Toxins, Contaminants and their prevention by usage of toxin binder and feed sanitation program

Dr. Bikash Puri

Introduction

• Poultry is one of the fastest growing agricultural sub-sector and its growth is expected to continue.
• Global human population is estimated to reach 9.6 billion in 2050, with about 70% living in urban areas and income increasing by 2% annually.
• In this context, Alexandratos and Bruisma (2012) projected that the demand for animal source food could grow by 70% between 2005 and 2050.

<table>
<thead>
<tr>
<th>Meat</th>
<th>%Increase (expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>66</td>
</tr>
<tr>
<td>Pork</td>
<td>45</td>
</tr>
<tr>
<td>Poultry</td>
<td>121</td>
</tr>
<tr>
<td>Egg</td>
<td>65</td>
</tr>
</tbody>
</table>

• Quality feed = healthy livestock’s
• Remember: Quality feed requires control of feed contaminants.
• However, in many countries public concern about the safety of foods of animal origin has been heightened.
• Contaminants:
  – A substance which **not intentionally added to feed** but present in feed as a result of production, processing, treatment, packaging, transport or as a result of environmental contamination.

• Toxic:
  – Substances found in feeds which produce deleterious effect on ingestion
  – Toxic substances are generally lethal beyond a given level of intake and/or on prolonged ingestion produces adverse physiological responses.

**Possible contaminants in animal feed**

1. **Biological Contaminants**
   – Transmissible Spongiform Encephalopathies: Example-Bovine spongiform encephalopathy (BSE),
   – Pathogenic enteric microbes: Example- Bacteria (Bacillus sps, Clostridium Sps, Escherichia coli, Mycobacterium sps, Salmonella enterica, etc.

2. **Chemical contaminants**
   – Pesticides/Pesticide residues: Example- Aldrin, Benzenes, Chlorpyrifos,
   – Heavy metals/Radionuclides: Example- Arsenic, Cadmium, chromium, lead, cesium,
   – Medicated feed additives
   – Mycotoxins; Other: Example- Ethoxyquin, Dioxins, PCBs, Others

3. **Physical contaminants**
   – Foreign material (Plastics, glass, rocks, dirt, stalks); Metal (equipment); Wood, etc

**Biological Contaminants**

• Animal feed provides an **ideal nutrition source for microorganisms** and generally has a pH value in the range needed for proliferation.

• Source: Contaminated raw ingredients, or due to contamination during harvesting, processing, distribution and/or preparation at the feed mill, or on-farm.
• These microorganisms and those from contamination through slaughtering can migrate to the skeletal muscles via the circulatory system.

• When carcasses and cuts are subsequently handled through the food distribution channels, where they are reduced to retail cuts, they are subjected to an increasing number of microorganisms from the cut surfaces.

Example:
– The transmission of *Salmonella* from feed to animals, and to derived food products, has already been established.
– Emergence of unknown pathogens in livestock, such as prions (causing transmissible bovine encephalitis) (Sakuda et al., 2011).
– Similarly spores of *B. anthracis* are capable of surviving for long periods in the environment and in contaminated animal feed, particularly meat and bone meals prepared from animals which have died from anthrax.

2. Chemical Contaminants

• A wide range of organic and inorganic compounds are present in feedstuffs,

• Examples:
  – *Pesticides/Pesticide residues*: Example- Aldrin, Benzenehexa chloride, Chloropyrifos, Dieldrin, DDT, Methoxychlor, etc.
  – *Heavy metals/Radionuclides*: Example-Arsenic, Cadmium, chromium, lead, cesium, plutonium,
  – *Other*: Example- Ethoxyquin, Dioxins, Metal, Others

• These compounds are effectively transferred from feed to milk and eggs and accumulate in meat and liver imposing serious health hazards to consumers.

Examples:
– Cows grazing pastures that are close to industrial areas produce milk with higher dioxin content than cows from rural farms.
– Contamination of feeds and herbage with cadmium may occur as a result of applying certain types of fertilizers to crops and pastures.
– On the other hand, mercury in feeds arises from the use of fish meal while mercury contamination arises from industrial and urban pollution.
**Fungal contaminants**

- Fungi frequently contaminate grains in the field, during harvest or during storage, processing or feeding.
- Fungi growth typically is associated with extremes in weather conditions.
- It has been estimated that 25% of the world's crop production is contaminated with mycotoxins (Surai and Mezes, 2005).
- Fungal contamination won't always contain mycotoxins.
- However, contamination of the feeds with fungi damages their organoleptic properties and increases poisoning risk by decreasing their nutritional value.
- Thereby, adversely affecting the production and health of animals.

