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## Abstract

A USDA Natural Resources Conservation Service, Conservation Innovation Grant project coordinated by the United Egg Producers (UEP) conducted concurrent demonstrations in Iowa and Pennsylvania (PA) at commercial laying hen facilities. The goal was to document manure nutrient and gas emission improvements through the use of dried distiller's grain with solubles (DDGS) diets and/or other dietary modifications while maintaining or improving hen productivity. Results of the PA trial are presented here. Diets containing 10% corn DDGS with (D+P) or without (D) the probiotic Provalen™ were compared to a corn-soybean based control diet (CON). The isocaloric, amino acid balanced diets were fed to three groups of 39,800 Lohmann hens in one house. Hens were 20-65 wk of age with each diet provided to 2 of 6 rows of stacked cages with manure belts (six decks high). Feed intake, water consumption, hen body weight (BW), egg production (EP), egg case weight, mortality, feed cost (FC), and egg income (EI) were provided weekly by the cooperating egg company. Replicated monthly data, including egg weight (EW), albumen height (AH), Haugh units (HU), yolk color (YC), shell strength (SS) and shell thickness (ST), were determined from eggs collected from six 4-cage sections of hens on each diet. Replicated monthly samples of hen manure (fresh and from storage) were analyzed for moisture and major nutrients. Ammonia (NH<sub>3</sub>) gas measurements utilized a non-steady state flux chamber method coupled with photoacoustic infrared gas analyzer. There was no clear trend in the magnitude of NH<sub>3</sub> emissions relative to the diets within the hen house as measured on the manure belt. At 32 and 36 wks of age, NH<sub>3</sub> emissions were significantly ( $P < 0.10$ ) higher in D while D+P and CON were lower and similar. At 48 and 52 wks, NH<sub>3</sub> emissions from D were similar to D+P and significantly lower than CON. Emission rate from belt manure averaged  $0.42 \pm 0.025$  g bird<sup>-1</sup> d<sup>-1</sup> for all treatments and dates. There was no significant impact of diet on BW, EW, HU, SS, or ST ( $P = 0.10$  to  $0.66$ ), however, CON hens had lower EP, AH, and YC compared to D and D+P hens ( $P = 0.05$ ). Fresh manure total phosphorus (P<sub>2</sub>O<sub>5</sub>) was higher for CON samples ( $P < 0.05$ ) while other major agronomic nutrients and moisture were not significantly different among treatments. Stored CON manure samples had increased moisture and NH<sub>4</sub>-N compared to those of D and D+P treatments ( $P < 0.10$ ). Weekly EI minus FC averaged \$6,146, \$6,215, and \$6,209 for the CON, D, and D+P diets, respectively.

## Keywords

Emission, mitigation, diet, poultry, ammonia, gas, egg, production

## Disciplines

Bioresource and Agricultural Engineering

## Comments

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# AMMONIA EMISSION, MANURE NUTRIENTS AND EGG PRODUCTION OF LAYING HENS FED DISTILLER DRIED GRAIN DIETS

