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Full Length Research Paper

Review on Mycotoxins in Feeds: Implications to Livestock and human health

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The objective of this review was identifying mycotoxins in livestock feeds and effects on livestock as well human health. Mycotoxins are toxic secondary metabolites produced by wide range of fungi (molds) toxic to humans, livestock and plants. There are over 100 species of fungi that can infect plants and forages and produce mycotoxins. Mycotoxins are mainly produced by Aspergillus, Penicillum and Fusarium genera which invade crops in the field and may grow during storage under favorable conditions of temperature and humidity. Aflatoxins, trichothecenes, zearalenone, ochratoxins, and fumonisins are some of mycotoxins that found in feeds. Consumption of a mycotoxins-contaminated diet may induce acute and long-term chronic effects resulting in teratogenic, carcinogenic, and oestrogenic or immune-suppressive effects. Direct consequences of consumption of mycotoxins-contaminated livestock feed include: reduced feed intake, feed refusal, poor feed conversion, diminished body weight gain, increased disease incidence (due to immune suppression), and reduced reproductive capacities. Three fundamental factors exist for the development of fungi and the production of mycotoxicosis are physical, chemical and biological factors are determined. The effect of mycotoxins in human and animal health can be determined by amount of affected feed/ food, length of time, age, species as well as environmental factors. Ruminants such as cattle, sheep and goats are less common for their sensitivity to the negative effect of mycotoxins than non ruminants. Mycotoxins have direct influence on features of specific organs (liver, kidneys, reproductive System). To control mycotoxins in feeds before harvest and post harvest mechanisms are available and these methods include different physical, chemical and biological systems depending on their availability.

Key words: Mycotoxin, feed, livestock, human, health.

INTRODUCTION

Livestock production is an important part of national economy and it plays a significant role in providing the high quality and quantity food for human beings. The role of livestock sector enhancing agricultural productivity is well recognized and its contribution to alleviate poverty in rural areas is enormous (Abedullah *et al*., 2009). Mycotoxins have long been a concern to livestock producers when environmental conditions during the growing season were conducive to mold growth on the field crop. Mycotoxins have been detected in various food commodities from many parts of the world and are presently considered as one of the most dangerous contaminants of food and livestock feed (Okoli, 2007).

Mycotoxins are now more frequently being associated with crops like corn silage that include not just grain but a high percentage of stalks and Stover. Differences of opinion exist regarding the role of molds and mycotoxins in livestock problems basically because their effects on animal health and production (Seglar and Mahanna, 1995). They are regularly implicated in toxic syndrome in animal and human (Charoenpornsook and Kavisarasai, 2006). Due to the diversity of their toxic effects and their synergetic properties mycotoxins are considered as a risky to the consumers of contaminated food and feeds (Omed, 2008).

Mycotoxins are toxic, chemically diverse secondary substances or metabolites produced by a wide range of fungi. There are over 100 species of fungi that can infect plants and forages and produce mycotoxins. Mycotoxins are mainly produced by Aspergillus, Penicillum and Fusarium genera which invade crops in the field and may grow on foods during storage under favorable conditions of temperature and humidity (Akande *et al.,* 2006). Infections by mold and mycotoxins production can develop at various stages of crop production: in the field, during harvesting and transportation or storage (Martins *et al.,* 2007). Factors that influence the mycotoxins production include: temperature, moisture, oxygen, substrate aeration, inoculums concentration, microbial interaction, mechanical damage and insect infestation. (CAST, 2003).

Mycotoxins are in general stable and capable of persisting into final products (Sabater Vilar, 2003). Experimental evidence characterizing the potential of mycotoxins and moldy feedstuffs to cause animal disease, definitively linking a disease outbreak in the field to specific mycotoxins can be very difficult. Briefly, the problem is that mycotoxins often do not cause acute disease and, when they do, there are often multiple interacting factors that can modify the expression of toxicity (Morgavi and Riley, 2007).

