CHAPTER 11

Feed Safety of DDGS

Introduction

FEED SAFETY HAS A SIGNIFICANT IMPACT ON OUR GLOBAL FOOD SAFETY SYSTEM because it not only directly affects animal health and productivity, but it also affects the safety of animal-derived food products for human consumption. Feed contamination can affect the entire food chain and costs millions of dollars in lost revenue and increased costs. Furthermore, it creates fear and panic among consumers, reduces the amount of food available for consumption and reduces consumer trust in the food system. Illness, death and potential future health risks can also occur. As a result, feed safety is directly linked to food safety and had led to the concept of "feed is food."

We live and work in a global economy, with feed ingredients and food products imported and exported in all countries. However, feed and food safety standards and regulations vary dramatically among countries. Feed and feed ingredients can potentially be contaminated with undesirable microbiological, physical and chemical hazards, and because of the increasing interconnectivity of global supply chains, one feed contamination event can have widespread effects on animals and food. Therefore, as the global marketing, production and distribution of feed and food continues to increase, the potential risks of acquiring undesirable feed contaminants also increases (Liu, 2011). In fact, the increased need for transparency of origin of some feed ingredients has led to the development of analytical technologies to authenticate and differentiate botanical and geographical origin of grains and co-products in the international feed market (Tres et al., 2014; Tena et al., 2015).

It is essential for feed ingredient suppliers, buyers and feed manufacturers to not only be in compliance with local government regulatory agencies, but also develop and implement programs for continuous quality and safety improvements in all aspects of the feed and food chain. Many progressive feed and animal production companies in over 150 countries have implemented ISO (International Organization for Standardization) standards to more efficiently and safely produce products which ultimately lead to more standardized products for consumers. Companies that implement ISO standards must document standards and ensure compliance through internal audits, while also verifying compliance through external audits with the goal of becoming certified. In addition, progressive feed manufacturers have also implemented HAACP (Hazard Analysis and Critical Control Point) systems which are designed to prevent feed and food contamination events along every step of the manufacturing, storage and distribution segments of the feed and food supply chains. There are seven principles in developing and implementing a HAACP plan including:

1. Conduct a hazard analysis
2. Identify critical control points
3. Establish minimum and maximum limits of the manufacturing process to control potential hazards
4. Establish critical limits
5. Establish monitoring procedures and corrective actions
6. Establish record-keeping procedures
7. Establish verification procedures

Food safety management systems must be designed to manage quality and provide continual improvement within feed companies by combining ISO 9001 and HAACP principles to decrease this risk of food-borne pathogens, emerging new pathogens and protect branded products by controlling risk.

Implementation and monitoring of feed and food safety systems are continually improving in many countries. In fact, the U.S. has recently adopted even more rigorous feed safety regulations (including DDGS production) to further minimize the risk of food safety hazards for consumers. In January, 2012, the Food Safety Modernization Act was signed into law in the U.S., and was the first significant update and expansion of the U.S. Food and Drug Administration's (FDA) food and feed safety regulatory powers in nearly 70 years (Brew and Toeniskoetter, 2012). Although feed production facilities (including ethanol plants) in the U.S. have been required to be registered with the FDA since 2002, this new law provides the FDA greater authority to revoke a facility's registration due to food or feed safety reasons. This law also prohibits shipping food or feed by interstate commerce without a current registration. As a result, the FDA can force termination of sales, and even order a mandatory recall, if it finds significant food or feed safety violations. The implementation of this new law requires ethanol plants to develop and implement a Hazard Analysis and Critical Control Point (HACCP) plan for the co-products they produce. This law requires feed manufacturers to evaluate known or potential feed safety hazards, identify and implement preventative control procedures, monitor those procedures, take corrective actions when they are not working and periodically verify the overall system is working effectively. There is also a requirement of written documentation of these feed safety production procedures, and ethanol plants are inspected by the FDA for compliance. Enactment of this new law will provide even greater assurance and confidence that U.S. DDGS will meet the most strict feed safety requirements in the world.