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## ABSTRACT

A USDA Natural Resources Conservation Service, Conservation Innovation Grant project coordinated by the United Egg Producers (UEP) conducted concurrent demonstrations in Iowa and Pennsylvania (PA) at commercial laying hen facilities. The goal was to document manure nutrient and gas emission improvements through the use of dried distiller's grain with solubles (DDGS) diets and/or other dietary modifications while maintaining or improving hen productivity. Results of the PA trial are presented here. Diets containing 10% corn DDGS with (D+P) or without (D) the probiotic Provalen<sup>TM</sup> were compared to a corn-soybean based control diet (CON). The isocaloric, amino acid balanced diets were fed to three groups of 39,800 Lohmann hens in one house. Hens were 20-65 wk of age with each diet provided to 2 of 6 rows of stacked cages with manure belts (six decks high). Feed intake, water consumption, hen body weight (BW), egg production (EP), egg case weight, mortality, feed cost (FC), and egg income (EI) were provided weekly by the cooperating egg company. Replicated monthly data, including egg weight (EW), albumen height (AH), Haugh units (HU), yolk color (YC), shell strength (SS) and shell thickness (ST), were determined from eggs collected from six 4-cage sections of hens on each diet. Replicated monthly samples of hen manure (fresh and from storage) were analyzed for moisture and major nutrients. Ammonia (NH<sub>3</sub>) gas measurements utilized a non-steady state flux chamber method coupled with photoacoustic infrared gas analyzer. There was no clear trend in the magnitude of NH<sub>3</sub> emissions relative to the diets within the hen house as measured on the manure belt. At 32 and 36 wks of age, NH<sub>3</sub> emissions were significantly ( $P < 0.10$ ) higher in D while D+P and CON were lower and similar. At 48 and 52 wks, NH<sub>3</sub> emissions from D were similar to D+P and significantly lower than CON. Emission rate from belt manure averaged  $0.42 \pm 0.025$  g bird<sup>-1</sup> d<sup>-1</sup> for all treatments and dates. There was no significant impact of diet on BW, EW, HU, SS, or ST ( $P = 0.10$  to  $0.66$ ), however, CON hens had lower EP, AH, and YC compared to D and D+P hens ( $P \leq 0.05$ ). Fresh manure total phosphorus (P<sub>2</sub>O<sub>5</sub>) was higher for CON samples ( $P < 0.05$ ) while other major agronomic nutrients and moisture were not significantly different among treatments. Stored CON manure samples had increased moisture and NH<sub>4</sub>-N compared to those of D and D+P treatments ( $P < 0.10$ ). Weekly EI minus FC averaged \$6,146, \$6,215, and \$6,209 for the CON, D, and D+P diets, respectively.

**KEYWORDS.** Emission, mitigation, diet, poultry, ammonia, gas, egg, production

## INTRODUCTION

According to the U.S. Environmental Protection Agency (EPA), egg farming contributed about one quarter of ammonia gas (NH<sub>3</sub>) emissions from the animal-agriculture sectors. Many management strategies are reported to mitigate NH<sub>3</sub> emission with reduced dietary protein a strategy widely applied in the industry (Liang et al., 2005). Dried distiller's grain with solubles (DDGS) has become a feed alternative for poultry due to its greater availability from increased

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production of ethanol for fuel and its competitive price supplying protein and other important nutrients.

There have been reports from laboratory and field studies of DDGS-diets offering reduced NH<sub>3</sub> emissions (Roberts et al. 2006; Hale 2008). A diet containing 10% DDGS fed to laying hens in a production environment reduced manure NH<sub>3</sub> emissions an average of 16.9% (Hale, 2008) with ranges from +6.3% to -33.3% compared to control groups. Wu-Haan et al. (2009) found a significant linear decrease in NH<sub>3</sub> emitted per kg nitrogen (N) intake during a laying hen laboratory study with 0, 10 and 20% DDGS diets. Our project goal was to document manure nutrient and gas emissions during the use of DDGS diets while maintaining or improving hen productivity and egg quality.

## MATERIALS AND METHODS

United Egg Producers (UEP) coordinated concurrent demonstrations of DDGS fed hens in Iowa and Pennsylvania (PA) at commercial facilities. Results of the PA trial presented here were conducted at a commercial hen farm set up for research trials with laboratory evaluations at The Pennsylvania State University (Penn State). Lohmann LSL-Lite pullets (119,400) were placed into the house at 18 wk of age and distributed randomly into 13,104 cages with 9 to 10 birds per cage (61×66×46 cm; LxWxH) and fed a commercial diet based on corn and soybean meal. The cages were arranged in 6 rows of 6 tiers with 2-cages back-to-back. Each tier-row of cages was equipped with an egg belt in the front and a manure belt underneath. One-third of the manure was removed from the house each day by running all belts for 6 min. Therefore, each belt had 1, 2 and 3 d manure accumulation depending on proximity to the belt scraper at the cross-conveyer. The feeding trial began when hens were 22 wk old. Environment and manure information was collected monthly during site visits to the facility starting with 23 week old hens in July 2008 and concluding when hens were 64 weeks of age in April 2009. Hen, egg, economic and other farm data were collected weekly to 65 wks (data to 56 wks are reported here). Eggs were sold to the breaker market so size and grade data were not available.

