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Adding Fiber to the Diet of Laying Hens Reduces Ammonia Emission

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Summary and Implications

Reducing ammonia emission from large-scale laying-hen operations is becoming an important issue facing the poultry industry. In this experiment, soy hulls, wheat middlings, or corn distillers dried grains with solubles were added to laying-hen diets to determine the effect of dietary fiber on manure ammonia emission. Results show that addition of any of the three types of dietary fiber reduces total manure ammonia emission without affecting egg production.

Introduction

The development of a sustainable, profitable, and competitive egg-production system is becoming a challenging issue facing the laying-hen industry. The excretion and volatilization of nitrogen is responsible for a large part of the environmental issues that have risen from intensive poultry production. As government agencies propose regulations on ammonia emission from livestock facilities, egg producers will need methods of reducing emissions while maintaining egg production.

Addition of fermentable fiber to pig diets reduces ammonia emission by shifting nitrogen excretion from urine (in the form of urea) to the feces (in the form of more stable microbial protein). This shift occurs because the pig does not fully digest dietary fiber; consequently, some of the fiber is available as an energy source for bacteria residing in the large intestine. In swine, the nitrogen used in the increased bacterial protein synthesis comes partly from nitrogen (ammonia) in the blood that would otherwise be excreted as urea in the urine. Therefore, less nitrogen is excreted in the urine and more in the feces. Although the total amount of nitrogen excreted may not change, the form in which it is excreted does (i.e., urea vs. bacterial protein). Bacterial protein is more stable than urea and less likely to be converted to ammonia after excretion. Additionally, increased bacterial growth in the large intestine increases the production of volatile fatty acids (VFA), which are excreted in the manure. These VFA reduce the pH of the manure, trapping ammonia (NH_3) as ammonium (NH_4^+) in the manure, which results in reduced ammonia emission into the air.

The objective of this trial was to determine if addition of fermentable fiber to laying-hen diets would reduce ammonia emission, similar to the effects shown in pigs, by shifting nitrogen excretion from uric acid to more stable bacterial protein and by reducing manure pH.

Materials and Methods

A total of 256 Hy-Line W36 hens, 45 weeks of age, were used for this trial. Dietary treatments, shown in Table 1, included three types of fiber (soy hulls, wheat middlings, and corn distillers dried grains with solubles [DDGS]) and a control diet. The DDGS was included at 10% of the diet, whereas soy hulls and wheat middlings were included to supply an equal amount of neutral detergent fiber (NDF) as the 10% DDGS. Diets were formulated to contain equal quantities of digestible amino acids and metabolizable energy and contained Celite™ as an indigestible marker. Hens were housed two per cage (corresponding to 96 in^2 per hen) and each cage was equipped with one nipple drinker and a plastic self-feeder.

Egg production was recorded daily, whereas feed intake (measured as feed disappearance) and egg mass (calculated as egg production × egg weight) were determined every week throughout the 12-week study. Six weeks into the study, manure samples were collected and analyzed for contents of dry matter, total nitrogen, uric acid, acid insoluble ash, and pH. Total manure and nitrogen excretion were calculated using acid insoluble ash as an indigestible marker. To obtain sufficient manure for ammonia-emission analysis, manure from cages receiving the same dietary treatment was collected daily, pooled, and stored at –20˚C until analysis of ammonia emission over 7 days.

Data were analyzed by ANOVA appropriate for a randomized complete block design with 32 replications. Data from the fiber treatments were compared to those of the control using contrasts. P-values less than 0.05 were considered significant.

Results and Discussion

Nitrogen Excretion

The hen has a very limited ability to digest fiber, so the addition of high-fiber ingredients to the diet could reduce protein digestibility and increase nitrogen excretion. The similar excretion of total nitrogen observed from hens fed the fiber diets compared to the control (Table 2) implies that the addition of dietary fiber did not reduce the nitrogen digestibility of the diets.

Uric Acid Excretion

Uric acid in the manure is rapidly converted to ammonia, which is then lost to the environment; a reduction in manure uric acid, therefore, would cause a reduction in ammonia emission. Addition of fiber to the diet reduced the uric acid excretion, although the difference was only significant when wheat middlings were fed (Figure 1) compared to the hens fed the control diet. Because manure uric acid was significantly reduced while total nitrogen excretion remained the same, we speculate that the amount of bacterial protein in the manure increased.

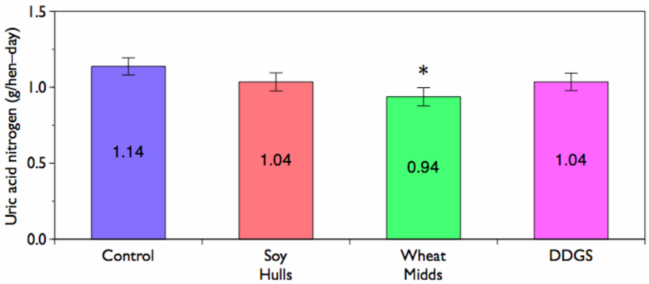

Figure 1. Uric acid nitrogen excretion in the manure. Data are means ± pooled SEM, n=32. *Different from control (P<0.05).

Manure pH

The pH was significantly reduced in the manure from the hens fed wheat middlings or DDGS compared to the control (Table 2). A lower manure pH shifts ammonia to the ammonium form, which is less volatile and therefore not lost to the environment.

Ammonia Emissions

The combination of reduced uric acid excretion and reduced manure pH contributed to a significant reduction in total ammonia emission from the manure of the hens fed the dietary fibers (Figure 2).

