Managing mycotoxins in on farm swine feeds in the northeastern U.S.

by

Megan Andersen

B.S., State University of New York at Cobleskill,
2016

A THESIS

Submitted in partial fulfillment of the requirements

for the degree

MASTER OF AGRIBUSINESS

Department of Agricultural Economics

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2020

Approved by:

Major Professor
Dr. Daniel O'Brien

ABSTRACT

The purpose of this thesis is to explore the possible affect that mycotoxins have on the aspects of hog production in the northeast region of the United States. Analyzing the impact of the most prevalent mycotoxins on hog health can show how a mycotoxin binder can be a positive influence on hog health and producers' pocket. Through profiles of both mycotoxins and commonly used binders it can be shown how these unseen toxins have a lengthy and costly harmful impact on the profitability of hog production if not effectively managed. Using a partial budget economic analysis approach, demonstrates how costs associated with mycotoxins can be mitigated. This study compares the economic impact of mycotoxins in swine feed rations that contain a binder on a regular basis verses rations including binders on an as needed basis. A literary review aspect of this thesis will look at how economic models can estimate the overall economic impact of mycotoxins in the hog and livestock industries.

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ACKNOWLEDGMENTS

The author wishes to acknowledge and thank her parents (Peter and Patti), for always pushing and supporting her as she completed her master's degree and follows her dreams and goals through life. She thanks her thesis committee (Dr. Dustin Pendell and Dr. Michael Tokach) and major professor (Dr. Daniel O'Brien) for guidance and knowledge that helped her succeed in completing her MAB Thesis. To the faculty and staff of the Master of Agribusiness program at Kansas State University, the author can not say thank you enough for making her master's degree experience pleasurable and memorable. Last but not least the author's fellow classmates, she thanks them for the countless memories and the support we gave each other.

CHAPTER I: INTRODUCTION

1.1 Background

Mycotoxins are secondary metabolites produced by some types of mold grown on feed ingredients used in swine feed rations. These mycotoxins can cause major problems for hog producers throughout the hogs' life cycle. Mycotoxins lead to swine health issues that can cause overall production to decrease with associated increase in production cost. Producers have some treatment and management options when it comes to managing mycotoxins within their hog production facilities and systems. These production system management practices including assessing aspects in the production chain as far back as grain harvest and storage practices, and as far forward as grain testing, inclusion of feed additives, and overall swine herd health management practices.

The presence of mycotoxins can cause a chain reaction throughout producers' hog operations. Along with direct impact on hog health and production, mycotoxins can have lasting effects on overall production system efficiency in the hog reproduction and growth phase. The immediate effect of ill hogs can lead to significant veterinary treatment and medication costs, increased hog death rates, decreased in litter size, and/or loss of litters all together. Taken together, these direct and indirect effects from mycotoxins can have a significant negative impact on herd health and farm swine production system economics.

By having a mycotoxin management system in place swine producers can mitigate the effects of mycotoxins. Recommended practices for mycotoxins that reduce the risk of exposure to hogs will be discussed below. Despite credible research-based evidence to the contrary, many hog producers in the northeastern U.S. do not realize the positive impacts of managing mycotoxins in their hog production operations. Rather, they are averse to the upfront, initial expense of mycotoxin avoidance and/or control – leaving themselves vulnerable to significant mycotoxin-related production losses by not managing the risk to their hog production operations. This study focuses on how elimination of hog exposure to mycotoxins may lead to a healthier, efficient, and economically sustainable on-farm hog production system.

1.2 Research Question

This thesis examines the effect of mycotoxins on hog production operations, and what mycotoxin-related swine production management practices may be used to produce sustainable profits for pork producers within the northeastern United States. Emphasis will be placed on the impacts that mycotoxins have on pork production systems and effective ways to manage them. Physical impacts on production efficiency, along with financial / economic impacts will be examined. The key issue addressed in this study is how mycotoxin management programs in the form of mycotoxin binders can impact hog production efficiency and economics in farm production systems in the Northeastern, United States.

1.3 Research Objective

The objective of this research is to provide hog producers and the hog industry with practical and economical ways to manage mycotoxins within farm facilities. This thesis research will also define and identify the most prevalent and frequent toxins found in corn along with most used binders within the northeastern United States. Other management factors will be discussed as they can play a very important role in limiting hogs' exposure to mycotoxins. Managing and mitigation of the effects of mycotoxins are key to keeping the cost of inputs as low as possible allowing producers to continue to make a profit.

1.4 Methods

The research for this thesis examines two different methods of mycotoxin management and control in order to back all necessary points. To examine the financial - aspects of a partial budget strategy will be utilized based on The Ohio State University 2018 Swine Production- Wean to Finish farm management budget. This budget will also be used to figure feed-to-gain ratio within different mycotoxin binder treatments in hog feed ratios. Profiles of the most commonly found mycotoxins in the northeastern United States and binders that are used to mitigate hog expose to mycotoxins will be presented. A supporting literature review is provided in the following section.