### Diets and hen performance

There were three diets used in this study: a control diet based on corn and soybean meal (CON), CON plus 10% corn DDGS (D) and CON plus 10% DDGS and 0.5g/kg probiotics (D+P). The probiotic used was Provalen<sup>TM</sup> (Agtech Product, Inc., Waukesha, WI), which contained dried *Bacillus subtilis* and *Bacillus licheniformis* fermentation product ( $1.5 \times 10^8$  CFU/g). Dietary treatments were formulated to contain approximately 1,300 kcal ME/kg and 16.9 to 19.0% crude protein. All other nutrients satisfied the NRC nutrient recommendations (NRC, 1994). Each of the diets was distributed automatically from one of three feed bins to two rows of cages per treatment. Feeding times were staggered throughout the 16 h light period each day and water was provided ad libitum with nipple drinkers in each cage.

Replicated data were collected during monthly farm visits (see below) and weekly from company-supplied records [egg production (EP), egg weight (EW), feed consumption, water intake, hen body weight (BW), egg case weight, mortality, feed cost (FC), and egg income (EI)]. A second measure of BW was determined during monthly site visits using a portable scale on hens in designated sections of the building representing each diet. In these 4-cage designated sections, eggs were collected for 5 to 14 h from 3 locations per row (6 locations per treatment representing 558 hens total) and refrigerated at 5°C for maximum of 7 d before external (EW, shape, air cell, specific gravity) and internal quality of eggs [albumen height (AH), Haugh units (HU), yolk color (YC), shell strength (SS) and shell thickness (ST)] were determined at Penn State laboratories. Because feed consumption was monitored automatically per row basis, EP over FC was determined on an average basis for each treatment. Statistical differences among treatments for replicated monthly production (and manure agronomic nutrient data, described later) were detected using a one-way ANOVA. Data analysis was done using the PROC GLM procedure

(SAS, 2003). Mean comparisons were made using Tukey's procedure and p-values  $P \leq 0.05$  were deemed significant.

### Ammonia emissions

With three dietary treatments under study in one house it was necessary to sample  $\text{NH}_3$  emission at its source. A flux chamber method was used for this purpose with the primary benefit being the ability to measure treatment effects among various surfaces. Emissions measured were not designed to simulate actual emission, as measured from the building, but instead offered a relative comparison of ammonia flux from manure of each diet. Ammonia flux was determined using a non-steady-state flux chamber based on a design of Woodbury et al. 2006. A 29 cm diameter stainless-steel, bowl-topped, skirted (28 cm H), flux chamber (volume  $0.027 \text{ m}^3$ ) was connected to a photoacoustic infrared analyzer (Model 1412, Innova Air Tech Instruments, Ballerup, Denmark). Detection limit for  $\text{NH}_3$  0.2 ppm; sensitivity to water vapor compensated. The analyzer was calibrated annually by California Analytical Instruments (Orange, CA) at expected gas range and humidity level for manure measurements. The chamber sampling ports connected to the analyzer via 1 m long Teflon™-lined tubing. The chamber had a small internal, 12 V battery-operated circulation fan. Providing air velocity over the enclosed manure has been shown to result in more realistic ammonia flux measurements (Blanes-Vidal et al. 2006; Ni, 1999). Deployment of the non-steady state flux chamber for a short time was desirable to minimize interference with accumulating gases and to monitor multiple locations to better capture variability in emissions from potentially non-uniform emission sources.

Flux measurements were collected at the top tier-cages of each row on one-third of the belt that contained 3 d manure accumulation. Three locations with two subsamplings per location of this segment of the belt were selected for these measurements ( $n=6$  for each cage row). Preliminary emission measurements determined that position along the manure belt did not affect  $\text{NH}_3$  measurements. When taking readings, a flat, 60 mm thick board, 0.25 m square was placed under the belt to provide a firm sealing surface. The chamber was forced downward through the manure until it seated firmly on the belt. The emission monitoring protocol included: 1) running the belt for 10 s to expose a section of belt that had been under cages to the location where the flux chamber could be placed for measurements (2.3 m from the scraped-end of the manure belt) and measuring two flux locations on the belt coinciding with manure accumulated under each of the 2 back-to-back cages 2) running the belt for 2 min and 30 s, thus removing manure from the house and obtaining a new belt location for dual flux readings and 3) running the belt again for 2 min and 30 s for the third pair of flux readings. The 1 d and 2 d manure accumulations were not monitored to reduce the number of variables under study. All emission measurements of the three dietary treatments in the hen house were conducted within a 5.5 h timeframe during each site visit commencing, on average, at 10:30 (range 9:30-12:00) to minimize the impact of diurnal variation.

