (deoxynivalenol) or Zearalenone.
b. A high incidence of digestive upsets. These upsets can take the form of diarrhoea and/or rumen stasis (impactions). Presence of a lot of mucos in the manure. This is symptomatic of all mycotoxins, but much more prevalent with aflatoxin or T-2 toxin. Presence of large amounts of mucos is symtomatic of a toxin, although it may not always be a mycotoxin.
c. A high incidence of disease associated with depressed immune function, such as urea plasma

or pasteurella pneumonia. Presence of a equalized tissue edema. This is often evidence by swelling in the brisket and hock areas. Cows are very sensitive to any type of impact or insult. Swelling is often in excess of what would be expected. This is associated with mycotoxins of the *Fusarium* sp.

d. High rate of abortion or fetal resorption without obvious infection disease involvement. A total rate abortion and resorption above 15% would be considered high again almost one molds provoke abortion. High levels of even benign molds can cause mycototic abortions. However high resorption rates coupled with short heats or nymphomana may indicate Zearalenone contamination.
e. A general unthrifty appearances of the cattle with lower milk production would be expected. Cows could have rough hair coasts, a "sad" appearance and generally a slightly arched back [20].

Early detection signs of mycotoxicoses include moldy feed and feed refusal however, *aflatoxins* are often present in feeds that appear to be normal. Death losses can occur without diagnosis of an infectious disease. In any case the diagnosis of mycotoxicosis is very difficult. This is due in part to the time lapse between exposure to the toxin and development of symptoms in the animal, and the observation of concrete clinical history should first be obtained [20]. Mycotoxicosis can also occur even if the feed supply remains constant due to the presence of "hot spot." Proper identification of an aflatoxin problem comes not only from a positive analysis of aflatoxins in feed and animal tissue but also from mild samples of lactating animals. When analyzing stored feeds, a representative sample of the lot must be carefully taken to ensure reliable analytical data [6,15].

Table 1: Mycotoxicoses Produced by Fungal Mycotoxins in Domestic Animals

Disease	Fungus	Mycotoxin	Contaminated Food Stuff	Animals Affected
Aflatoxicosis	*Aspergillus flavus*	Aflatoxins	Rice, Corn, sorghum cereals, peanuts, soyabean	Poultry, swine, cattle, sheep,dogs
Ergotism.	*Claviceps*	Ergort Alkaloids	Seedheads of many grasses, grains	Cattle, horses, swine poultry.
Mushroom poisoning	*Amanita Verna*	Amanitins	Eaten from pastures	Cattle
Poultry hemorrhagic Syndrome	*Aspergillus flavus* and others	Aflatoxins	Toxic grain and meat	Chikens
Sloppers	*Rhizoitonia*	Alkaloid slaframine	Red clover	Sheep, cattle
Tallfescue toxicosis	*Acremonium*	Ergot alkaloids	Endophyteinfected tall fescue plants	Cattle, horses
	Coenophialum (an endophytic Fungus)			

[16]

5. ANALYSIS AND IDENTIFICATION OF MYCOTOXINS IN FOOD/FEEDS

5.1 Sampling Skills

Mycotoxin contamination of foods and feeds is usually heterogeneous. Therefore, Precaution must be taken in sampling to obtain a reliable quantitative estimate of the concentration of a mycotoxin in a given food/feeds [22].

5.2 Sampling

a. Samples must be representative of entire lot (food)
b. Obtain samples from multiple locations
c. Use of a grain or forage sampling probe is recommended
d. Take samples at various unloading sites
e. 10 pounds minimum
f. Mix thoroughly
g. Sub sampling
h. Send 2 to 5 pounds for analysis
i. Freezing or air-tight packing if necessary (especially) for high moisture samples [23].
j. Sources of Mycotoxins test kits
a CSID
b Mini column [20]

6. PREVENTION OF MYCOTOXIN CONTAMINATION OF FOODS/FEEDS

1. Control the environmental factors that influence fungal growth [7]
   a. Moisture contents of grain (< 14%)
   b. Relative humidity (< 70%)
   c. Temperature (-22degree centigrade)
   d. Oxygen availability

2. Control the physical condition of the grain:
   a. Minimize grain damage during harvest
   b. Screen grain to reduce broken kernels
3. Clean storage system regularly [23]
4. Use mold inhibitors and anti-craking additives [7]
5. Ammoniation to reduce aflatoxin concentrations [7]
6. Floating separation – Fusarium – infected kernels are higher than sound Kernels [7]
7. Wash, wet or dry milling and heating process (roasting, boiling, baking and frying) [22].
8. Addition of 0.5%hydreated sodium calcium aluminosilicate in formulated feed [7].

7. ANIMAL ASPECTS

a. Reduce the stress to animals.
b. Increase plane of nutrition.

8. CONTROL OF MYCOTOXIN CONTAMINATION IN FOOD/FEEDS

If mycotoxin is suspected, the suspected feed should be removed or at least the quantities of the suspected feed decreased, and a toxin binder should be added to the ration. For examples: In order to make high quality silages, it is necessary to fill quickly and pack continuously. This is mainly impossible if hand labour is used to unload trucks and/or distribute the silages. It is the recommendation of almost all experts in the field that 15cm of silage be remove daily from across the entire face of the silo in order to prevent mold growth, another broad way of controlling mycotoxin contamination by mold is by daily treatment of the silo face with a mold inhibitor. Such as propionic acid, will help to reduce mold growth. In all cases of a proven mycotoxin, binder should be added to the ration wherever mycotoxin is suspected. The major setbacks of toxin binders vary in their ability to bind toxins, and some toxin binders can bind one type of toxin and not bind any of other type of toxin [7]. In conclusion, part of the deleterious impact of mycotoxins on ruminants may be caused by the indirect effects of reduced nutrition from infected grains or forages. Mycotoxins, especially those produced by *Fusarium* species may result in great losses in productivity, though aflatoxin is widely recognized as a potent toxigenic fungal compound [11].

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