CHAPTER II: LITERATURE REVIEW

This literature review focuses on economic models that have been used to analyze the financial impact of mycotoxins in the swine and livestock industries. The economic factors associated with mycotoxins in livestock production are hard to measure. This is mainly due to the insufficient availability of quantifiable data related to actual farm level losses in areas of animal health and productivity because of mycotoxins. The economic models that are available examine the financial impacts in areas such as animal health, mycotoxin control and prevention, foreign trade-related impacts on livestock exports, and impacts on grain markets from mycotoxin-affect livestock feed. After looking at each area, the economic models used bring the impacts together to get an estimated total, aggregate economic loss associated with mycotoxins.

2.1 Sourcing and Measuring Losses

In commonly used economic models and analysis, losses associated with mycotoxins in grain and livestock industries can be categorized one of four ways:

1. Domestic market losses for rejection of grain above limits set for animal feed
2. International market losses for rejection of grain above individual nation's animal feed limits,
3. Animal mortalities, and
4. Animal morbidities- from contaminated grain consumption

(Wu, Measuring the economic impact of Fusarium toxins in animal feed 2007)

Trade losses occur when gains are rejected or when prices received are reduced due to the lesser quality of grain being traded (Chapter 8. Economics of mycotoxins: evaluating costs to society and cost-effectiveness of intervantions n.d.). Mycotoxins can have a significantly large impact on grain prices received by crop producers as feed mills, livestock producers, and even ethanol producers are willing to pay a higher price for corn, feed, and other commodities for which the level of mycotoxin is known to be considerably lower (Wu and Munkvold , Mycotoxin in Ethanol Co-products: Modeling Economic Impacts on the Livestock Indusrty and Management Strategies 2008). Regardless of where grains are in the supply chain, all parties will experience testing costs at some point.

Animal health losses can result in a decrease in livestock productivity from either direct illness, secondary disease, or death of mycotoxins. These costly losses can have a serious economic impact on livestock producers and without warning. Not only will there be the immediate, direct effects from hog illness, but possibly also have long term health effects on hogs that might result in either treatment or culling of hogs. Losses in hog productivity are hard to measure and consequently to calculate – mostly due to challenges in obtaining useful, credible data.

2.2 Economic Models

To estimate the total economic impact of mycotoxins on livestock production and profitability, a model must include both market and trade impacts, as well as animal health impacts. An equation that demonstrates this is:

Total Economic Losses= (market rejection losses) + (animal health losses)

(Wu, Measuring the economic impact of Fusarium toxins in animal feed 2007)

This model demonstrated by Felicia Wu takes many aspects into consideration. In her model she states it would be helpful to know:

- Amount of grain sold for domestic animal feed usage,
- Amount of grain exported into international market for animal feed, and
- Amount of grain used for animal feed that never entered the markets, direct farm usage.

The last important point is that grain may never have been tested, leaving out or excluding the testing cost. In this situation there is high risk of mycotoxin exposure, potentially adding costs from production impacts. Wu's model specially looks at *Fusarium* toxins, which includes vomitoxin and zearalenone.

Wu's model for total economic losses is estimated by:

Total Economic Losses= $QdP_d r_d + Q e P_e r_e + \Sigma_a[N_a V_{N_a} + M_a V_{M_a}]$

Where the model's variables are defined as:

Q= total amount of a given grain produced in a nation or region;

d= proportion of grain sold domestically for feed;

e= proportion of grain sold for exported animal feed;

f= proportion of grain fed directly to animals on farm;

P_d, P_e= market price per unit for animal feed, domestic and export, respectively, and

r_d, r_e= proportion of grain rejected to excessively high mycotoxin levels given domestic and export standards.

Animal health loss for species "a" = $\Sigma_a[N_a V_{N_a} + M_a V_{M_a}]$

N_a= number of animals culled/died due to illness associated with mycotoxin consumption;

M_a= number of animals experiencing perceptible but sublethal health effects due to mycotoxin consumption;

V_{N_a},V_{M_a}= the market related value of mortalities and morbidities, respectively, for the animal species *a*.

Another model demonstrated using dried distillers' grains and solubles (DDGS) by Wu and Munkvold: *the economic impact on the livestock,* uses many of the same variables (Wu and Munkvold , Mycotoxin in Ethanol Co-products: Modeling Economic Impacts on the Livestock Indusrty and Management Strategies 2008). The model also includes mycotoxin concentration, amount of DDGS in feed *rations*, amount of mycotoxin before and after ethanol processing, and market value of animals.

CHAPTER III: IDENTIFYING MYCOTOXINS

3.1 Definition and Origin of Mycotoxins

Mycotoxins are secondary toxin compounds produced by molds that develop on a wide variety of feed ingredients. There are many factors that contribute to the growth of mycotoxin producing molds on agriculture commodities. Many studies point to grain harvesting and storage methods as a culprit to high mycotoxin levels. Other studies present general weather factors and temperature levels are particular key factors positively correlated with high mycotoxin levels in grain commodities. To understand the pressures mycotoxins put on aspects of swine production, it is first helpful to understand how and where they are formed.