The length of time the flux chamber was deployed (total of 4 min) was minimized to reduce perturbations of conditions in the near-surface atmosphere that can modify gas flux rate. One reading of  $\text{NH}_3$  concentration ( $C_x$ ) was obtained during one concentration measurement cycle. A measurement cycle consisted of the analyzer sample pump running for 19 s, which flushed the tubing and sample chamber, then the sample pump stopped for 41 s during which time the analyzer measured the gas concentration contained in the sample chamber. The flux chamber was placed on the manured surface as soon as the sample pump stopped running from drawing the background air ( $C_o$ ) sample from 0.5 m above the manure belt. The chamber was left on the manure belt undisturbed for 4 min, taking a concentration measurement every 60 s. This resulted in a total of 5 readings per measurement site. The first ( $C_o$ ), third ( $C_1$ ) and fifth ( $C_2$ ) readings were used in the emission flux rate calculation (Eqn. 1).

Ammonia flux rate from the manure covered by the chamber,  $f$ , was calculated as proposed by Livingston and Hutchinson (1995) for non-steady state flux chamber measurements. This equation calculates initial gas flux at the beginning of the sampling period:

$$f = \frac{V_c(C_1 - C_0)^2}{A_c t(2C_1 - C_2 - C_0)} \text{Ln} \frac{C_1 - C_0}{C_2 - C_1} \quad (1)$$

Where,  $f$  gas flux rate from the manure covered by the chamber,  $\text{g m}^{-2} \text{s}^{-1}$

$C_0$  background gas concentration,  $\text{g/m}^3$

$C_1$  gas concentration at a moment  $t$  after placing the chamber on the surface,  $\text{g/m}^3$

$C_2$  gas concentration at a moment  $2t$  after placing the chamber on the surface,  $\text{g/m}^3$

$V_c$  volume of the chamber,  $\text{m}^3$

$A_c$  area covered by the chamber,  $\text{m}^2$

$t$  time (s) between measuring  $C_0$  and  $C_1$ ; set at 120 s for this study

This model is non-linear, as it assumes that the rate of gas exchange is not uniform over the measurement period, but rather decreases as the gas accumulates inside of the chamber. It is essential to confirm for each flux measurement that this theoretical assumption is fulfilled by verifying Eqn. 2, otherwise a linear relationship is used. Flux from the surface was converted to per bird with an estimated 29 hens  $\text{m}^{-2}$  above the manure belt area.

$$\frac{C_1 - C_0}{C_2 - C_1} > 1 \quad (2)$$

### Manure sampling and storage emissions

Hen manure from the belt was collected from the entire area enclosed during ammonia flux chamber measurement with manure from the two spots at each belt location combined. This resulted in three manure samples per belt; six total for each diet at each data collection visit. Manure was placed in plastic bag, transported on ice to campus then immediately stored at  $-20^\circ\text{C}$ . Manure was homogenized before delivery to Penn State's Agricultural Analytical Services Laboratory [AASL] for nutrient analysis (moisture, total nitrogen (N), ammonium-N ( $\text{NH}_4\text{-N}$ ), organic-N, total phosphorus ( $\text{P}_2\text{O}_5$ ), and total potash ( $\text{K}_2\text{O}$ )). Storage and belt manure pH was measured on the last site visit samples (wk 64).

Ammonia flux measurements were taken from a manure storage building where treatment hen manure was segregated into subsamples ( $\sim 1 \text{ m}^3$ ) of manure from each dietary treatment. This manure was stored in the building between farm visits with no addition of manure. Subsamples were required because farm manure management would normally co-mingle manure from all cage rows into the covered storage. During flux measurements in the hen house, the two cage rows with each diet were measured sequentially so that manure was removed from the belts below these cages (the one-third of each belt containing the 3 d manure accumulation) and conveyed to storage. Manure from each diet treatment was placed into one of three open-front temporary bins ( $3 \times 1.2 \times 1.2 \text{ m}$ ;  $L \times W \times H$ ). Manure from each month was added on top of manure accumulated from the previous month. Flux measurements were conducted immediately upon arrival at the farm site from all three storage bins before additional manure was added. A preliminary analysis evaluated calculated  $\text{NH}_3$  emissions from 3 positions within each storage bin and determined that only one replicate was statistically similar to overall mean from 2 or 3 replicates; so 2 manure storage positions in each bin were measured for flux with 1 replicate each. Manure samples from the stored manure for each diet was collected from each flux measurement location ( $n=2$ ) for analysis at AASL.