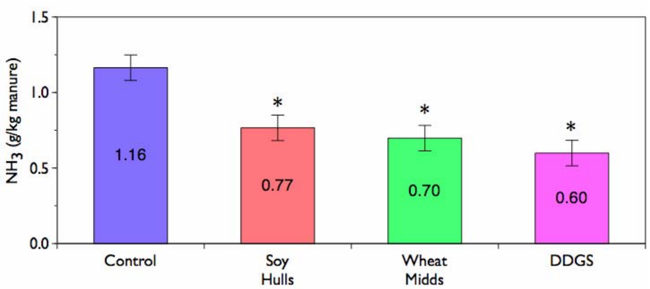

Figure 2. Total ammonia emission from manure over 7 days. Data are means ± pooled SEM, n=6. *Different from control (P<0.05).

Ammonia is lost primarily from the top few inches of a manure pile. With daily manure production, the 'active' manure layer is quickly buried under new, fresh manure. As a result, the ammonia emission rate is equally important and indicates how fast ammonia is lost from manure. Hence, a slow emission rate is desired, such that less ammonia is evaporated and more is 'trapped' under new layers of manure. Addition of any of the fiber types to the laying-hen diet reduced the rate of ammonia emission compared to the control (Figure 3).

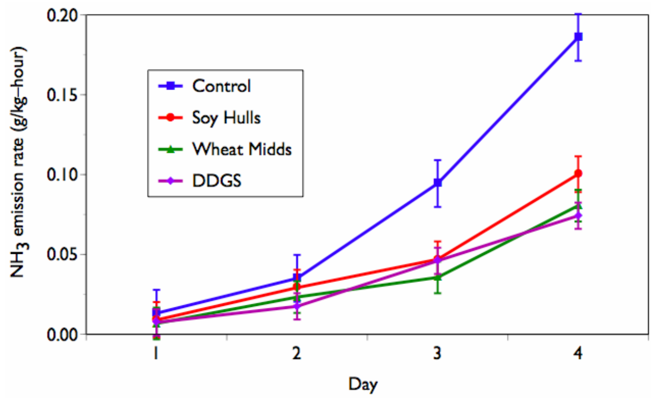

Figure 3. Ammonia emission rate from manure. Data are means ± pooled SEM, n=6.

Hen Performance

Addition of dietary fiber did not significantly affect egg production or egg mass (Table 2). Although the egg weight was significantly greater from hens fed the soy-hulls diet, the effect was counteracted by a numerically (but not statistically) lower egg production.

All diets were formulated to be isoenergetic and we therefore expected that hens fed any of the four treatments would consume similar amounts of feed. However, hens fed soy hulls or DDGS consumed significantly more feed than the control hens. This effect was likely due to the table values for energy contents of the fiber ingredients being too low.

Conclusions

Addition of the three fiber sources (i.e., soy hulls, wheat middlings, or DDGS) to the diets of laying hens caused a decrease in total ammonia emission and emission rate from the manure by up to 50%. This decrease was realized partly through a reduction in the amount of manure uric acid and partly through a lowered manure pH. Egg production and egg mass were not affected by the dietary fiber additions, although feed consumption increased slightly (by 2%). Further research is warranted to determine the inclusion rate of the three fiber sources that minimizes ammonia emission without affecting feed intake.

Table 1. Composition and chemical analysis of diets.

Item	Control no fiber added	Soy Hulls	Wheat Middlings	DDGS
Composition (%)				
Corn	62.82	56.56	54.92	51.90
Soybean meal (48% CP)	18.52	18.43	17.62	18.37
Meat and bone meal	5.00	5.00	5.00	5.00
Vegetable fat blend	2.27	3.88	3.85	3.65
Soy hulls	—	4.80	—	—
Wheat midds	—	—	7.30	—
Corn, distiller's grain with solubles	—	—	—	10.00
Alimet™	0.17	0.19	0.17	0.13
Dicalcium phosphate	0.27	0.28	0.21	0.14
Limestone	8.96	8.90	8.98	9.00
Sodium bicarbonate	0.20	0.12	0.10	—
Salt (iodized)	0.19	0.25	0.24	0.21
Trace-mineral premix	0.30	0.30	0.30	0.30
Vitamin premix	0.30	0.30	0.30	0.30
Celite™	1.00	1.00	1.00	1.00
Calculated analysis				
Crude protein (total), %	16.94	16.77	17.05	18.37
MEn, kcal/kg	2,840	2,840	2,840	2,840
Calcium, %	4.00	4.00	4.00	4.00
Phosphorus (non-phytate), %	0.37	0.37	0.37	0.37
Neutral detergent fiber, %	9.20	11.21	10.73	11.67
Dietary electrolyte balance (K+Na–Cl), mEq	191	191	191	191
Digestible amino acids (%)				
Methionine + cystine	0.61	0.61	0.62	0.61
Methionine	0.39	0.40	0.39	0.38
Lysine	0.73	0.73	0.73	0.73
Threonine	0.54	0.53	0.53	0.56
Tryptophan	0.18	0.18	0.18	0.19
Valine	0.70	0.69	0.70	0.75
Isoleucine	0.60	0.59	0.60	0.64

Table 2. Manure and performance data.

Item	Control No fiber added	Soy Hulls	Wheat Middlings	DDGS	SEM
Manure N excretion (g/hen–day)	1.67	1.55	1.46	1.66	0.08
Manure pH	7.08	6.86	6.80*	6.78*	0.08
Egg mass (g/hen–day)	54.11	54.57	55.03	54.93	0.43
Egg production (%)	89.13	87.81	89.34	89.69	0.78
Egg weight (g/hen–day)	60.69	62.16*	61.69	61.37	0.45
Feed intake (g/hen–day)	97.75	99.78*	99.31	99.72*	0.66

*Different from control $P<0.05$, n=32.

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