While there are hundreds of scientifically identified mycotoxin producing molds, the most common belong to the Aspengillus, Fusurium, and Penicillium genera (Turner, Subrahmanyam and Piletsky 2009). The most common mycotoxins found in the Northeast U.S., and the ones this thesis will focus on are Aflatoxin, Vomitoxin, and Zearalenone. Not all molds that grow on corn are mycotoxin producing, but levels can be impacted by weather, temperature, and growth stages along with harvesting and storage methods.

The environmental factors that cause high levels of mycotoxins may be a combination of general weather factors, temperature in combination with the time of year and/or the current growth stage of the crop. Any additional stress or damage to the crop may lead to or increase potential for higher mycotoxin levels. For example, it is known that Aflatoxin levels in grains are positively impacted by high temperatures and drought like conditions. These environmental conditions allow for Aflatoxin to spread on grain crops and compromise their growth. Whereas other toxins such as Fumonisin levels are impacted by not only temperature levels but from other courses of crop damage including that from insects.

A study published in the National Hog Farmer suggested that cleaning and screening corn can lead to decreased mycotoxin levels (Yoder and Jones 2017). This study shows that cleaning and screening could lead to reducing Aflatoxin levels by 26% and Fumonsin by 45%, on average. As cleaning and screening are both common methods used, this study brings out the possible "cost-saving" aspects associated with mycotoxin management in livestock feeding.

CHAPTER IV: COMMON MYCOTOXINS AND IMPACTS ON HOG PERFORMACE

4.1 Mycotoxin Profiles

In the Northeastern United States, the most prevalent mycotoxins that have the greatest damaging impact on hog production includes Aflatoxin, Vomitoxin, and Zearalenone. Mycotoxins can impact many aspects of a hog operation, from herd health to operation costs. Mycotoxicosis occurs when hogs ingest grains that contain toxic metabolites (mycotoxins) produced by certain fungi (Iowa State University College of Science and Technology n.d.). Symptoms of mycotoxicosis include impairment to metabolic, nutritional, and/or endocrine functions in swine that allow for secondary disease to take over and have a negative effect on them.

4.1.1 Aflatoxin

Aflatoxins are produced by *Aspergillus flavus* and *A. parasiticus* (Herrman and Trigo-Stockli, Kansas State University Department of Plant Pathology 2002). Increased levels can be expected when drought-like conditions and other common crop damage occur, such as insect and weather damage. Like many symptoms of mycotoxins, Aflatoxicosis impacts liver and kidney function, gastrointestinal effects, weakened immunity system along with other secondary complications and diseases. Symptoms with the most long term impact on hog health and production costs are feed refusal, decreased feed intake, porcine pulmonary edema (PPE), and suppressed immune system which all lead to secondary health issues (Biomin n.d.). The under lying secondary issues in swine can be weight loss, reduced milk production in lactating sows, and other common illness found in hogs (Menegat, et al. 2019).

4.1.2 Vomitoxin

Vomitoxin, otherwise known as Deoxynivalenol or DON, is produced before harvest by *Fusarium graminearum* (Menegat, et al. 2019). Like most mycotoxins, Vomitoxin levels are weather dependent, growing quickly in hot, wet climates. Since mycotoxins are produced prior to grain harvest it has not been found that their levels increase while in storage if moisture is kept below 19%. *Fusarium* optimum growth is within 19% to 25% moisture. Vomitoxin appears most commonly among mycotoxins, and is said to be a major factor of economic loss due to reduced swine performance (Pierce 2019).

Similar to the symptoms of other mycotoxins, Vomitoxin has major impacts on herd health and performance. Major Vomitoxin symptoms are related to fertility and gastrointestinal health. Growing hogs will show signs of weight loss from feed refusal, digestive disorders, diarrhea and vomiting. Reproductive effects such as piglet abortions, still births, reduced litter size, prolapses, and some cancers can also occur (Biomin n.d.). These symptoms and health issues can lead to secondary health problems that can lead to devastating effects.

4.1.3 Zearalenone

The mycotoxin Zearalenone, also known as ZEN, is characterize by its major effects on swine reproduction and its capability of being produced prior to harvest by the ascomycte fungal pathogen *Fusarium graminearum* (Menegat, et al. 2019). Like Vomitoxin, the mycotoxin Zearalenone is produced when conditions are hot and wet. Levels of Zearalenone increase when harvest is delayed and rarely increase after harvest unless the moisture level of grain is 22% or greater (Herrman and Trigo-Stockli, Kansas State University Department of Plant Pathology 2002).