## **RESULTS AND DISCUSSION**

### Hen performance and egg quality

Dietary treatments had a significant impact on EP and two egg quality parameters (AH and YC) with the CON diet being significantly lower than D or D+P fed hens ( $P \leq 0.05$ : Tab. 1; Fig. 1). Table 1 reflects findings of replicated monthly measurements on a sample of hens from each diet in the study house. There were no significant impacts on hen BW or egg parameters EW, HU, SS, or ST ( $P > 0.05$ ) among the diets. Based on company-supplied weekly data for the whole flock for the CON, D, and D+P diets, respectively, hen-day EP averaged 85.8, 85.2, 85.7% over the study

period and total eggs per hen housed were 271, 270 and 271 at 65 wks of age. Mean feed intake and feed conversion were similar among the diets for the CON, D, and D+P diets, respectively, at 100.0, 100.0, and 104.3 g hen<sup>-1</sup> d<sup>-1</sup> and 1.91, 1.95, 1.95 kg feed per dozen eggs. For the CON, D, and D+P diets, respectively, weekly average FC was \$6,705, \$6,599, and \$6,671 and breaker-market EI \$12,851, \$12,801, and \$12,864 resulting in higher average weekly farm revenue (EI-FC) from the two DDGS diets (\$6,215 (D) and \$6,209 (D+P)) versus the CON diet (\$6,146).

**Table 1. The effect of DDGS with (D+P) or without (D) probiotic supplementation on hen body weight, egg production and egg quality versus Control diet (CON) of monthly on-farm collected data.**

Diet	Body Weight	Hen-Day Egg Prod. <sup>1</sup>	Egg Count <sup>1</sup>	Egg weight <sup>3</sup>	Shell <sup>4</sup> Strength	Shell Thick.	Albumen Height <sup>4</sup>	Haugh Unit	Yolk Color Score
	kg/hen	%	mean/trt	g/egg	g force	mm	mm		
CON	1.57	91.26 <sup>b</sup>	33.83	58.74	4094	0.373	7.62 <sup>b</sup>	86.83	7.27 <sup>b</sup>
D	1.58	94.69 <sup>ab</sup>	36.39	59.34	4180	0.376	7.86 <sup>a</sup>	87.65	7.80 <sup>a</sup>
D+P	1.57	94.84 <sup>a</sup>	36.69	59.12	4117	0.374	7.85 <sup>a</sup>	88.01	7.83 <sup>a</sup>
SEM <sup>2</sup>	0.009	0.941	0.813	0.251	33.94	0.0013	0.051	0.392	0.039
P-value	0.662	0.027	0.049	0.244	0.180	0.302	0.001	0.099	< 0.0001

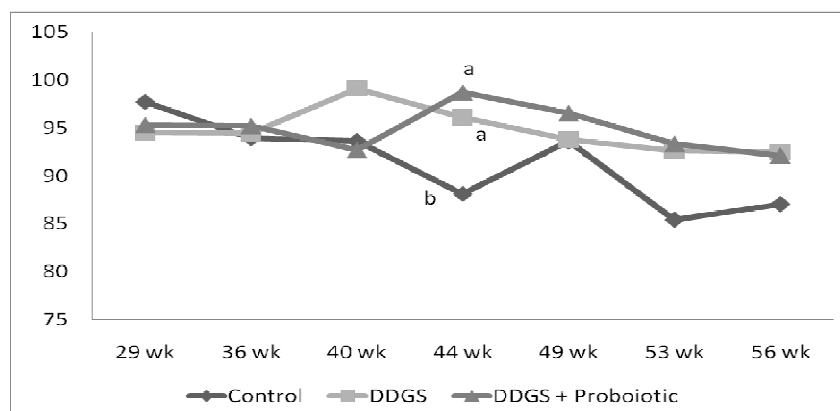
<sup>a,b</sup> Means within a column with different superscripts differ significantly (P < 0.05)

<sup>1</sup> Hen-Day Egg Production calculated as the ratio of # eggs to # hens in six 4-cage sections per treatment from which eggs were sampled for quality measurements. Egg Count is number of eggs laid by these hens.