In addition to new regulations and compliance with the Food Safety Modernization Act regulations, some U.S. ethanol plants are also implementing GMP (Good Manufacturing Practices)+ Feed Certification to meet strict feed safety standards for co-products in many countries and markets. The GMP+ Feed Certification Scheme was first developed in 1992 by the feed industry in the Netherlands in responses to various events involving contamination of feed ingredients. Today, GMP+ Feed Certification has expanded to become an international program managed by GMP+ International in collaboration with numerous international stakeholders. In 2013, the GMP+ program was further expanded to now include GMP+ Feed Safety Assurance and GMP+ Feed Responsibility Assurance. Implementation of GMP+ Feed Safety Assurance by ethanol plants is becoming necessary as a "license to sell" DDGS to progressive integrated feed and animal production companies in many countries and markets by complying with standards for the assurance of feed safety throughout all segments of the feed supply chain. Furthermore, there are increasing demands for the global animal feed industry to operate in a more responsible manner by sourcing feed ingredients that minimize effects on competing with food security for humans (e.g. soybeans and fishmeal) and the minimizing negative impacts on the environment.

Fortunately, the risk of hazardous microbial, physical and chemical contaminants in U.S. DDGS is extremely low. Corn and corn DDGS have no antinutritional factors except phytate indigestible form of phosphorus), which is found in various concentrations in all grains and grain-based co-products. However, widespread commercial availability and use of phytases have been shown to be cost effective for degrading phytate and improving phosphorus digestibility of grain-based diets for monogastric animals.

The focus of this chapter to provide a brief overview of potential feed safety microbiological, chemical and physical risk factors in DDGS that need to be considered when feeding DDGS to various food animal species. The primary potential contaminants of concern are pathogenic microorganisms, mycotoxins, antibiotic residues and sulfur, and readers are encouraged to refer to **Chapter 13** (Antibiotic Use in DDGS Production), **Chapter 14** (Mycotoxins in DDGS), **Chapter 15** (Benefits and Concerns of Sulfur in DDGS), and **Chapter 19** (DDGS and *E. coli* O157:H7 Shedding in Beef Cattle) for more detailed information on these topics.

Potential Microbiological Risk Factors

Corona virus transmission in feed and feed ingredients

Corona viruses (transmissible gastroenteritis virus – TGEV; porcine delta corona virus – PDCoV; porcine epidemic diarrhea virus - PEDV) have had devastating effects in the global pork industry. These viruses are excreted in feces; can be transmitted by contaminated equipment, personnel and other fomites; cause severe diarrhea, high mortality, subsequent reductions in growth performance and reduce profitability. The Porcine Epidemic Diarrhea virus (PEDV) had devastating effects on pig mortality in the U.S. in 2013, and feed and feed ingredients were identified as significant risk factors for its transmission. As a result, research was conducted to determine corona virus survival in feed and feed ingredients and potential mitigation strategies to minimize their transmission through feed to pigs. Dee et al. (2015) showed that PEDV survival in feed varies among types of ingredients and appears to survive the longest in soybean meal, but applying a formaldehyde-based liquid treatment caused virus inactivation in all ingredients. Similarly, Trudeau et al. (2017) evaluated survival of PEDV, TGEV and PDCoV in various feed ingredients, including DDGS sources with variable oil content (**Figure 1**). The PED virus survived the longest, and TGEV and PDCoV also had high survival in soybean meal compared to several all other ingredients. Interestingly, virus survival was very low in the low- and high-oil DDGS sources (1.0 and 0.8 days for TGEV and 0.7 to 0.6 days for PEDV, respectively), compared with the medium-oil DDGS source (1.7 days for TGEV and 7.3 days for PEDV). In contrast, PDCoV survived longer in the low- and high-oil DDGS sources, compared with medium-oil DDGS, blood meal, complete feed, meat meal and spray dried plasma. Survival time of all viruses was much less in DDGS sources than in soybean meal, and survival of TGEV and PDCoV in DDGS was much less compared with corn. These results suggest soybean meal is a greater risk factor for transmission of corona viruses via feed than DDGS and other common feed ingredients. Unfortunately, no studies have been conducted to determine if other pathogens, such as avian influenza virus, can be transmitted through feeding ingredients, or their potential survival in feed ingredients during transport and storage.

