Feed Management

A Key Ingredient in Livestock and Poultry Nutrient Management

Diet and Feed Management Practices affect Air Quality from Poultry and Swine Operations

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Disclaimer
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Introduction

This fact sheet has been developed to support the implementation of the Natural Resources Conservation Service Feed Management 592 Practice Standard. The Feed Management 592 Practice Standard was adopted by NRCS in 2003 as another tool to assist with addressing resource concerns on livestock and poultry operations. Feed management can assist with reducing the import of nutrients to the farm and reduce the excretion of nutrients in manure.

Swine and poultry production operations can emit various gas emissions, particulate matter (dust) and odors which may affect the quality of air surrounding the operation. These gas emissions and dust come from manure generated on the operation, the feeding system and spoiled feeds, and feathers from poultry or dandruff and hair from swine. Emissions of gases, odors and dust are located in buildings, manure storage and during land application of manure. Diet ingredient sources, forms and levels can influence the availability (digestibility) and retention of nutrients in the animal and the levels and chemical forms of the nutrients excreted.

Immediately after excretion and during storage, microbial degradation of manure creates gaseous emissions and often times, offensive odors. These odors have been generally grouped as sulfurous compounds, indoles and phenols, volatile fatty acids, and ammonia (NH_3)and volatile amines. Since the animal is the initial source of nutrient excretions and odors from animal operations, diet manipulation is a practical and economical way to control excess nutrient excretion and reduce gaseous emissions. This fact sheet is a summary of key diet formulation and feed management practices to minimize dust, gas emissions and odors from swine and poultry operations.

Generally, there are two general types of diet modification to achieve emission reductions:

1. Nutrient input mass reduction
2. Nutrient form modification

The first, nutrient input mass reduction, changes the concentrations of the nutrient being fed such as decreasing the total dietary amount of nutrients (protein, sulfur, etc.) while still supplying enough to meet the animals requirements (e.g. the amino acid needs for animal performance using supplemental amino acids) or improving utilization of existing nutrients. For example, reductions in nitrogen (N) fed has been shown to reduce ammonia (NH_3) emissions by 10 to 40% in poultry and swine without impacting performance.

The second, nutrient form modification, changes the chemical form of the nutrients being excreted through diet manipulation (i.e. diet acidification, dietary inclusion of additives such as urease inhibitors, or feedstuff selection to shift the site of N excretion). Strategies that reduce nutrient input mass decrease nutrient mass output, yet those that change the nutrient form excreted may initially reduce nutrient emissions to air because they "trap" nutrient in chemical forms that are not volatilized. The important question that needs answering is - for how long are these nutrients trapped in a solid form? These strategies have the potential for longer term reductions and can impact emissions of compounds such as NH_3 by up to 40-50%.

Thus, the extent to which any reductions observed in the animal housing area through dietary strategies that change the excretion form are preserved during manure/litter storage is limited. Also, research on optimal combinations of dietary and post-excretion strategies to reduce emissions has largely been unexplored.

Feed Ingredients and Processing

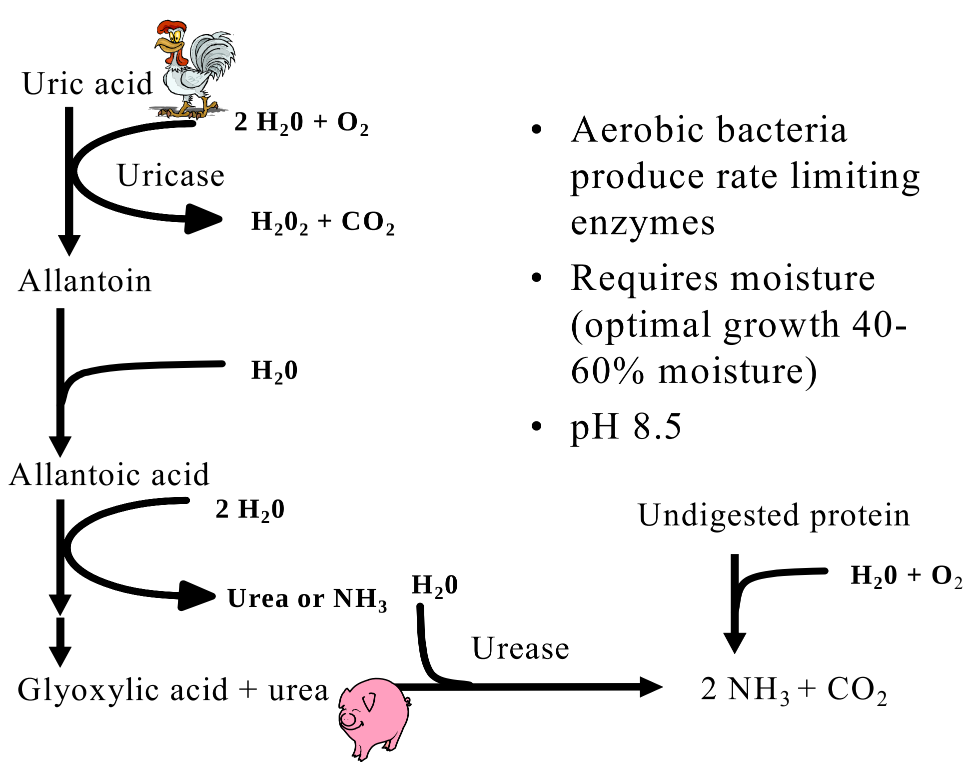
Any diet formulation and management procedure that improves the overall efficiency of feed nutrient utilization in swine and poultry will generally reduce the total amount of manure and nutrients excreted and potentially decrease the precursors of gaseous emissions and offensive odors. For example, use of sub-therapeutic levels of feed grade antibiotics can improve feed efficiency from 5 to 15% and have reduced some isolated odor compounds (p-cresol; skatole; Cromwell, 2001). Copper sulfate addition to the diet has been shown to improve swine feed efficiency 5 to 10% and reduce odors (Armstrong et al., 2000). Growth promotors also have the potential to reduce air emissions. For example, diets for finisher (185 lb) pigs containing 20 ppm of a β- agonist (Paylean®) decreased total N excretion by 10.7%, total manure output by 3.9%, reduced NH_3 emissions by 20%, decreased ammonium-N in stored manure (8 to 21%) and reduced odor emissions (DeCamp, et al. 2001; Hankins, et al. 2001).