<sup>2</sup> Standard error of the mean with 6 replicates per treatment per data collection date.

<sup>3</sup> Recorded from the 15 selected eggs per sampling cage.

<sup>4</sup> External egg quality (shell strength and thickness) was performed in alternate months with internal egg quality (albumen height, Haugh unit, and yolk color).



**Figure 1. Hen day egg production of laying hens fed a typical commercial corn-soybean meal based-diet (Control), a diet with DDGS, or with DDGS plus probiotics (based on monthly farm visit data).**

### Manure characteristics

Table 2 provides a summary of manure characteristics of samples collected from the hen house manure belt at locations where emissions were determined for each diet treatment. Only manure P<sub>2</sub>O<sub>5</sub> was significantly different among the diets (P < 0.05), being higher in CON samples than the DDGS samples. The DDGS-based diets may offer advantage for crop management plans utilizing layer hen manure in PA where phosphorus-based nutrient management plans (rather than N-based) have been used when there is a high potential for phosphorus loss to waterways. Manure moisture, total N, NH<sub>4</sub>-N, organic-N, and K<sub>2</sub>O were not significantly different among the dietary treatments.

**Table 2. Solids content and major nutrients in manure accumulated for 3 d on belt under cages of laying hens fed Control diet (CON), DDGS (D), or a DDGS diet supplemented with probiotics (D+P).**

Diet	Solids (%)	Total-N	NH <sub>4</sub> -N	Organic-N	Total P <sub>2</sub> O <sub>5</sub>	Total K <sub>2</sub> O
		(g/kg of manure, DM basis)				
CON	39.93	49.26	9.47	39.79	45.73 <sup>a</sup>	23.02
D	40.37	49.78	8.96	40.80	39.26 <sup>b</sup>	23.60
D+P	39.71	50.12	8.55	41.57	39.39 <sup>b</sup>	22.93
SEM <sup>1</sup>	1.623	1.641	0.462	1.685	1.127	0.310
P-value	0.9578	0.9332	0.3915	0.7591	0.0013	0.2873

<sup>a,b</sup> Means within a column without the same superscripts differ significantly (P < 0.05)

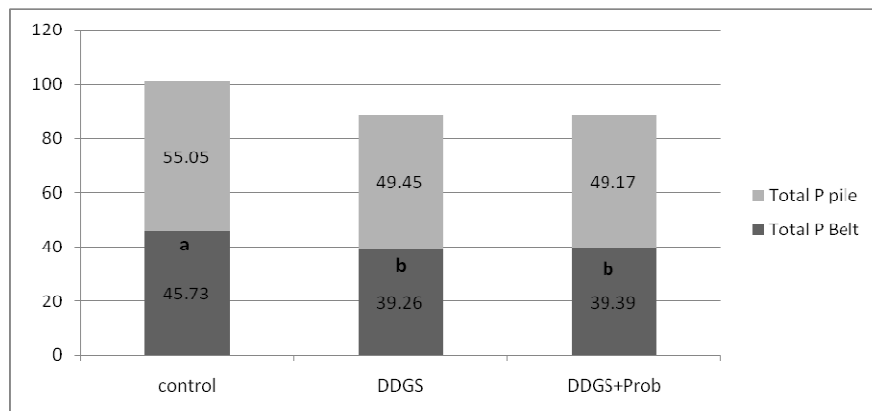
<sup>1</sup> Standard error of the mean of 6 samples per treatment per sampling date.

Results from the stored manure pile analyses are included in Table 3. After storage the only significantly different ( $P < 0.10$ ) characteristics were CON manure having higher moisture and  $\text{NH}_4\text{-N}$  than D or D+P manures. A trend for reduced phosphorus in the DDGS treatment manures is observed but differences with the CON diet are no longer highly significant ( $P=0.13$ ) for the stored manure. For manure stored in 34 high-rise commercial layer houses on three farms Behrends and Roberts (2009) found mixed results comparing 0, 8 and 12% DDGS diets' impact on  $\text{P}_2\text{O}_5$  content of manure. One farm had a significant increase in high-rise manure  $\text{P}_2\text{O}_5$  but no difference was observed at the other two farms. Behrends and Roberts (2009) DDGS diets did not affect N content of manure stored at any of the three farms. Figure 2 compares manure total  $\text{P}_2\text{O}_5$  for belt and stored manure for all three diet treatments while Figure 3 offers a similar comparison for manure  $\text{NH}_4\text{-N}$ .

