Dietary Manipulations to Lower Ammonia Emission from Laying-Hen Manure

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Species: Poultry (Layers)
Use Area: Animal Housing
Technology Category: Dietary Modification
Air Mitigated Pollutants: Ammonia

Description:

Ammonia emission is a major environmental concern for egg producers. The nutrient composition and chemical characteristics of an animal's diet influence nutrient composition and characteristics of the manure and research has shown that adjusting the laying hens' diet can lower ammonia emission from the manure. The dietary manipulation techniques considered in this paper include:

- Reduced crude protein diets;
- Inclusion of high-fiber ingredients (e.g., corn distiller's dried grains with solubles [DDGS], wheat middlings, or soybean hulls); and
- Inclusion of EcoCal™—a proprietary mixture of calcium sulfate (gypsum) and zeolite.

Mitigation Mechanism:

Diets with reduced crude protein contents have been used successfully to lower ammonia emission from pig manure (van der Peet-Schwering et al., 1996) and laying hen manure (Liang et al., 2005). Animals can only perform (whether egg production or muscle growth) to the level of the first limiting amino acid in their diet. Amino acids supplied above the level of the first-limiting amino acid cannot be used and the nitrogen is therefore excreted in the urine. A reduced crude protein diet is typically formulated by including crystalline amino acids such that the inclusion of protein-supplying ingredients (e.g. soybean meal) can be decreased while still maintaining a nutritionally adequate diet. This technique allows the amino acid content of the diet to more closely resemble the amino acid requirement of the animal, thereby limiting the amount of excess nitrogen that must be excreted. In a field-scale study reported by Liang et al. (2005), laying hen diets were formulated to contain one percentage unit lower crude protein compared to a control diet and resulted in a 10% decrease in ammonia emission (Table 1). The study involved 4 high-rise laying-hen houses, each containing approximately 75,000 hens. Two houses were assigned to a standard diet and two houses were assigned to a reduced crude protein diet and emissions were measured over one year.

High-fiber ingredients are typically not included in diets for monogastric animals (i.e., pigs and poultry). However, research in Europe showed that including fiber in pig diets lowered ammonia emission from manure slurry (Kruezer and Machmuller, 1993; Tetens et al., 1996; Cahn et al., 1996; Shriver et al., 2003). Our group conducted an experiment to evaluate the effect of including high-fiber ingredients (i.e., corn DDGS, wheat middlings, or soybean hulls) in laying-hen diets on ammonia emission and found that high-fiber ingredients led to a decrease in ammonia emission from laying-hen manure (Roberts et al., 2007). Including 10% corn DDGS caused a 41% decrease in ammonia emission, 7.3% wheat middlings caused a 38% decrease in ammonia emission, and 4.8% soybean hulls caused a 27% decrease in ammonia emission from the manure. Our hypothesis of this mechanism is two-fold: 1. fiber provides energy to bacteria in the lower gastrointestinal tract where the bacteria use nitrogen, that would otherwise be excreted as uric acid, for bacterial protein synthesis; and 2. the bacterial metabolism produces short-chain fatty acids that lower manure pH, thereby shifting ammonia (NH3) to ammonium (NH4+), which is less volatile. The results of the experiment showed that the manure pH was lower from the fiber-fed hens, but it was not clear if nitrogen repartitioning from uric acid to bacterial protein occurred. This laboratory-scale study involved 128 cages of hens (2 hens per cage), each assigned to a control, corn DDGS, wheat middlings, or soybean hulls diet. Further research is continuing to investigate the effects of corn DDGS on ammonia emission from laying-hen manure and to elucidate the mechanism.

Our research group is currently working on two separate field-scale studies, each involving multiple high-rise houses, to determine the effect of dietary corn DDGS on ammonia emission under commercial production conditions.
EcoCaltm is a proprietary mixture of calcium sulfate (i.e., gypsum) and zeolite. Calcium sulfate is added to the diet as an acidifier, replacing part of the dietary calcium carbonate (i.e., limestone). As described in the previous paragraph, lower manure pH shifts ammonia to ammonium, which is less volatile and will tend to stay in the manure rather than escaping to the air. Zeolite is a binder that traps the ammonium in the manure, thereby lowering volatilization.