In the past, most investigations have focused on bacterial or viral diseases in cattle, whereas mycotoxins were only studied in monogastric animal species like poultry and pigs. Another dilemma associated with the effects of mycotoxins in ruminant is based on the paradigm that ruminants are relatively tolerant to adverse effects of mycotoxins, presumably due to ability of rumen micro flora to detoxify the mycotoxins. Rumen metabolites are more toxic than parent mycotoxins i.e. conversion of zearalenone to α-zearanol (Kiessling *et al*., 1984). Mycotoxins impair ruminal functions by exerting antimicrobial effects on rumen micro flora. Increased rate of passage of feed through the rumen may possibly overwhelm the ability of the rumen to completely denature the toxins (Fink-Gremmels, 2008).

Ruminant's diet generally includes both forages and concentrates (Azam *et al*., 2009) and may have an increased probability of multiple mycotoxins contamination. Animals vary in their susceptibility to mycotoxins, according to the age and the species of animal and the specific toxin involved (Pier *et al*., 2007). Mycotoxins can cause damage to organ systems, reduce production and reproduction, and increase diseases by reducing immunity. Some mycotoxins are carcinogens, some target liver, kidney, digestive tract or the reproductive system (Akande *et al*., 2006). Aflatoxins, fumonisins and zearalenone are most common mycotoxins in Africa (Devegowda *et al*., 1998).

The Objective of this paper is**:-** review presence of mycotoxins in feeds, implications to livestock and human health

Definition and types of mycotoxins

What are Mycotoxins?

Mycotoxins are toxic secondary metabolites produced by fungi (molds) toxic to humans, livestock and plants. Their ingestion, inhalation or dermal absorption may cause different diseases and even death. Mycotoxins are undesirable, but mostly unavoidable, mold produced feed contaminants. Mycotoxicosis is diseases caused by exposure to foods or feeds contaminated with mycotoxins (Nelson *et al*., 1993). Mycotoxins cause a toxic response (mycotoxicosis) when ingested by livestock. Cereal plants may be contaminated by mycotoxins in two ways: fungi growing as pathogens on plants and/or growing saprophytically on stored plants. Moulds and associated mycotoxins are important factors adversely affecting foods produced using contaminated plant products or animal products derived from animals fed on contaminated feeds (Robens and Cardwell, 2003).

Mycotoxins are toxic to humans and animals, which explains the major concern of food and feed industries in preventing them from entering the food chain (Pierre, 2007). All fungal growth didn't results in mycotoxins formation and detection of fungi does not imply necessarily the presence of mycotoxins. Consumption of a mycotoxins-contaminated diet may induce acute and long-term chronic effects resulting in teratogenic, carcinogenic, and oestrogenic or immune-suppressive effects. Direct consequences of consumption of mycotoxins-contaminated animal feed include: reduced feed intake, feed refusal, poor feed conversion, diminished body weight gain, increased disease incidence (due to immune suppression), and reduced reproductive capacities (Voss and Haschek, 2007).

Toxinogenic (mycotoxins producing) fungi can be distinguished such as *Fusarium* which invade their substrate and produce mycotoxins on the growing plants before harvesting: this is the category of field (pre-harvest) toxins. Aflatoxins and *Fusarium* toxins are included in this group. And the other group contains fungi which produce toxins after harvesting and during crop storage and transportation. These toxins are named storage (or post-harvest) toxins and ochratoxin A belongs to this group (Te Giffel, 2008).

Types of mycotoxins

More than 300 chemically different mycotoxins formed by more than 350 fungal species and causing diseases (mycotoxicosis) to living organisms (Steyn, 1998) have been documented. Once active growth is no longer possible, they frequently respond by undergoing morphological and biochemical differentiation resulting in the production of a chemically diverse range of

Table: Mycotoxins and their effect on different livestock species.

Mycotoxins	Species susceptability	Effects
Aflatoxins	All domestic animals and poultry	Hepatoxic,carcinogenic, immune suppressive
Zearalenone	Mainly pigs and dairy animals	Estrogeni and reproductive disorder
Vomitoxin	Mainly pigs and dairy animals	Dermatotoxic, feed refusal
Ochratoxin	Mainly pigs and poultry	Nephrotoxic, gout
T-2 Toxin	Mainly pigs and poultry	Mouth lesions, loss of appetite
Fumonisins	Mainly pigs and horses	Neurological disorders, liver damage.