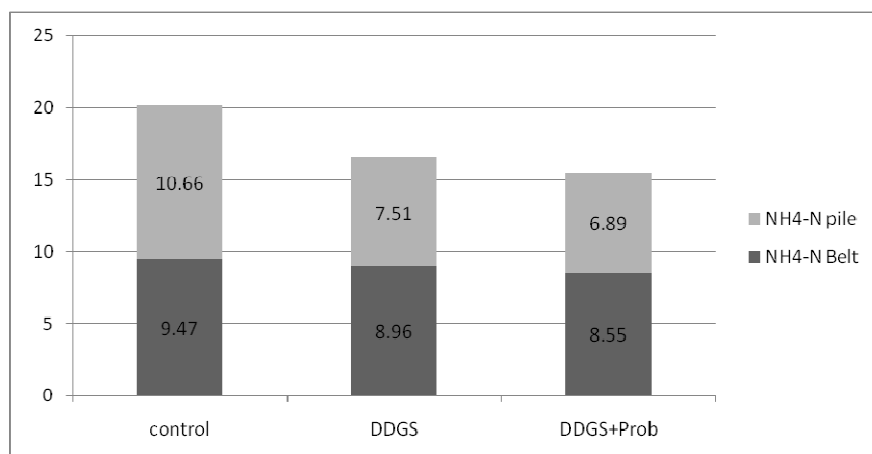
**Table 3. Manure storage pile solids and major agronomic nutrients from laying hens fed corn-soybean-diet (CON), a similar diet containing DDGS (D), or a DDGS diet supplemented with probiotic (D+P).**

Diet	Solids (%)	(g/kg of manure, DM basis)				
		Total-N	$\text{NH}_4\text{-N}$	Organic-N	Total $\text{P}_2\text{O}_5$	Total $\text{K}_2\text{O}$
CON	56.78	50.69	10.66	40.02	55.05	26.89
D	64.98	44.89	7.51	37.38	49.45	26.38
D+P+Pro	62.65	41.18	6.89	34.29	49.17	26.65
SEM <sup>1</sup>	1.526	2.362	0.681	2.999	1.611	0.497
P-value	0.0662	0.1382	0.0556	0.4893	0.1339	0.7827

<sup>1</sup>Standard error of the mean of 2 samples per treatment per sampling date.



**Figure 2. Comparison of total  $\text{P}_2\text{O}_5$  (g kg<sup>-1</sup> DM) for samples from manure belt under hens and storage pile manure.**