Unpublished research from our group indicates the 3.5% dietary inclusion of EcoCaltm led to a 23% decrease in ammonia emission from laying-hen manure during the winter months (December to May) in the Midwest. This study involved two high-rise laying-hen houses, each containing approximately 250,000 hens. Hens in one house were fed a standard diet while hens in the other house were fed a diet containing 3.5% EcoCaltm.

Table 1 shows the ammonia decrease observed in various experiments conducted by our group. Emission rates are affected by many variables such as season, which may influence the actual reduction that is realized at a specific farm. Choice of dietary manipulation should be made by the egg producer based not only on anticipated ammonia reduction but also on ingredient cost, availability, and logistics of changing the diet.

Table 1. Comparison of diets

Item	Ammonia Decrease %	Inclusion Rate %	Diet cost[1] ¢/kg ($/2,000 lb)
Standard corn, soy, meat and bone meal diet	–	–	26.6 (241)
One percentage unit lower crude protein[2,3]	10	–	26.1 (237)
Corn distiller's dried grains with solubles (DDGS)[4]	41	10.0	25.5 (231)
Wheat middlings[4]	38	7.3	26.7 (242)
Soybean hulls[4]	27	4.8	27.6 (250)
EcoCal™,[5]	23	3.5	27.6 (250)

[1]Ingredient costs used were those reported for Midwest United States markets for April 2008 (see text). EcoCal™ cost from personal communication: E.C. Hale, III (April 15, 2008).
[2]In the study performed by Liang et al. (2005) and in the sample diet used for cost comparisons, DL-methionine, L-lysine, and L-threonine were added to meet the methionine + cystine, lysine, and theonine requirements, respectively, and soybean meal was added to meet the fourth-limiting amino acid requirement.
[3]Ammonia decrease was based on a one-year study by Liang et al. (2005) under commercial production involving 4 high-rise laying hen houses.
[4]Ammonia decrease was based on a 10-month study by Roberts et al. (2007) that involved 256 hens.
[5]Ammonia decrease was based on a 6-month study under commercial production involving 2 high-rise laying hen houses.

Applicability:

The research described herein focuses on lowering ammonia emission from laying hens using dietary manipulation. Some work has been done using these methods in pigs and the mechanisms should hold true for other types of poultry (i.e., broiler chickens and turkeys). However, these discussions are only directly relevant for laying hens.

Limitations:

Livestock producers should consult a qualified nutritionist prior to making changes in any diets to assure optimum nutritional status and animal performance.

Care should be taken when formulating reduced crude protein diets. The amino acid requirements of the animals must be precisely known for the specific production situation considered. Inclusion of dietary amino acids above the animals' requirements is costly and contributes to nitrogen excretion, thereby decreasing the overall effectiveness of the ammonia-lowering regimen. Furthermore, the digestible amino acid contents of all ingredients in the diet must be known, so that the diet can be balanced with amino acid contents closely resembling the requirements of the animal. If the animals' amino acid requirements are not precisely known or the amino acid contents of feed ingredients are overestimated, the diet may be deficient in one of more amino acids, which will decrease production and indirectly increase ammonia excretion. If the animal has an amino acid deficiency, it will excrete the nitrogen from all amino acids fed above the level of the deficient amino acid.

There are a few points to consider when including high-fiber feed ingredients in laying-hen diets. The nutrient content and digestibility of the "new" ingredient should be evaluated so the diet formulation can take full advantage of those nutrients. High-fiber ingredients tend to have a lower amino acid digestibility compared to corn and soybean meal, so diets should be formulated on a digestible amino acid basis. Furthermore, high-fiber ingredients usually have low energy content, which may make such ingredients unsuitable for nutrient-dense pullet or peaking diets. As with any feed ingredients, producers should secure a consistent, high-quality supply for optimum diet quality and animal production.