Source:(Ratcliff, 2002).

secondary metabolites (Bhatnagar *et al.*, 2002). Toxigenic fungi have been roughly classified into two groups' field fungi and storage fungi (Pierre, 2007). Most of the known mycotoxins have been recognized as secondary metabolites of *Fungi imperfect,* particularly of the genera *Aspergillu*s, *Penicillium*, *Fusarium*, *Claviceps*, *Alternaria*, *Neotyphodium*, *Stachybotrys*, *Myrothecium*, *Phoma* and *Diploidia* (Sabater Vilar, 2003).

Pre- Disposing Factor for Mycotoxins in Livestock Feeds

Substrates differ in their ability to support fungal growth due to differences in their physical and chemical characteristics, which include water activity, oxygen availability and surface area, while chemical characteristic include carbohydrates, fat, protein, trace elements and amino acid composition (Manal *et al*, 2012). High temperatures and relative humidity provide ideal conditions for growth and/or development of moulds with possible production of mycotoxins (Pitt and Hocking, 1997). Excessive moisture in the field and in storage, temperature extremes, humidity, drought, variations in harvesting practices and insect infestations are major environmental factors that determine the severity of mycotoxins contamination (Hussein and Brassel, 2001)

Most fungi are little affected by pH over a broad range, commonly 3 to 8 at high water activities, fungi compete with bacteria as food spoilers. However, the pH of a medium may exercise important control over a given morphogenic event without remarkably influencing the overall growth of a fungus (Pitt and Hocking, 1997). Oxygen is essential for the growth of fungi, but certain species can also grow under anaerobic conditions with the formation of ethanol and organic acids. Oxygen also influences production of mycotoxins. The production of patulin and penicillic acid decrease sharply at low oxygen concentrations, but fungal growth is not noticeably influenced. *Aspergillus* growth is restricted at an oxygen concentration of less than 1% (Pitt and Hocking, 1997). Three fundamental factor exist for the development of fungi and the production of mycotocosis are physical, chemical and biological factors are determined (Gimeno, 2000).

Mycotoxicosis symptoms depend on the mycotoxins involved, on biological systems interaction and on mutual influence between toxin and stress factors (Whitlow *et al.*, 2002). Infections by mold and mycotoxins production can develop at various stages of crop production: in the field, during harvesting and transportation or storage (Martins *et al.,* 2007).

Aspergillus species normally grow at lower water activities and at higher temperatures than do the *Fusarium* species. Therefore, *Aspergillus flavus* and aflatoxin are more likely in corn grown in the heat and drought stress associated with warmer climates. Aflatoxin contamination is enhanced by insect damage before and after harvest. *Penicillium* species grow at relatively low water activities and low temperatures and are widespread in occurrence. Because both *Aspergillus* and *Penicillium* can grow at low water activities, they are considered storage fungi (Christensen *et al.*, 1999).

Implications of Mycotoxins in Livestock and Human Health

The effects of mycotoxicosis in livestock's are diverse, varying from immune suppression to death in severe cases depending on: toxin-related (type of mycotoxins consumed, level and duration of intake), animal-related (animal species, sex, age, breed, general health, immune status, nutritional standing) and environmental (farm management, hygiene, temperature) factors. The consumption of multiple mycotoxins contaminated diet may induce hematological, biochemical and liver physiological changes and growth depression in livestock (Gowda *et al.*, 2008), and thus the presence of mycotoxins in poultry feeds causes significant economic losses to animal industries (Awad *et al.*, 2006).