Other feed management practices that enhance feed efficiency and reduce nutrient excretion are: fine grinding of grain, pelleting (reduces dry matter and N excretion 10-15%) and other feed processing techniques, reduced feed wastage, dividing the growth period into more phases (phase feeding), and split-sex feeding. Phase feeding and split-sex feeding allows the producer to formulate diets to more closely meet the animal's amino acid and other nutrient requirements, thus reducing feed costs and nutrient excretion. For instance, increasing the number of feed phases fed in grow-finish pig production from one to three can reduce N excretion up to 15%. Providing feed in the pellet or crumble form reduces feed wastage and dust. Adding fat or oil to the diet can also reduce dust emissions. For example, dust from corn was reduced by 86 percent when as little as 1% soybean oil was added, with a further reduction by 80% when 3% was added (Mankel et al., 1995; similar results reported by Heber, 2002). The use of wet-dry feeders also reduces dust formation in the building. By-product feedstuffs can provide an economical source of nutrients for pigs and poultry; however, they must be formulated carefully in the diet because they may create an imbalance in some nutrients and provide excess levels of nutrients (e.g. non-essential amino acids) above the animal requirements. For example, if additional N or sulfur is excreted from by-product feeds in the diet, it is likely that increased NH_3 and sulfurous compounds will result from the degradation of the excess N and S. Avoiding excessive safety margins is critical to reduce excessive excretion of nutrients. Formulating nutrients in the diet to no more than 5% above the animal's requirements is recommended.

Reducing Nitrogen in the Diet

Many of the air emissions from manure come from the degradation of amino acids. For example, the release of NH_3 from urinary urea N is caused by the enzymatic conversion of urea by urease in the manure and it can occur within a short time after excretion. Uric acid in manure from poultry is broken down by the enzyme uricase and urease to NH_3 (Figure 1). Indoles and phenols come primarily from the degradation of amino acids tyrosine, phenylalanine and tryptophan.

Figure 1. Conversion of uric acid and urea to NH_3



Most of the work on reducing N through dietary means has focused on reducing dietary crude protein (CP) through supplementation of amino acids that are most limiting in the diet. (Refer also to *Protein and Amino Acid Requirements of Poultry and Swine Factsheets*). This reduces feed protein sources (i.e., soybean meal, meat meal, distiller's dry grains plus solubles) that are oversupplying amino acids that are not limiting. This leads to reductions in dietary CP, excreted N and N (generally NH_3) emissions. As a guide, for each percentage unit reduction in dietary CP, estimated N excretion and NH_3 emissions are reduced by 8 to 10% in poultry and swine. Current industry swine and poultry diets are being formulated with crystalline L-lysine (Lys), DL-methionine (Met), and L-threonine (Thr), but as availability increases and cost decreases for the next co-limiting amino acids further reductions in excreted N and emissions will occur. Although the nutritionist cannot prepare a perfect amino acid balance from natural feed ingredients, the use of computers and having an array of different feed ingredients and supplemental amino acids allows nutritionists to produce diets that have reduced amino acid excesses while still meeting the pig and bird amino acid requirements and productivity. With increasing public and regulatory interest in air emissions from livestock and poultry operations, researchers have more recently begun quantifying dietary impacts on emissions reductions. The following studies are examples of plausible NH_3 reductions with reduced CP diets.