EcoCaltm is added at either 3.5 or 7.0% of the diet, replacing equal parts of calcium from calcium carbonate. The mixture of calcium sulfate and zeolite is adjusted according to the desired addition. The calcium in the product can be considered in the total diet formulation, lowering the inclusion of calcium carbonate (i.e., limestone). When feeding EcoCaltm, egg producers should be aware of a potential increase in hydrogen sulfide emission stemming from the sulfur in the calcium sulfate. While feeding 3.5% dietary EcoCaltm caused a 23.2% decrease in ammonia emission from laying hens, a 134% increase in hydrogen sulfide was observed (1.82 ± 0.07 mg/d per hen for control-fed hens and 4.38 ± 0.20 mg/d per hen for the EcoCaltm fed hens) over a 173-d experiment conducted by our research group (unpublished data). Hydrogen sulfide concentrations were maintained below 200 ppb or 0.2 ppm at the exhaust fans in the treatment house. Although significant increases in hydrogen sulfide concentrations and emissions were observed, the levels remain low and should not cause worker or hen health concerns or trigger reporting thresholds. For instance, the emergency planning and community right to know act (EPCRA) requires reporting of hydrogen sulfide releases greater than 45 kg (100 lb) per day. At the observed, elevated hydrogen sulfide emission rate of 4.38 mg/d per hen, it would take 10.3 million hens to emit 100 lb per day.

Cost:

To compare cost differences between mitigation strategies, example diets were formulated and costs calculated (Table 1). Ingredient costs published in Feedstuffs magazine April 14, 2008 for Chicago markets were used. The following ingredients' prices are not published by Feedstuffs and were set as listed: calcium carbonate 3.2¢/kg ($29/2,000 lb), l-lysine HCl $2.20/kg ($2,000/2,000 lb), dl-methionine $2.55/kg ($2,313/2,000 lb), l-threonine $2.82/kg ($2,560/2,000 lb), and EcoCaltm 16.5¢/kg ($150/2,000 lb). Ingredient nutrient values published by NRC (1994) were used for all ingredients except corn DDGS nutrient values (not including energy) taken from University of Minnesota (UMN, 2008) and soybean hulls and wheat middlings values published by Hy-Line (2006). A value of 2,805 kcal/kg (1,272 kcal/lb) was used for the metabolizable energy content of the corn DDGS (Dakota Gold, 2008). Calcium content of EcoCaltm was assumed to be 17.14%. Diets were formulated to contain 2,850 kcal/kg (1,293 kcal/lb) metabolizable energy. Total lysine was set at 0.80% of the diet and other amino acid inclusions were calculated using the ideal amino acid profile reported by Bregendahl et al. (2008). For all other nutrients, recommendations published by NRC (1994) were used.

Diets were formulated by including dl-methionine to meet the methionine + cystine requirement and adding soybean meal to meet the second-limiting amino acid requirement. Meat and bone meal was added to meet the requirement for available phosphorus. The reduced-protein diet was formulated by including dl-methionine, l-lysine, and l-threonine to meet the methionine + cystine, lysine, and threonine requirements, respectively, and including soybean meal to meet the fourth-limiting amino acid requirement. EcoCaltm, corn DDGS, soybean hulls, and wheat middlings inclusion rates were set at the inclusion used in the respective experiment (3.5%, 10%, 4.8%, and 7.3%, respectively). All nutrient contributions from each ingredient were considered in the formulations. For the example diets prepared, the cost of the standard diet was $241/2,000 lb. The corn DDGS diet was $10/2,000 lb less expensive while the reduced protein diet was $4/2,000 lb less expensive compared to the standard diet. The wheat middlings diet was $1/2,000 lb more expensive and the EcoCaltm and soybean hulls diets were each $9/2,000 lb more expensive compared to the standard diet.

Implementation:

Producers should use care when reformulating diets to assure that all nutrient requirements of the hens are met. Feed ingredients should be sourced from a reputable company with high-quality, consistent products and should be analyzed to determine nutrient content of the ingredients prior to diet formulation to ensure optimal performance of the hens. Ingredient costs may vary greatly for different egg producers based on the proximity to the supplier and private contracting (including volume discounts)

Technology Summary:

Dietary manipulations can lower ammonia emission from laying-hen manure. Options discussed in this report include:

- Reduced crude protein diets;
- Including high-fiber ingredients (e.g., corn DDGS, wheat middlings, or soybean hulls); or
- Including EcoCal™.

Each different dietary manipulation technique offers positive and negative aspects that will fit differently into individual production systems. Producers should work closely with a qualified nutritionist to decide which diet would be best suited for their operation and to implement the changes such that all diets are nutritionally balanced and optimal egg production is achieved. Cost comparisons should be evaluated as the cost of the total diet and calculated for each individual production situation.

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