Ruminants such as cattle, sheep and goats are less common for their sensitivity to the negative effect of mycotoxins than are non ruminants. However, production (milk, beef or wool) reproduction and growth can be alerted when ruminants consume mycotoxins contaminated feed for extended periods of time (Hussien and Brasel, 2001). Mycotoxins in combination appear to exert greater negative impact on the health and productivity of livestock in comparison to their individual effect (Smith and Seddon, 1998). The impact of reduced animal productivity, increased incidence of disease due to immune suppression, damage to vital organs and interference with reproductive capacity is many times greater than the impact caused by death due to mycotoxins poisoning (Akande *et al*, 2006).

Consumption of low levels of mycotoxins through the feeds do not cause overt mycotoxicoses, but often predisposes to various infectious diseases and especially to secondary bacterial infections or to a heavy progression of some often encountered parasitic diseases (Koynarski *et al*., 2007).

Many of these metabolites show some form of biological activity including antibiosis, phytotoxicity and toxicity to livestock and humans. The subset of low-molecular weight secondary metabolites proven to exert significant toxic effects in livestock and humans is defined as mycotoxins (Biro, 2003). Besides having a direct negative impact on animal performance directly related with the molecules' toxicity, mycotoxins have a negative effect in the nutrient uptake, or in other words, they inhibit the absorption of nutrients by the animals (Awad *et al*, 2004). A given fungus may be capable of producing more than one toxin; a given toxin may be produced by different genera of fungi (Fink – Gremmels, 1999). The mycotoxins are in general stable and capable of persisting into final products (Sabater Vilar, 2003).

Prolonged exposure results in an increased susceptibility to secondary diseases caused by viruses, bacteria, and fungi. Frequently, there are synergistic effects between several mycotoxins multiplying adverse influences on the animal's health and production potential. Today, even though there is great experimental evidence characterizing the potential of mycotoxins and moldy feedstuffs to cause animal disease, definitively linking a disease outbreak in the field to specific mycotoxins can be very difficult. Briefly, the problem is that mycotoxins often do not cause acute disease and, when they do, there are often multiple interacting factors that can modify the expression of toxicity (Morgavi and Riley, 2007).

In dairy cows Follicular fluid mycotoxins concentration varies accordingly to the duration of follicular exposition to zearalenone: follicular cysts present a higher concentration of zearalenone than normal follicles (detection rate 35% and 18.8%) (Takagi *et al*. 2008). In an *in vitro* experiment, oocytes were exposed to high concentration of zearalenone for 21 days in order to simulate acute exposure to zearalenone and it was found that ZEA levels in follicular fluid were often high ,and it reduction of the conception rate. This symptom of infertility can be attributing to prolonged zearalenone intake in dairy cows (Minervini *et al*., 2008).

Witte et Hooser (2003), zearalenone have various effects on reproductive symptoms: abnormal estrus cycle, vulva wetness, reduced milk production and increased udder size. In monogastrics, kidney damage, dehydration, reduce immune response, lower dry matter intake and lower production may be caused by ochratoxin-A but have no on direct effect on dairy cows (Yiannikouris et Jouany, 2002). T2-toxin effects on heifers' fertility (Huszenicza *et al*., 2000).

Fumonisins cause neurological disease in horses, indicating multifocal CNS (central nervous system) involvement. The initial clinical signs include depression; in appetence after a period of eating contaminated feed, horses become lethargic and, as neurotoxin effects become apparent, develop uncoordinated movement (blind staggers) (Wilson *et al*., 1992). Hepatic lesions are less common than CNS lesions in horses exposed to fumonisis. Ruminant's diet generally includes both forages and concentrates (Azam *et al*., 2009).

In animals, their effects vary with the dose, length of exposure, species, breed, diet or nutritional status. Generally, calves are more susceptible than older animals. It exerts carcinogenic, teratogenic, hepatotoxic and mutagenic effects and also suppresses the immune system of cattle. Aflatoxins exert acute and chronic effects in animals (Aydin *et al*., 2008). Aflatoxins can cause liver damage, gastrointestinal dysfunction ,reduced productivity, decreased feed utilization and efficiency, decreased reproductive performance , reduced milk or egg production embryonic death, tetratogenicity (birth defects), tumors and suppressed immune system function, even when low level are consumed (Cortyl, 2008).