If young gilts consume Zearalenone contaminated feed, they may have increased suffering and negative effects in the long term. Without their fully developed digestive and immune system young gilts are more susceptible to the effects of Zearalenone. Common effects found in gilts are hyperestrogenism (hyperaemia and vulva swelling), uterus mass increase, ovarian follicle atresia and atrophic ovaries, and/or vaginal or rectal prolapse (Biomin n.d.). Not only do these Zearalenone associated issues cause major health concerns but can lead to underlying secondary diseases and health problems within the gilts.

Sows have similar symptoms and effects as gilts, but sows may also show signs of false heats and pregnancy, abortions of piglets, and reduced or lose of litters (Biomin n.d.). Unborn litters are also affected, experiencing embryonic death, restricting fetal development, reduced litter size, and decreased birth weight (Biomin n.d.). Male hogs are also affected by Zearalenone consumption, as they show symptoms including feminization, enlargement of mammary glands, impaired semen quality, and testicular atrophy (Biomin n.d.).

4.2 Dietary Mycotoxin Levels

A large part of mycotoxin management is understanding the guidance level limits. Many times, corn and other grains that contain low levels of mycotoxins are used in hog diets. These mycotoxins levels must be low enough that they will not impact hog health. Table 4.1 gives mycotoxin levels and ranges that effect hogs at different points throughout the life cycle, along with clinical signs and associated effects (Menegat, et al. 2019). When high levels are present in corn and other grains intended to be used for hog rations there are effective ways to manage them and mitigate livestock health risks. Some of these methods include dilution with grains that have lower mycotoxin levels, cleaning and screening, and/or adding a binder or mold inhibitor to rations.

Table 4.1 Mycotoxin effects and signs associated with toxicity levels and life stages of hogs

Mycotoxin	Life stage	Toxicity level	Effects and signs
Aflatoxin	Grower-finisher	<100 ppb	No signs
		200 to 800 ppb	Low feed intake, low growth rate, immunosuppression
		800 to >2000 ppb	Severe liver disfunction, hemorrhages, jaundice, and sudden death
	Breeder	400 to 800 ppb	No signs on breeders, slow-growing sucking pigs due to aflatoxin in milk
Vomitoxin	Grower-finisher	< 1 ppb	No signs
		2 to 8 ppb	Sharp decrease in feed intake, low growth rate
		10 ppb	Complete feed refusal, vomit, diarrhea, severe digestive lesions, sudden death
Zearalenone	Gilts and sows	1 to 3 ppb	Vulvar swelling and redness, prolapses of rectum and vagina
		3 to 10 ppb	Anestrus, false pregnancy
		>30 ppm	Early embryo loss
		>40ppm	Low libido

Adapted from (Menegat, et al. 2019)

4.3 The Legal Ramifications of Aflatoxin

The Food and Drug Administration (FDA) has set action levels for aflatoxin in all animal feed and animal feed stuffs. In 1960, the FDA set an action level of 20 parts per billion (ppb) for aflatoxin in all food, this including animal feed (U.S. Department of Health and Human Services , et al. 2019). This was set to push aflatoxin levels to the lowest possible level to mitigate exposer. In later years, 1970's and 1980's studies showed the FDA that levels over 20 ppb could be fed to some meat producing livestock without putting animals in harm or increase risk to meat consumers. This lead the FDA to adjust the aflatoxin action level for livestock feed and feed stuffs for beef cattle, hogs, and poultry (U.S. Department of Health and Human Services , et al. 2019). The FDA's set regulation limit for aflatoxin management for hog feed and feed stuff is 20 ppb for grower hogs, 200 ppb for finishing hogs 100lbs or over, and 100 ppb for breeding hogs (Menegat, et al. 2019).

CHAPTER V: BINDERS AND THEIR IMPACT

5.1 Binder Definition and Function

As much as feed manufacturers and livestock producers would prefer the lowest levels of mycotoxin on feed and feed stuffs, it is not always an acceptable or reasonable option for them. For example, mycotoxin binders are not approved by the Food and Drug Administration (FDA) for animal consumption for the purpose of adsorbing mycotoxins. However, it has been found that when added for the purpose of milling and pelleting of livestock feed, they have an effect on reducing clinical signs associated with mycotoxicosis in hogs and other livestock.

The most efficient binder products consist of charcoal or active carbon, silicate binder such as clays, or organic polymers as binders including yeasts (Whitlow 2006). These materials target the mycotoxins within the hogs' gut and bind to the mycotoxin blocking it from being absorbed and causing mycotoxicosis. To be categorized as a mycotoxin binder, such products should be able to effectively prevent animal mycotoxicosis by adsorbing one or more mycotoxin without causing harm or residues to livestock. The ability to prevent animal mycotoxicosis must be combined with the ability to be usable in milling of feed or feed stuffs, and the capability of having its positive impact be verifiable (Whitlow 2006).

5.2 Binder Products Profiles

Each binder product can be used to specifically target one or more types of mycotoxins by adjusting the percentage in the diet needed for the age, weight, and/or type of mycotoxin. This has been shown in several studies, (Devreese, et al. 2014); (Whitlow 2006); (Devreese, et al. 2014); and (Chaytor, et al. 2011).