**Mycotoxins**

- Majority of the fungi that form mycotoxin belong to three genera: *Aspergillus*, *Penicillium* and *Fusarium*.
- It is well documented that mycotoxin consumption causes a decrease in performance as well as decreased growth rate and poor feed efficiency (Pestka, 2007; Hanif et al., 2008).
- However, the toxic effects depend on the amount of absorption, number of the metabolites that are formed, exposure period and sensitivity of the animal.

<table>
<thead>
<tr>
<th>Mycotoxin</th>
<th>Resistant</th>
<th>Sedentary</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>aflatoxin</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>t3 fumonisin</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>deoxynivalenol</td>
<td>+</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>zearalenone</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>fumonisin</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table**: Susceptibility of different mycotoxins on different livestock species (++++ = highly resistant, +++ = resistant, ++ = moderately resistant, + = susceptible).

- The most important role of feed mills is to keep the levels of mycotoxins as low as possible, while multi-mycotoxin contamination should be also avoided.
- Most of the mycotoxins occur concurrently and a commodity usually contains more than one mycotoxin at the same time.
Veterinary drugs in animal feeds

- Some veterinary medicines used to treat animals can produce residual contamination in meat and milk products and may result in acute food poisoning, allergic reactions or the development of antibiotic resistant microorganisms and risk to human health.
- The concern remains that the use of antibiotics may contribute to the prevalence of antimicrobial resistance (Lynas, et al., 1998). So reducing their effectiveness in human disease.
- Chlortetracycline, sulphonamides, penicillin and ionophores are amongst the most widely used antibiotics.

PLANT TOXINS

- Toxic compounds are present in the foliage and/or seeds of plant that is used in practical animal feeding (D'Mello, 2000).
- These substances that when present in animal feed or water reduce the availability of one or more nutrients.
- Thereby, adversely affecting the health of poultry flock.
### COMMON ANTINUTRITIONAL FACTORS

<table>
<thead>
<tr>
<th>SN</th>
<th>Antinutritional factor</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arabinoxylans</td>
<td>Reduced nutrient digestibility and absorption</td>
</tr>
<tr>
<td>2</td>
<td>Beta-glucans</td>
<td>Formation of gels that increase the viscosity of the intestinal contents.</td>
</tr>
<tr>
<td>3</td>
<td>Sinapoyl</td>
<td>Yolk discoloration</td>
</tr>
<tr>
<td>4</td>
<td>L-Canavanine</td>
<td>Adversely affect utilization of the amino acid arginine in intact feed proteins.</td>
</tr>
<tr>
<td>5</td>
<td>Lectins</td>
<td>Causes the atrophy of the microvilli, reduces the viability of the epithelial cells, and increases the weight of the small intestine caused by hyperplasia of crypt cells.</td>
</tr>
<tr>
<td>6</td>
<td>Phytate</td>
<td>Block the absorption of phosphorus and other minerals, particularly calcium, magnesium, iron, and zinc.</td>
</tr>
<tr>
<td>7</td>
<td>Protease inhibitors</td>
<td>Reduce the availability of amino acids</td>
</tr>
<tr>
<td>8</td>
<td>Saponins</td>
<td>Bitter and reduce feed intake</td>
</tr>
<tr>
<td>9</td>
<td>Tannins</td>
<td>Tannins have the ability to bind protein making it unavailable for absorption</td>
</tr>
</tbody>
</table>

### A systematic approach to prevent contaminants in animal feed

1. **Raw material selection and purchase**
   - Quality feed not just about nutritional content
   - Handling, storage and source affect the level of bacterial and mould contamination
   - Evaluate suppliers, additives needs: dosage and application
   - Supplier history
   - Certificate of analysis if available
   - Audit of high risk materials and suppliers

   **Improve raw materials microbiological quality to stop or decrease continuous entrance of these undesirable microorganisms**

2. **Formulation**
   - Reduce or avoid ingredients which can harbor high levels of *microbes*, eg. fishmeal, meat meal, blood-derived products
   - However, these ingredients offer certain benefits (low cost and/or high protein quality) that eliminating them from formulas can be problematic.
   - Thus, it is best to implement a quality control program that includes microbiological monitoring.
3. Prevent contamination from entering the facility
   • Controlling dust & Managing the flow of equipment
   • Reducing rodent infestations
   • Preventing contamination from wild birds
   • Ensuring the sanitation of transport vehicles

Potential contaminants entering the dump pit by truck

4. Reduce microbial multiplication within the plant
   • Discovering microbial growth niches and reducing conditions that lead to growth
   • Identify poor handling practices
   • Identify maintenance problems
   • Train the workers
   • Avoid cross contamination

Looking for **HOT SPOT**

A hot spot is:
   • Either a point INSIDE THE LINE where microbial growth is occurring
   • Or a point where contamination is introduced into the line

Gives a quick picture of the feed mill
Bacterial Control

- An effective bacterial control programme
- Eliminates bacteria
- Prevents re-contamination
- Improves feed hygiene and biosecurity
Decontamination Options