Among animals, pigs are the most susceptible to vomitoxin, while poultry and ruminants are less susceptible. Clinical signs include gastrointestinal problems, soft stools, diarrhea, increased susceptibility to other diseases and decreased performance. In pigs, mild renal nephrosis, reduced thyroid size, gastric mucosal hyperplasia, increased albumin/alphaglobulin ratio, and sometimes mild changes in other haematological parameters have been reported (JEFCA, 2001). Aflatoxin can decrease egg production and increase liver fat (fatty liver syndrome) (Komesli *et al*., 2012).

Control measures of mycotoxins in livestock feeds

Mycotoxins can contaminate agricultural product, both in the field as well as during storage. The use of pre-harvest control strategies for such resistance varieties, field management, the use of biological and chemical agents, harvest management and postharvest applications, including improving drying and storage conditions, together with the use of natural and chemical agents and irradiation have clearly been shown to be important in the prevention of mycotoxigenic mould growth and mycotoxins formation (*CAC,* 2002). The prevention of contamination of corn with fumonisins may be achieved by the use of resistant corn varieties, insect control and seed treatment (Marasas, 1995). At present, the most potent dietary approach to prevent mycotoxicoses in poultry is the use of adsorbents (Surai, 2005).

The use of physical or chemical methods may accomplish detoxification. The effect of heat on fumonisin aqueous solution to 150 ^{0}C or higher, or heating moist corn kernels, indicate a significant reduction of fumonisin concentration. However, heating causes hydrolysis of the primary amine group of the fumonisins, leaving the backbone of the molecule intact. Chemical detoxification of fumonisin-contaminated corn can be achieved by treating it with $Ca\ (OH)_2$, and significant reductions of FB1 (up to 95%) have been reported (Munkvold and Desjardins, 1997).

Pre-harvest control has involved using agronomic practices, which minimize mycotoxins accumulation in the field. These include proper irrigation, pesticide application in some cases, resistant or adapted hybrids, tillage type, and proper fertilization. Unfortunately, breeding for mycotoxins-resistant hybrids has been only partially successful. Fungicides have shown little efficacy in controlling pre-harvest aflatoxin contamination in corn (Duncan *et al*., 1994). Improved screening techniques are needed for monitoring mycotoxins occurrence, for diagnosing toxicities, and for prevention and treatment (CAST, 2003).

Detoxification of mycotoxins by chemical applications was not an acceptable practice in some regions, physical separation of contaminated crops was a very important option for the producer . When contamination cannot be prevented at pre-harvest or during the post-harvest stage, decontamination/ detoxification procedures played an important role in helping prevent exposure to the toxic and carcinogenic effect of mycotoxins through the physical separation and physical, chemical and biological inactivation and/or Any detoxification procedure to reduce the toxic and economic impact of mycotoxins needs the following basic criteria :It must destroy, inactivate or remove the mycotoxins in foods and feeds, It must not produce or leave toxic and/or carcinogenic residues in the final products, It should not alter significantly the nutritional and technological properties of the product, It must be capable of destroying fungal spores and mycelia in order to avoiding new toxin forming under favorable conditions, It had to be technically and economically feasible (Kabak *et al*., 2006).

Cleaning of the maize removed 26.6 to 69.4% of the fumonisins (Sydenham *et al*., 2004), while a 40 to 80% reduction in aflatoxin levels were reported after physical cleaning and separation of mould-damaged kernels and seeds (Park, 2002). Cleaning grains removed kernels with extensive mold growth, broken kernels and fine materials, which reduced mycotoxins concentration (Bullerman and Bianchini, 2007).