Swine – Recently, Powers et al. (2006) evaluated the effect of feeding reduced CP diets with supplemental amino acids on air emissions. When grower diets with reduced CP and supplemental amino acids were fed (22.1 vs. 18.8, and 17.2%), a daily mass of NH_3 emitted of 88.0, 68.9, and 46.0 mg per kg body weight, respectively, was reported. A series of additional studies (Sutton, et al., 1999; Prince, et al., 2000; Richert and Sutton, 2006) have reported that reducing the CP from 3.5 to 4.5% of a corn-soy diet with supplemental Lys, Met, tryptophan (Trp) and Thr fed to grow-finish pigs compared to a commercial diets reduced slurry pH (0.4 units), total N (30 – 40%), ammonium N (20 – 31%), as well as reduced aerial NH_3 40 – 60%, hydrogen sulfide 30 – 40%, and total odors 30 – 40%. More importantly for the producer, manipulation of dietary CP levels had no effect on pig performance. This demonstrates that a substantial amount of undigested N and N above nutrient requirements is currently being fed by the swine industry.

Broilers – Most dietary strategies investigated thus far for broilers have focused on low CP diets with up to three supplemental amino acids, resulting in 10 to 15 percent reductions in NH_3 excretion. Angel et al. (2006) investigated further strategies of increasing number of diet phases and supplemental amino acids beyond crystalline Met, Lys, and Thr. For those studies, five flocks of broilers were reared to 42 days of age. Broilers on the control treatment were fed a four phase feeding program with supplemental Met and Lys, whereas the low CP treatment consisted of feeding a six phase feeding program with supplemental Lys, Met, Thr, isoleucine (Iso), valine (Val), Trp, and arginine (Arg). The lowered CP diets with additional feeding phases reduced NH_3 emissions by greater than

40%. While increases in dietary phases are commercially feasible, dietary inclusion of supplemental amino acids other than Lys, Met, and Thr is not economically feasible at this time.

Turkeys – Little work has been reported investigating dietary means to reduce N excretion and and subsequent NH_3 emissions in turkeys. Applegate et al. (2008) fed turkeys either 100 or 110% of NRC (1994) amino acid requirements for tom turkeys to 20 weeks of age. Differences in dietary CP between the 100 or 110% NRC (1994) amino acid formulations were 1.2 to 1.8 %-units more CP for diets formulated to 110% NRC (1994). Diet formulation had no effect on body weight or yields, but toms fed the 100% NRC diet had lower N intake (7%) compared to toms fed the 110% NRC diet. This lower N intake resulted in 0.8 kg less N in litter/pen (7%) from birds fed the 100 % NRC diet versus those fed the 110% NRC diet.

pH Manipulation of Diet

As mention earlier, NH_3 is a primary byproduct of uric acid (poultry) and urea (swine) degradation as well as microbial degradation of undigested protein. Primary factors affecting NH_3 conversion in poultry and swine manure/litter is temperature (75+ F), moisture (40 to 60 %), and pH (>7.0; i.e. higher pH increases NH_3/ NH_4 ratio) (Groot Koerkamp, 1994) as well as the presence of two rate-limiting enzymes: uricase (uric acid conversion to allantoin) and urease (urea to NH_3). Once NH_3 is formed, it can either be volatilized, or remain in the non-volatile state as ammonium (NH_4^+). A pH below 7.0 is required to keep the released N in the non-volatile state, NH_4. Examples of how dietary manipulation can alter manure pH are shown below.

Swine – In addition to the release of NH_3 and other nitrogenous compounds during anaerobic degradation, many volatile organic acids are emitted from the degradation of amino acids and fermenting a multitude of carbohydrates by the indigenous bacteria. These volatile organic compounds (especially volatile fatty acids) can change the pH of manure. Numerous strategies have been implemented in pigs to reduce NH_3 emissions, including dietary fiber addition and dietary acidification.

Addition of small amounts of fiber (soybean hulls, sugar beet pulp, wheat midds, wheat bran) to the diet (5 to 10%) will result in a reduction in swine manure pH (Sutton, et al., 1999; Prince, et al., 2000; Richert and Sutton, 2006). Soybean hulls appear to have the greatest effects on reduced NH_3 emission (from 16.9% to 35.8%) but soybean hulls can increase short chain volatile fatty acids (VFA) in feces. Addition of 10% soy hulls with 3.4% fat to practical corn-soybean meal diets reduced aerial NH_3 by 20%, hydrogen sulfide by 32%, and reduced odor detection threshold by11%. Nitrogen accumulation in manure was increased 21%, pH of the manure was decreased and VFA concentrations were increased by 32% in manure from pigs feed diets with soy hulls inclusion. Using 5% soy hulls with low nutrient excretion corn-soy diets (reduced CP and supplemental amino acids) reduced NH_3 emissions 50%, hydrogen sulfide 48% and odor detection threshold 37%.