**Figure 3. Manure  $\text{NH}_4\text{-N}$  (g kg<sup>-1</sup> DM) for belt and pile manures ( $P=0.056$  Pile).**

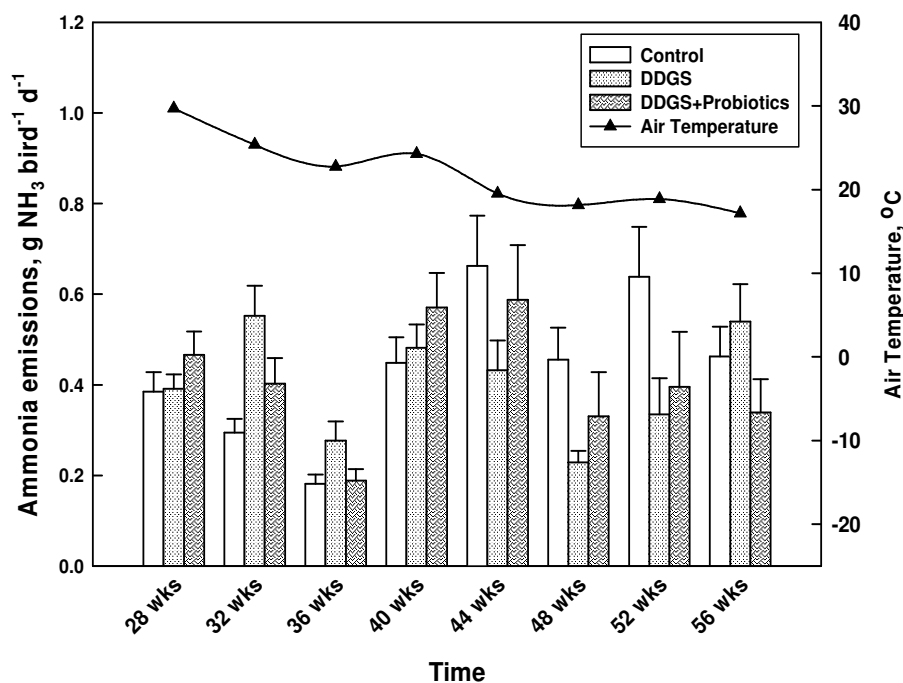


## Ammonia emissions from hen house and storage

There was no clear trend in the magnitude of NH<sub>3</sub> emissions within the hen house as measured at the manure belt between DDGS treatments and CON diet during the measurement periods (Fig. 4). At 32 and 36 wk of hen age (P= 0.003; 0.064, respectively), NH<sub>3</sub> flux was significantly (P <0.10) higher in D than for the other two diets, while D+P flux was similar to CON. At 48 and 52 wk of age (P= 0.078; 0.084, respectively), NH<sub>3</sub> flux from D and D+P were similar and significantly lower than CON. Average ammonia flux rate for all diets was 0.419 ± 0.025 g b<sup>-1</sup> d<sup>-1</sup> over the study period ranging from a high of 0.663 ± 0.11 for CON at 44 wks to a low of 0.182 ± 0.02 for CON at 36 wks of hen age. Air temperature was not correlated with NH<sub>3</sub> emission within the laying hen house (P=0.984), likely due to the rather narrow temperature range (average 22°C; range 16.4-26.3°C) maintained during the study period. In contrast, air temperature in the storage building was significantly correlated with manure pile NH<sub>3</sub> flux. Manure pH was not significantly different among the diet treatments (Tab. 4. P=0.54 belt; P= 0.66 pile), which can partially explain the similar ammonia emissions. During storage the manure pH increased 1 unit for all diets resulting in a pH above 8 that would favor ammonia emission.

**Table 4. Manure pH of samples collected at hen age 65 wk for Control (CON), DDGS (D) and DDGS + probiotic (D+P) dietary treatments. Manure belt samples of 3 d accumulation of fresh manure while storage pile manure samples are from the top few centimeters of month-old manure.**

Diet	Hen House Manure Belt pH		Manure Storage Pile pH	
	average (n=6)	stdev	average (n=2)	stdev
CON	7.21	0.14	8.22	0.04
D	7.41	0.56	8.38	0.15
D+P	7.20	0.24	8.22	0.29



**Figure 4. Average ammonia flux from 3 d manure accumulation on manure belts of caged laying hens fed with three amino-acid balanced diets and average air temperature within the house during data collection (typically 10:30-16:00).**

## CONCLUSIONS

The goal of the project was to document the impact of DDGS-based hen diets on ammonia emissions, manure nutrients, hen production and egg quality. The diets, corn-soybean Control, 10% DDGS, and 10% DDGS with Probiotic, showed no clear impact on NH<sub>3</sub> emissions measured at the manure belt. At 32 and 36 wks of age, NH<sub>3</sub> emissions were significantly higher in the

DDGS treatment while DDGS+Probiotic diet was similar to Control diet. At 48 and 52 wks, NH<sub>3</sub> emissions from the two DDGS diets were significantly lower than Control (P < 0.10). Dietary treatments did not significantly impact hen body weight, egg weight, and most egg quality parameters (P > 0.05); however, the Control hens had lower egg production, albumen height and yolk color compared to the two DDGS diets (P ≤ 0.05). Manure moisture, total nitrogen, ammonium-N, organic-N, and potash (K<sub>2</sub>O) did not differ significantly by dietary treatment, but manure total phosphorus (P<sub>2</sub>O<sub>5</sub>) was higher for Control samples (P < 0.05). Stored manure for Control diets had greater moisture and more ammonium-N compared to samples from the two groups of DDGS-fed hens (P < 0.10). Weekly egg income minus feed cost (e.g. farm revenue) was higher for the two DDGS diets versus the Control.

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