5.2.1 Charcoal or Active Carbon Binders

A study done by Ghent University concluded that active carbon had the capability to prevent the absorption of Vomitoxin (DON) within the intestinal tract of hogs (Devreese, et al. 2014). After hogs were given one oral bolus of 0.05 mg Don/kg bw., a detectable amount of toxic amount was confirmed in plasma and monitored over time. A second group of hogs were also given 0.05 mg/kg bw. Of DON along with active carbon. This group showed that the active carbon stopped the absorption of DON.

Active Carbon is material that has large surface characteristics that allows for its excellent adsorptive capability (Whitlow 2006). Even though charcoal or active carbon binders have been proven to be beneficial to the absorption of DON and other mycotoxins, it is not known to be physically and/or economically practical in large production units (The Merck Veterinary Manual 2005).

5.2.2 Silicate and Clay Binders

Silicate binders are sub-classed by their structure make-up, with phyllosilicates (sheets) and tectosilicates (frameworks) being looked at as adsorbent materials (Whitlow 2006). Clay products that can be effective at decreasing the effects of Aflatoxin and some other mycotoxins include bentonites, hydrated sodium calcium aluminosilicates (HSCAS), and zeolites (Chaytor, et al. 2011). Silicate or aluminosilicate binders trap and absorb mycotoxins because of their porous structure of silica (Menegat, et al. 2019). These binders are known to absorb Aflatoxin the best, while having limited effects on other mycotoxins.

There have been numerous studies on the effects of HSCAS on Aflatoxin, not only in hogs but other species as well. The study by Girish and Devegowda's study focuses on HSCA's effect on Aflatoxin mycotoxicosis individually, and also when rationed with T-2 toxin in commercial broiler chicken (Girish and Devegowda 2006). The main focus of the study approved by Virginia Tech Department of Animal and Poultry Science was on preventing negative effects of Aflatoxin accomplished by using HSCAS in young growing hogs (Harper, et al. 2010). This study also analyzed the addition of antioxidants to a contaminated swine diet. The results of this study are relevant to the purpose of this thesis in relation to HSCAS effects. In this study, a total of ninety hogs were weaned at twenty-two days of age (plus or minus two days), and then separated into pens of three with six pens being fed each dietary treatment. Eighteen hogs were fed contaminated feed with 500 ng per g of Aflatoxin, another eighteen hogs fed the same concentration of contamination but rationed with 0.5% HSCAS, and another eighteen hogs fed the same corn-soy based diet but not rationed with contamination or HSCAS binder. All hogs had access to water, and all diets were provided well-balanced rations.

Twenty-one days later at the conclusion of the study, all hogs appeared healthy. Results showed that at day eleven hogs that had been fed the contaminated feed only with no binder additive had grown at a slower rate than the control hogs that had been fed the uncontaminated and no binder feed. This trend continued for the remaining ten days of the study. The slower growth rate was correlated with 29% lower daily feed consumption, which led to 27% slower growth rate.

Differences in performance occurred between the hogs on the control treatment and those that had been fed the contaminated feed with those fed the contaminated and binder ration at day eleven. However, from day twelve to day twenty-one in this feeding trial there was no difference in terms of growth rate, growth performance, and feed consumption between the control hogs and the binder test. The overall end result showed that hydrated sodium calcium aluminosilicates (HSCAS) did aid in controlling or managing the negative effects caused by Aflatoxin.

5.2.3 Organic Polymers and Yeast Binders

The polysaccharides in the cell walls of yeast, being categorized as complex indigestible carbohydrates can absorb mycotoxins (Whitlow 2006). Zearalenone (ZEN) is known to be absorbed by yeast without altering the mineral and vitamin value of the ration (Fruhauf, et al. 2012). When looking at yeasts as a binder it is key to understand that molecular components are β-D-glucan and cell wall structure. In the process is important that the cell material be prepared correctly prior to their use as a binder. If not prepared in a correct manner there can be a negative impact on the absorption of mycotoxins (Fruhauf, et al. 2012)

A study evaluating the efficacy of mycotoxin sequestering agents for binding or degrading focused on ten different binders including a yeast cell wall product (Kong, Youp Shin and Gyun Kim 2014). It was found that the percent Aflatoxin absorbed by a yeast cell wall product was 92.7%. Vomitoxin (DON) was also included in this study. Results showed that 22.9% of DON was absorbed by the yeast cell wall binder product. In the case of having high DON toxicity, the recommendation may be to pair the yeast cell wall product with another binder or use another binder, that known to be more associated with absorbing DON.