Salmonella transmission in feed and feed ingredients

No data are available, nor are there government regulations related to controlling potential *Salmonella* contamination of DDGS. There has been a long-term scientific debate regarding the feasibility and likely efficacy of enforcing a Salmonella negative standard for animal feeds to reduce the incidence of human salmonellosis (Davies et al., 2004). It is difficult to assess the impact of reducing *Salmonella* contamination in animal feeds on the risk of human foodborne salmonellosis. Factors that may reduce or eliminate the potential benefit of regulatory interventions in commercial feed include:

- Widespread use of on-farm feed mixing
- Incomplete decontamination of feed during processing
- Post-processing feed contamination at the feed mill
- Contamination during feed transport or on-farm storage
- Numerous non-feed sources of *Salmonella*
- High risk of post-farm infection in lairage
- Post-harvest sources of *Salmonella* contamination

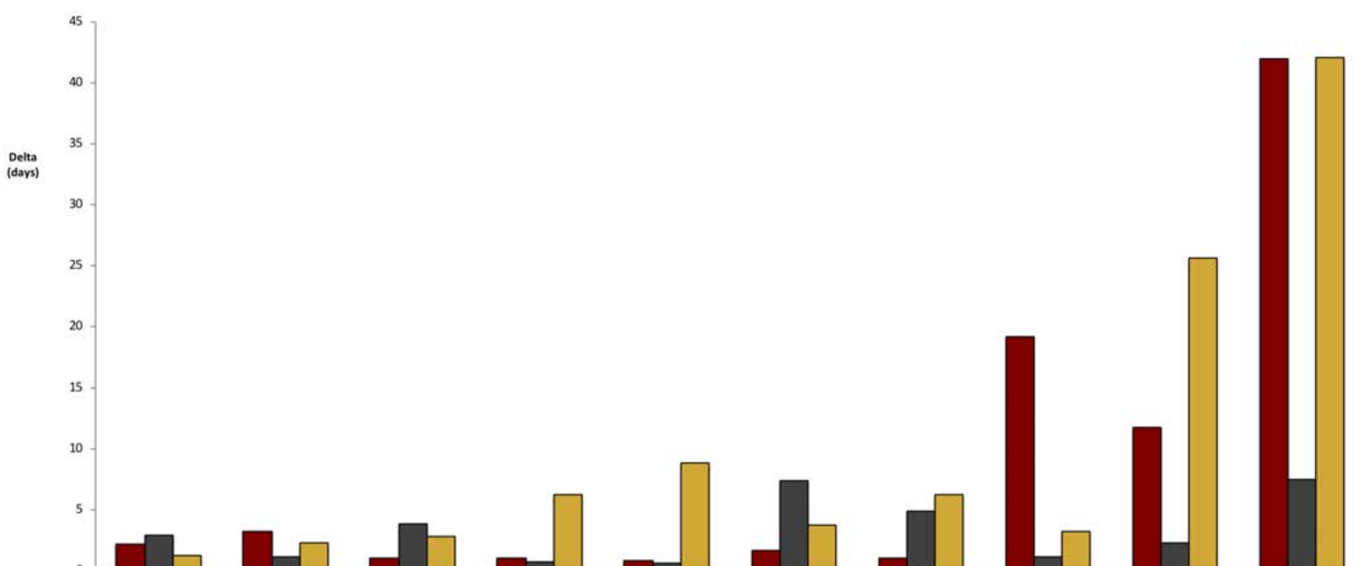
Potential risk of *Salmonella, Escherichia coli O157:H7* and *Clostridium perfringens* shedding when feeding DDGS diets