- Thermal processing (pelleting)
- Chemical addition
  - Organic acid
  - Probiotics alone or combination
  - Formaldehyde based products

Heat treatment

- Standard pelleting temperature and time not sufficient to kill salmonella
- Special equipment now installed in feed mills to achieve minimum log 6 reduction in salmonella like: Expanders/Extruders, long term conditioners, sterilization chambers, etc

- Recognised standard for achieving minimum 6 log reduction in salmonella:

  A combination of heat, moisture and time is required to achieve salmonella kill

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>10% moist</th>
<th>15% moist</th>
<th>20% moist</th>
</tr>
</thead>
<tbody>
<tr>
<td>74</td>
<td>19</td>
<td>3</td>
<td>0.6</td>
</tr>
<tr>
<td>85</td>
<td>6</td>
<td>1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

  82°C for 2 minutes at minimum 15% moisture
Heat treatment

- Steam heating, pelleting, extrusion and expansion all can reduce the microbial load in ingredients and complete feeds provided
  - Temp > 85°C, for at least four minutes
  - Moisture content of between 14.5% and 15%
- Required temperatures to achieve zero *Salmonella* concentrations usually end up being destructive to the nutritive value of the heated feedstuff
- High cost of investment
- Higher running costs, particular start up
- Can reduce throughput
- Excessive heat can lead to denaturation of proteins, Destruction of enzymes and vitamins

Other re-contamination points include:

- Bucket elevators and conveyors
- Finished product silos
- Finished product bulk discharge
- Trucks
- Bags in mill ware house
- Bulk feed and bags on farm

Adding organic acids

- Organic acids known to be quite effective against *Salmonella* & other microbes in animal feed when used at the **correct dosage**
- Problem with this mode of control is that the **required dosage** is rather higher than currently practiced (for cost saving reasons) No care is taken - acidity buffered by other ingredients in the diet
Cont..
• Not broad spectrum & pH dependent activity
• Corrosiveness
• Quoted vs non quoted OA
• OA may negatively affect diet palatability
• Recontamination
• Note:
  – Organic acid act by lowering the PH.
  – Gram negative more sensitive than gram positive organism

Feed hygiene using formaldehyde
• Wide spectrum of antibacterial activity
  • Gram positive bacteria (including Clostridium spp.)
  • Gram negative bacteria
• Unique properties against
  • Mold and spores
  • Virus
  • Protozoa
• Does not generate bacterial resistances

Protocol for sanitizing feed and feed mill
• Mix 5 kg (formaldehyde + organic acid) premix with corn or wheat because they are more abrasive than DORB.
• The usual practice is to back again next day in the morning, minimum 8 hours gap is recommended
Factor to be considered while selecting the mycotoxin

- Able to adsorb a wide range of mycotoxins
- Low inclusion rate
  - Reduce cost, dilution effect, but harder to mix evenly
- Easy to mix uniformly
- Heat and storage stability
- No affinity for vitamins, minerals, etc.
- Functional under pH ranging from 2-7
- Biodegradability after excretion
- Safe for animals and humans
- Palatability
- No potential for other sources of contaminants

Adsorbents: Mineral clays

- Many products available
  - Bentonites
  - [used as a pellet binder, but require >4%]
  - Zeolites
  - Aluminosilicates
  - Hydrated sodium calcium aluminosilicate (HSCAS)
  - Activated charcoal
- Adsorption depends on the chemical structure
- Capacity can vary from 0 to 87%
- Mostly effective for aflatoxins, but little efficacy for: Zearalenone, T-2 toxin, Ochratoxin, Diacetoxyscirpenol, Fescue Toxin
- Mineral clays reduce the utilization of Mn, Zn, Mg, Cl, Cu and Na

Adsorbents: Yeast cell wall

- Yeast cell wall derived and/or modified glucomannan
- Pros and Cons
  - Lower inclusion levels than clays
  - less dilution of diet
  - Broader claims for different types of mycotoxins
  - Efficacy often variable
- Saccharomyces cerevisiae is a yeast species which has been domesticated for at least 3,000 years
- Not live yeast, rather the yeast cell wall
- Manno-oligo saccharides
  - 1,3, 1,6 β glucans
  - Diverse molecule
  - Strong immune stimulator effect

The ability of various bacteria, yeast, fungi and enzymes in detoxifying mycotoxins by transformation, cleavage and catabolism has been recently reviewed

Example: *Eubacterium* mycocharum, *Acarospora* cerevisiae lactobacillus 9980-795
To Avoid Mycotoxin Formation Consider the following:

1. Moisture content below 12%.
2. Relative humidity below 60%.
3. Storage temperature below 20 °C.
4. Clear grain, avoid broken kernels.
5. Control insects and rodents.
6. Avoid stress (frost, heat, pH changes).
   • The incorporation of technical mould inhibitors further enhances stability of feed and ingredients during storage.