CHAPTER VI: FINANCIAL IMPACTS OF MYCOTOXINS AND BINDERS

The economic impacts of mycotoxin contamination should not be taken lightly. Losses can come from a wide variety of categories related to human health, livestock health, and foreign trade of U.S. agriculture products. The two categories pertaining to the swine production industry are hog health related issues, and foreign trade-related regulations and their effect on hog prices. Measuring the economic losses due to mycotoxins is not an easy task, as there are many fluctuating variables to consider. The hidden or underlying costs associated with mycotoxicosis in hog production can accumulate and have a devastating financial impact on hog operation profitability.

6.1 Economics of Mycotoxins within the Swine Industry

There are many aspects of hog production systems in which swine health that can be negatively impacted by mycotoxins and lead to production and economic losses. The impacts on hog production systems that can occur include decreased hog productivity and reproduction efficiency, increased disease pressure caused by a suppressed immune system, lasting swine health effects, and increased swine mortality rates, as discussed in previous sections. If any one of these areas are impacted, producers could be faced with higher veterinary bills, animal death loss, decreased production, feed losses, increased mycotoxin testing and feed additive costs, as well as other increased production expenses.

Many studies indicate the difficulty of measuring these losses because of the wide array of elements of the production system effected as well as the lack of detailed, specific production process-related data on both the animal health and trade (Wu and Munkvold , Mycotoxin in Ethanol Co-products: Modeling Economic Impacts on the Livestock Indusrty and Management Strategies 2008); (Iheshiulor , et al. 2011). Studies of the overall economic impact of Mycotoxins on hog production are underrepresented relative to the economic relevance of the issue. Most studies mainly look at the economic impact of either exposure or contamination of mycotoxins (Iheshiulor , et al. 2011).

Economic models have been used to show some of the losses associated with mycotoxins in the swine and livestock industry. Wu and Munkvold developed a model correlating various factors effecting mycotoxin concentration in dried distillers grains and soluble (DDGS) and animal feed, animal health effects, and the economic impact on the livestock industry (Wu and Munkvold , Mycotoxin in Ethanol Co-products: Modeling Economic Impacts on the Livestock Indusrty and Management Strategies 2008).
This same study, Wu and Munkvold also looks at "Estimated Losses to the Swine Industry form Reduced Weight Gain". Applying the same economic model to a case study focused on the correlation between fumonisin mycotoxin and weight gain decrease in swine. The analysis of the case study concluded that with the presence of fumonsin mycotoxin in swine feed rations, if there is 10% DDGS inclusion in the swine diet, and the market penetration of DDGS in the U.S. swine feed industry was 25%, then decreased hog weight gains would result in an annual average of $18 million in expected additional annual financial losses to the U.S. swine industry.

6.2 Mycotoxin Testing

Mycotoxin testing can be beneficial and yet increase the cost of managing mycotoxins in hog production. In other words, the process of testing to detect mycotoxins in feed and feed stuffs before it is consumed brings about added cost to the hog production process. Many swine producers rely on feed and milling companies to test commodity grains for mycotoxins before they purchase and accept them into the feed chain on their individual farm operations. That said, hog producers that produce their own grain take a greater risk, facing the risk of either possible crop losses due to the presence of high mycotoxin levels or decreases in hog health and production efficiency and/or associated death losses from mycotoxicosis.

The most common and accurate on-site way of testing for mycotoxins is to use enzyme-linked immunosorbent assay test kits (Herrman, Department of Grain Science and Industry 2002). Average test costs per test is $7.36 (only test). Some tests require other equipment, such as scanners, testers, or readers that can add thousands to testing costs (Herrman, Department of Grain Science and Industry 2002). Table 6.1 shows costs associated with mycotoxins testing, including start-up costs for a scanner, test kits, and other needed supplies, along with training and labor testing. For an example Feed Mill located in the northeast U.S. to be explained below, estimated overall cost per test is $28.90.

Table 6.1 Estimated Testing Costs for Mycotoxins in Commodity Corn Being Used for Livestock Feed

Estimated Capital Cost	
$2,370.90	Cost of tester, supplies, 2 test kits (DON & Alfatoxi
$340.00	Cost of 3rd test kit (Zearalenone)
$2,710.90	Total material start up cost
Estimated Cost of Testing	
$340	Cost/ test kit w/ 50 strips
$6.80	Cost of 1 test strip
$20.40	Cost of test strips if testing for all 3 mycotoxins
Estimated Time Cost	$17 per hr.
5	Hrs of Training
$ 85.00	Cost of training
0.5	hr. start to finish testing- if running 1 or 3 three tests
$8.50	
Estimated Testing Costs/Test	
$28.90	

6.3 Economics of Mycotoxins at the On-Farm Level

The Ohio State University (OSU) 2018 Swine Production-Wean to Finish farm management budget, an Excel® spreadsheet for swine enterprise budgeting to evaluate potential income, costs, and profitability. Appendix A provides The Ohio State University 2018 Swine Production-Wean to Finish farm management budget, which was used to obtain the most accurate swine production figures for the Northeast, United States (Ricker and Ward 2020).