The gastrointestinal tracts of animals naturally contain *E. coli O157:H7* and *Salmonella*, which are foodborne pathogens and can be shed in feces leading to potential contamination of food products and cause illness to consumers. A series of studies have been conducted by one research group (Jacob et al., 2008a,b,c) that showed an inconsistent but generally low prevalence of *E. coli O157:H7* shedding when DDGS was fed to beef cattle. Other studies (Peterson et al., 2007; Nagaraja et al., 2008) have also shown that *E. coli* shedding occurs in beef cattle, but feeding high dietary levels of DDGS did not influence pathogen shedding. Furthermore, there was no association between feeding DDGS or dry-rolled corn diets on *E. coli O157:H7* or *Salmonella* prevalence (Jacob et al., 2009). These results indicate there is minimal risk of increased shedding of *E. coli O157:H7* or *Salmonella* from feeding DDGS to cattle.

Further studies in growing-finishing pigs have shown no effect on the susceptibility or colonization of *Salmonella typhimurium* when feeding DDGS diets (Rostagno et al., 2013). In broilers, Loar et al. (2010) showed feeding DDGS diets had no effect on *Clostridium perfringens* and *Escherichia coli* counts in cecum contents of broilers. These results indicate there appears to be minimal risk, if any, that feeding DDGS to beef cattle, swine and broilers is associated with increased risk of transmission of food-borne pathogens to meat products.

Mycotoxins

Of all feed safety risk factors for DDGS, the potential for mycotoxin contamination is perhaps the greatest concern. Mycotoxins are produced by fungi during the growing season and under specific environmental conditions during storage. From a human food safety perspective, aflatoxins are the only class of mycotoxins regulated by the U.S. FDA because of it's carcinogenic effects. However, if feed ingredients contain high dietary concentrations of various mycotoxins, detrimental effects on nutrient utilization, immune function and several other adverse physiological effects can occur that lead to reduced animal health and performance. Swine and poultry are generally more susceptible to mycotoxins than ruminants, and young animals are more susceptible than older animals in each species. Although mycotoxins are produced by specific fungi strains, measuring mold counts in feed ingredients are worthless because these analyses provide no information or confirmation regarding the potential presence or concentrations of mycotoxins.



	Blood Meal	Complete Feed	Meat Meal	Low Oil DDGS	High Oil DDGS	Medium Oil DDGS	Meat and Bone Meal	Spray Dried Porcine Plasma	Corn	Soybean Meal
TGEV	2.2	3.2	1.0	1.0	0.8	1.7	1.0	19.2	11.8	41.9
PEDV	2.8	1.1	3.9	0.7	0.6	7.3	4.9	1.1	2.3	7.5
PDCoV	1.2	2.3	2.8	6.2	8.8	3.8	6.2	3.3	25.6	42.0

Figure 1. Corona virus (transmissible gastroenteritis – TGEV, porcine epidemic diarrhea – PEDV, porcine delta cornona virus (PDCoV) survival in complete feed and common feed ingredients (Trudeau et al., 2017)

The prevalence and concentrations of mycotoxins in corn, other grains and DDGS vary among countries around the world (Biomin, 2014). Studies have shown that the prevalence of mycotoxin contamination and concentrations in DDGS produced in the USA are much lower compared with feed ingredients produced in China (Biomin, 2014; Guan et al., 2011; Li et al., 2014). Two extensive surveys of mycotoxin contamination in DDGS produced in the USA have been published (Zhang et al., 2009; Khatibi et al., 2014) that show relatively low concentrations of various mycotoxins in DDGS relative to existing guidelines. Zhang et al. (2009) analyzed a total of 235 DDGS samples from 20 ethanol plants in the U.S., as well as 23 DDGS samples collected from 23 export shipping containers from 2006 to 2008, and reported that:

1. None of the DDGS samples contained aflatoxins or deoxynivalenol concentrations above the U.S. FDA guidelines for use in animal feed.