Extraction with a variety of solvents including ethanol, aqueous isopropanol, methanol–water, and acetonitril–water removed aflatoxins from contaminated commodities such as cottonseed and peanuts. On the other hand, high cost and problems related to disposal of the toxic extracts restrict its use for large scale application (Rustom, 1997). Chemical compounds (fungicide, herbicide, and surfectant) are known to prevent both mycotoxigenic mould growth and mycotoxins formation during post-harvest season. In addition to application of plant extracts and chemical agents as well as antagonistic microorganisms, such as lactic acid bacteria with their antifungal properties, seem to be potentially very effective in the prevention of mycotoxins formation. The precise antifungal properties of lactic acid bacteria are still largely unresolved but may involve microbial competition (El-Gendy*,* 1981), as Many strategies to prevent mycotoxins contamination of food and animal feed have been developed (Yılmaz*,* 2001).

The fluorescence sorting of maize, cottonseed and figs by examination under UV light is known to be the cheapest and the simplest acceptable way for the screening of aflatoxins. It is clear that no single currently available physical or chemical detoxifycation method will be suitable for all foods and animal feeds. The effectiveness of a method in the detoxification of mycotoxins depends on the nature of the food, environmental conditions such as moisture content, temperature, as well as the type of mycotoxins, its concentration and the extent of binding between mycotoxins and constituents (*Bata,* 1999). Any management practice to maximize plant performance and decrease plant stress will decrease aflatoxin contamination (Widstrom 1996).

CONCLUSION AND RECOMMENDATION

Livestock production is a major source of income in most sub-Saharan countries and they have different source of feed for their livestock depending on their environment and way of production system. Mycotoxins are ubiquitous and have been detected in many parts of the world and are presently considered as one of the most dangerous contaminants of food and animal feeds. Different mycotoxins such as Aflatoxins, Zearalenone, Vomitoxin, Ochratoxin, Fumonisins and T-2 Toxin are produced by fungal genera aspergilus , fusarium and pencillin. Mycotoxins formed before harvesting or post harvesting (storage) of plants or forage materials. Formation of mold as a result mycotoxins in feeds are a major barrier for livestock production as it reduce feed and food availability, risk for health of animal as well human, decrease product and productivity of livestock.

Adverse effect on animal health and production have been recognized in intensively farmed animals such as poultry , swine and cattle as a consequence of the consumption of high level of cereals and oilseeds in the diet. Animals have varying susceptibility to mycotoxins depending on physiological, genetic and environmental factors. Different factors affects for mycotoxins in feeds like physical (water activity, oxygen availability and surface area), chemical (carbohydrates, fat, protein, trace elements and amino acid composition) and environmental (Excessive moisture in the field and in storage, temperature extremes, humidity, drought, variations in harvesting practices and insect infestations).

The effects of mycotoxicosis in livestock's are diverse, varying from immune suppression to death in severe cases, depending on toxin-related (type of mycotoxins consumed, level and duration of intake), animal-related (animal species, sex, age, breed, general health, immune status, nutritional standing) and environmental (farm management, hygiene, temperature). Ruminants such as cattle, sheep and goats are less common for their sensitivity to the negative effect of mycotoxins than are non ruminants. However, production reproduction and growth can be alerted when they consume mycotoxins contaminated feed for extended periods of time. Mycotoxicosis produce a variety of clinical signs, depending on factors such as type and concentrations of mycotoxins, the duration of exposure, and the species, gender, age, and health status of the animal.

Mycotoxins can contaminate agricultural product, both in the field as well as during storage. The use of pre-harvest control strategies for such resistance varieties, field management, the use of biological and chemical agents, harvest management and postharvest applications, including improving drying and storage conditions, together with the use of natural and chemical agents and irradiation have clearly been shown to be important in the prevention of mould growth and mycotoxins formation. Chemical compounds (fungicide, herbicide) are known to prevent both mould growth and mycotoxins formation during post-harvest season. The effectiveness of a method in the detoxification of mycotoxins depends on the nature of the food, environmental conditions such as moisture content, temperature, as well as the type of mycotoxins. Therefore presences of mycotoxins in feeds have great impacts in livestock and human health.

So to prevent and control their negative impact the following points are forwarded:

Feeds have to be kept hygienically and prevent molds formation by using available methods that is accessible for them in their environment Aware Extension workers and owner's of livestock on impact of mycotoxins in feeds: implications to livestock and human health.

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