The model was intended to be used to show the economic impacts of adding binders to hog diets, compared to not adding them to diets and having the potential costs and ramifications of ill hogs. As data and scenarios were put into the model and others like it, it was found that there was not a way to get exact, reliable figures on which management practice was more economical. This is due to the fact that there are too many fluctuating variables to take into consideration along with the lack of data at the on-farm level in the areas of animal health, productivity, and losses that are associated with mycotoxins. This was discovered as the thesis progressed and as a result the recommendation to develop a model budget that focuses on the impacts of mycotoxins be taking into consideration more so than preexisting budgets do.

6.4 Mycotoxin Binder Effect on Hog Feed Efficiency

Even though the OSU model was not used as it had been intended, figures were used along with a Kansas State University (KSU) study “Effects of Mycotoxin Binders and a Liquid Immunity Enhancer on the Growth Performance of Wean-to Finish Pigs” to compare different mycotoxin “treatments”, such as binders that were added to swine rations on over all hog feed to gain efficacy ratios (Jacela, et al. 2009). Appendix B refers to the “Analyzed mycotoxin content (ppm) in diet sample (as-fed)” and Appendix C is the data collected by the study and is a table of “Effect of mycotoxin binders and a liquid immunity enhancer on growth performance of wean-to-finish pigs”.

From the OSU budget the amount of feed needed in the time frame of weaning to finish, 132 days was calculated, 673.8 lbs. of a corn and soybean meal. The vitamin and mineral requirements were not calculated in the 673.8 lbs. The KSU study looked at four different treatment scenarios of mycotoxin binders, range from not including any binder to including three different types of binders and a liquid immunity enhancer. Table 6.2 shows the feed to gain figures for each treatment. These show that at a small-scale hog operation like the one in the study or one in the Northeast, United States there is not a statistically difference between treatments. If this same study or one similar to it was conducted at a large-scale there could be a statistical difference. This study also states that mycotoxin binders and the liquid immunity enhancer had no effect on hog growth performance, along with mycotoxin levels being known to be well below limit standards when feeding hogs.

Table 6.2 Feed to Gain Ratios of the Effects of Mycotoxin Binder Treatments of Growth Performance of Wean-to-Finish pigs

Treatment	**BW @ Day 0**	**BW @ Day 132**	**Overall lbs. gained**	**Feed to gain**
1	15.90	233.00	217.10	3.10
2	16.00	234.00	218.00	3.09
3	16.10	234.60	218.50	3.08
4	15.90	235.30	219.40	3.07

CHAPTER VII: CONCLUSION

Mycotoxins have a large impact on many aspects of the swine industry that could result in health risks to hogs causing economic losses. While there is no one way to avoid mycotoxins all together, there are ways to efficiently manage them that can aid and help keep costs as low as possible for hog producers. Through management practices such as testing for mycotoxins, the use of good harvest and storage practices, and the use of feed binder additives, the negative impact of mycotoxins can be mitigated.

Being able to use economic models to analyze the financial impacts of mycotoxins gives the swine industry an idea on how to calculate losses due to mycotoxins. Even though economic factors associated with mycotoxins are difficult to measure, the models give the industry and producers a direction on how to create economical management practices that will aid in the mitigation of hog exposure to mycotoxins.

With the use of profiles of common mycotoxins found in the Northeast, United States and the binders that are most effective of absorption, hog producers are able to see how both mycotoxins and binders effect hog health and out of pocket costs. Even with having guidance level limits and legal ramifications on mycotoxins, producers still need to understand what they are and how high levels can affect hog health. When levels accede the acceptable thresholds, there are ways that producers can mitigate the expose on mycotoxins in swine feed that are economical.

Along with losses from hog morbidities and mortalities producers can also see an economic impact from restricted hog growth and performance in conjunction with added testing cost and expense of binders. With economic factors being hard to measure it is a challenge to see how mycotoxins and binders specially impact the swine industry at the farm level. With the use of The Ohio State University model and the Kansas State University study it was determined that at the small-scale farm level mycotoxins and binder treatments are not statically impacting hogs in any way but could at a much larger scale. It was recommended that in order to accurately get an economic figure on which management practices were more economical that a budget focusing on mycotoxins and binder should be developed. Using the OSU budget and others like would not have given an accurate and factual representation of the impacts associated with mycotoxins and binders.