2. None of the DDGS samples had fumonisins concentrations greater than FDA guidelines for use in dairy, beef, swine, poultry and aquaculture feeds, and only 10 percent of the samples contained concentrations of fumonisins greater than maximum recommend concentrations for use in horse and rabbit feed (which are the most sensitive species to fumonisins).

3. None of the samples contained detectable concentrations of T-2 toxins, and most samples contained undetectable concentrations of zearalenone.

4. Use of containers to export DDGS did not lead to increased mycotoxin production.

More recently, Khatibi et al. (2014) conducted a DDGS mycotoxin survey where they collected and analyzed 141 corn DDGS samples, from 78 ethanol plants located in 12 states in the U.S., for the presence and concentrations of various tricothecenes. There was an unusually high prevalence of *Fusarium spp.* molds in corn produced in the USA in 2011, which was a result of adverse weather conditions during the corn growing season. In this extreme case, 69 percent of the samples contained no detectable levels of deoxynivalenol, only 5 percent of the samples were above the FDA advisory levels for swine, and only 19 percent of the samples contained detectable concentrations of zearalenone.

Results from these studies indicate mycotoxins can be present in corn DDGS, but the prevalence and concentrations of DDGS produced in the U.S. are much lower than DDGS produced in China. Therefore, depending on geographic origin and the prevalence of mycotoxins in corn during a given year, high diet inclusion rates of DDGS can be used if the prevalence and concentrations of mycotoxins are low to minimize the risk of exceeding total diet mycotoxin concentrations above recommended levels.

Potential Chemical Risk Factors

Antibiotic residues

A few types of antibiotics are often added in small amounts to fermenters to control bacterial infections during starch fermentation to produce ethanol and co-products. The U.S. FDA has not restricted the use of antibiotics in ethanol production, and the predominant one used (virginiamycin) has been reviewed by expert scientific panels and deemed Generally Recognized as Safe. The global use of antibiotics for growth-promoting purposes has been eliminated in the U.S. and E.U., with other countries also decreasing their use in food animal production. The primary concerns related to antibiotic use are the potential risks of residues in meat, milk and eggs and the development of antibiotic resistance in animals and humans. The U.S. FDA has conducted surveys to determine the prevalence and concentrations of several antibiotic residues in DDGS using a multi-residue detection method (de Alwis and Heller, 2010; Kaklamanos et al., 2013), but the results have not been published. Choice of analytical procedures is very important because the presence of some antibiotic residues (e.g. virginiamycin) can only be accurately quantified using bioassays.

Only one study has been conducted to determine the prevalence, concentrations and biological activity of antibiotic residues in 159 distillers co-product samples, collected quarterly from 43 ethanol plants in nine states in the U.S. (Paulus-Compart et al., 2013). The results from this study showed that 13 percent of the samples contained low (less than1.12 mg/kg) concentrations of antibiotic residues. When extracts of samples were tested for biological activity using selected sentinel bacteria, only one sample (which had no detectable concentrations of antibiotic residues) inhibited growth of *Escherichia coli*, and none of the samples inhibited *Listeria monocytogenes* growth. Therefore, the likelihood of detecting antibiotic residues in DDGS is very low, and if detected, there is minimal risk that residues have any residual biological activity. Since the time this study was conducted, there has been a significant decline in antibiotic use in ethanol production, which is attributed to improved sanitation and availability of other non-antibiotic additives to control bacterial infections during fermentation. In fact, some ethanol plants are now producing antibiotic-free DDGS.

Dioxins

No studies have been conducted to assess potential dioxin contamination in DDGS, nor are there any regulations. Dioxins are a group of chemicals representing over 210 different compounds and are ubiquitous to the environment. Only 17 of these compounds are of toxicological concern and are not produced intentionally. Therefore, they can't be simply prohibited. Dioxins are formed as a by-product of chemical processes, and are insoluble in water and soluble in lipids. Dioxins are not biodegradable and can accumulate in the food chain. Maximum dioxin concentration limits have been established for citrus pulp and kaolinitic clay, and fish oil and fish meal are the most common feed ingredients with dioxin contamination. Animal fats may also contain dioxins, but at low concentrations, while cereals and seeds, milk by-products and meat and bone meal are less commonly contaminated with dioxins.