Reductions in urinary pH can also be achieved through use of 0.7 to 1.0 % calcium-salts (NH_3 emission reductions 26 to 53%; Canh et al., 1997), calcium-benzoate (NH_3 reduction of 37%), combination of phosphoric acid and calcium sulfate (NH_3 reduction of 30%; Kim et al. 2000), combination of monocalcium phosphate, calcium sulfate, and calcium chloride (NH_3 reduction of 17%; Kim et al, 2000). In several of these studies, measures were made after less than 24 hours post-excretion. Longer-term impacts, however, remain in question.

Laying Hens – The primary strategy for changing pH of excreta in laying hens by diet manipulation includes replacing a portion of limestone in the diet with calcium sulfate (gypsum; up to one third can be replaced without affecting bird performance or shell characteristics; Keshavarz, 1991). Wu et al. (2007) noted that replacement of 35 % of dietary limestone with Ca-sulfate in combination with 1.25% zeolite and slight reductions in dietary CP resulted in nearly a 40% reduction in NH_3 emissions, but at the expense of a 3-fold increase in H_2S emissions.

Ammonia Binding – Urease Inhibition

Several feed additives claim to reduce N excretion and NH_3 emission potential by binding NH_3 or inhibiting urease. Yucca plant extracts have reduced NH_3 emissions from swine manure (Sutton, et al, unpublished data). Amon et al. (1995) fed a yucca extract, to finishing pigs and observed reduced NH_3 concentrations in the feeding rooms over a 7-wk period. Ammonia concentration was reduced, on average, 26% in rooms where the extract was fed. Similarly, NH_3 emission was reduced 26% in the study. Dietary inclusion of clinoptilolite and other clay minerals to reduce NH_3 emissions has resulted in variable results.

Sulfur Emissions Reduction

Poultry - Methionine is the substrate from microbial decomposition for production of odorous compounds such as methyl mercaptan, hydrogen sulfide, dimethyl sulfide, dimethyl disulfide, dimethyl trisulfide, and carbonyl sulfide (Kadota and Ishida, 1972). Powers et al. (unpublished data, 2005) demonstrated the magnitude of impact that a minimal change in diet formulation can have on H_2S emissions from 21-wk-old laying hens. The H_2S emissions were 42% less from birds fed 0.1% less Met versus a control diet containing 0.2% supplemental Met (total dietary sulfur was reduced by 0.01 %-units). Chavez et al. (2004) noted that in fresh broiler manure, the production of H_2S, and other sulfide gases were fairly similar between birds fed either liquid methionine hydroxy-analog and DL methionine, but were much less than birds fed dry methionine hydroxy-analog and all three dietary treatments were less than those fed sodium methioninate aqueous solution. The odor detection threshold (as determined by a trained odor panel), however, was not different between treatment groups.

Swine - Beyond minimizing sulfur amino acid concentrations in the diet (methionine and cysteine), another considerable source of sulfur in the diet is through sulfated mineral sources. For example, when Kendall et al. (2000) replaced mineral sulfate sources (Zn, Fe, Mn, and Cu) in diets for grow-finish pigs with carbonate, oxide, and chloride sources, H_2S concentrations in room and exhaust air from confinement buildings were numerically reduced by 39 and 30 %, respectively.

Summary

It is clear that feed formulation and feed management practices have a dramatic affect on gaseous and odor emissions from manure and facilities. Amino acid balanced (correct ratios and concentrations) diets with lower intact CP levels are effective at reducing aerial NH_3, manure N, and manure pH. In addition, if adequate amino acid levels are included in the diet, growth performance is comparable to a diet without supplemental amino acids. Additional reductions in the amount of each of these compounds emitted can be accomplished through form modification. In the case of N, reductions in NH_3 can be accomplished through compounds that acidify manure and/or urine, sequester NH_3, or inhibit the conversion of uric acid and urea to NH_3. Addition of small amounts of fiber (<10%) in the diet reduces NH_3 emissions and manure pH. Reducing mineral sulfates in the diet helps reduce H_2S emissions. Formulating feed to reduce safety margins to 5% of NRC requirements, and using feed management practices of phase feeding, split-sex feeding, feed processing technologies, inclusions of grow promotants and enzymes to enhance feed utilization will reduce nutrient excretions and reduce gaseous emissions in pork and poultry operations. While short-term studies have been accomplished, a thorough investigation of long-term effects of dietary strategies and combinations of mass reduction and form modification has not been adequately addressed to date.

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Project Information

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