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APPENDIX A

The Ohio State University
College of Food, Agricultural and Environmental Sciences

2018 Swine Production - Wean to Finish
1 Hog

5/1/2018

ITEM		QUANTITY/UNIT		PRICE PER UNIT		AMOUN	YOUR BUDGET
RECEIPTS [1]							
Market Hogs		270	lb.	$0.54	/lb.	$143.26	$143.26
Manure Nutrient Revenue		190	gal	$0.02	/gal	$4.54	$4.54
Total Receipts						**$147.80**	**$147.80**
VARIABLE COSTS							
Feed Costs							
Corn		9.8	bu.	$4.00	/bu.	$39.20	$39.20
Soybean Meal		125	lbs.	$0.19	/lb.	$23.13	$23.13
Vitamin/Minerals		15.04	lbs.	$0.45	/lb.	$6.77	$6.77
Pre Nursery Diet				$3.00	/pig	$3.00	$3.00
Processing and delivery				$3.00	/pig	$3.00	$3.00
Other		0	lbs.	$0.00	/lb.	$0.00	$0.00
Total Feed Costs						**$75.09**	**$75.09**
Other Variable Costs							
Purchasing Weaned Pig		1	head	$49.00	/head	$49.00	$49.00
Vet and Med. [2]						$2.87	$2.87
Labor [3]		0.4	hours	$15.00	per hour	$6.00	$6.00
Marketing, Supplies, and Misc. [4]						$5.12	$5.12
Repairs and Utilities [5]						$5.74	$5.74
Manure Costs [6]		190	gal	$0.0125	/gal	$2.38	$2.38
Interest on Operating Capital [7]	$90.54	5.5	mo.	4.50%		$1.87	$1.87
Total Other Variable Costs						**$72.97**	**$72.97**
TOTAL VARIABLE COSTS						**$148.07**	**$148.07**
RETURNS ABOVE VARIABLE COSTS						**-$0.27**	**-$0.27**
RETURNS ABOVE FEED COSTS						**$74.83**	**$74.83**

Values highlighted in gold may be changed to assist in computing "Your Budget" Column using formulas embedded within the spreadsheet.

Values highlighted in light blue are cells embedded with formulas and will be calculated for the user based on data entered. These cells may be input manually, but formulas will be overwritten!

Values highlighted in gray are stand alone cells that require direct input from the user.

Footnotes

1 Gross weight at market value with additional revenue from manure
Revenue accounts for 5% death loss. This loss is assumed for a pig of an average weight of 40 lbs. $2/per pig is subtracted from "Market Hogs" revenue to account for this death loss.

2 Vet and Med

3 Labor includes cost of wages and benefits

4 Costs of marketing, supplies, and misc. estimated by authors based on industry experience and expertise, includes transportation, marketing, contract production expense, and supplies.

5 Repairs and utilities estimated by authors based on industry experience and expertise includes electric and propane costs based on surveys

6 Manure quantity and costs are from 2012 Ohio Industry Source
http://www.extension.iastate.edu/agdm/livestock/pdf/b1-21.pdf

7 Includes full cost of weaned pig plus 1/2 costs of feed, vet med, and marketing, supplies, and misc. for 5.5 months

APPENDIX B

Table 1. Analyzed mycotoxin content (ppm) in diet samples (as-fed)

Mycotoxin	Nursery diet	Finishing diet
Aflatoxin B1	<.02	<.02
Fumonisin	<2.0	<2.0
T-2	<0.5	<0.5
Vomitoxin	<0.5	<0.5
Zearalenone	<0.5	<0.5

APPENDIX C

	Treatment 1	Treatment 2	Treatment 3	Treatment 4		Sex			Probability, P<		
T-BIND:	-	+	+	+							
Biomannan (d 0 to 55):	-	+	+	+							
Biomannan (d 55 to 132):	-	-	+	+							
ARNAp:	-	-	-	+	**SEM**	**Barrow**	**Gilt**	**SEM**	**Treatment x sex**	**Treatment**	**Sex**
Weight, lb											
d 0	15.9	16.0	16.1	15.9	0.26	16.0	15.9	0.18	0.95	0.94	0.57
d 55	85.7	87.1	87.1	88.4	1.21	86.9	87.2	0.86	0.62	0.5	0.81
d 132	233.0	234.0	234.6	235.3	1.44	237.3	231.1	1.02	0.77	0.73	0.0001
d 0 to 55											
ADG, lb	1.26	1.29	1.29	1.32	0.019	1.29	1.29	0.013	0.58	0.28	0.73
ADFI, lb	2.1	2.09	2.11	2.13	0.043	2.10	2.12	0.03	0.98	0.94	0.59
F/G	1.66	1.62	1.64	1.61	0.024	1.63	1.64	0.017	0.87	0.56	0.71
d 55 to 132											
ADG, lb	1.91	1.89	1.91	1.90	0.02	1.94	1.86	0.014	0.5	0.93	0.0004
ADFI, lb	4.93	4.93	4.98	4.97	0.046	5.11	4.80	0.032	0.61	0.76	<.0001
F/G	2.58	2.60	2.61	2.62	0.022	2.63	2.58	0.015	0.98	0.61	0.02
d 0 to 132											
ADG, lb	1.64	1.64	1.65	1.65	0.011	1.67	1.62	0.008	0.73	0.73	0.0004
ADFI, lb	3.74	3.74	3.87	3.78	0.037	3.84	3.67	0.026	0.81	0.77	<.0001
F/G	2.28	2.28	2.29	2.28	0.019	2.31	2.26	0.013	0.95	0.96	0.02