Genetically modified corn (GM)

Unlike the U.S., several countries have concerns about the safety of genetically modified (GM) crops, and as a result, legally prohibit or restrict production or imports of some, if not all GMO grains and grain co-products. This restriction continues to be controversial, although there are limited supplies of feedstuffs for animal production in many countries around the world to provide adequate food security. In 2015, about 92 percent of all corn acres planted in the USA utilized genetically engineered varieties (USDA-NASS, 2015). Therefore, the majority of U.S. corn DDGS that is produced uses GM corn varieties.

More than 165 genetically engineered events in 19 plant species (including corn and soybeans) have been approved in the U.S. (James, 2013), and all were evaluated using a comprehensive safety risk assessment by the U.S. FDA. All of the genetically modified events evaluated by the U.S. FDA, as well as regulators in Japan, during the past 20 years have been shown to have equivalent safety compared with conventional crop varieties (Herman and Price, 2013). Furthermore, internationally accepted guidelines developed by the Codex Alimentarius Commission (www.codexalimentarius.org) are used for risk assessment of genetically modified organisms.

There is a substantial amount of scientific evidence that GMO crops are safe. The Council for Biotechnology Information has published a statement indicating that "The Food and Drug Administration (FDA) has determined that biotech foods and crops are as safe as their non-biotech counterparts. The American Medical Association, the American Dietetic Association, and the U.S. National Academy of Sciences have also declared biotech foods safe for human and animal consumption. In addition, since being introduced to U.S. markets in 1996, not a single person or animal has become sick from eating biotech foods. Other international groups that have concluded biotech foods and crops are safe are The United Nations Food and Agriculture Organization, the World Health Organization, the International Council for Science, the French Food Agency, and the British Medical Association. The European Food Safety Authority (EFSA) has also found several biotech varieties to be safe for human and animal consumption." Related links for detailed analysis of the safety of GM crops in the food chain are as follows:

Position of the American Dietetic Association: Agricultural and Food Biotechnology
http://download.journals.elsevierhealth.com/pdfs/journals/0002-8223/PIIS0002822305021097.pdf

World Health Organization: Modern food biotechnology, human health and development: an evidence-based study
http://www.who.int/foodsafety/publications/biotech/biotech_en.pdf

United Nations:Effects on human health and the environment
http://www.fao.org/newsroom/en/news/2004/41714/index.html

National Academy of Sciences: Safety of Genetically Engineered Foods
http://books.nap.edu/catalog/10977.html?onpi_newsdoc07272004

Food producing animals have been consuming 70 to 90 percent of genetically modified crops and co-products for more than 15 years (Flachowsky et al., 2012). A recent comprehensive review (van Eenennaam and Young, 2014) analyzed data representing over 100 billion animals fed genetically modified crops and co-products and found no evidence of adverse effects on animal health and productivity. Unfortunately, despite the absence of adverse effects, trade barriers and import restrictions have been created in some countries to prevent importation and use of corn and DDGS produced in the USA in animal feed in those countries.

Potential Physical Risk Factors

The risk of physical contaminants is extremely low. The most common physical contaminants in grain and feed ingredients are stones and fragments of metal, glass, wood or plastic. Physical hazards are classified as "hard or sharp" or "choking" hazards in food products. Agricultural production and loading facilities frequently have compacted gravel or stones which can inadvertently contaminate feed ingredients during loading. Metal to metal contact of conveyors and loading equipment can produce metal fragments during normal wear, and these fragments can occasionally be found in the grain or feed ingredient mass in transport containers or vessels. In facilities that use glass and plastic containers for storing materials, broken fragments of the materials can also contaminate feed ingredients. All of these potential physical hazards are uncommon, but can be present as a result of facilities and processes used to produce, load and transport feed ingredients.

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