Mitigating Ammonia Emissions from High-rise Hen Houses through Dietary Manipulation

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Summary and Implications

Dietary manipulation can substantially lower ammonia (NH_3) emissions from laying-hen houses or manure storage. Recent lab studies showed a NH_3 emission reduction for experimental diets with EcoCal™ and corn dried distiller's grain with solubles (DDGS) as compared to the standard or control diet. The study reported here was a field verification test about the effects of diets containing DDGS and EcoCal™ on air emissions, hen production performance, and the economic returns for a commercial high-rise layer operation in Iowa. Comparative data were collected during December 2007 to Dec 2009. Feeding EcoCal diet at 7% inclusion rate and DDGS diet at 10% inclusion rate to laying hens in the high-rise houses showed 39% and 14% overall reduction in NH_3 emissions, respectively. There were few differences in egg production, egg weight or egg mass (output) for hens fed the EcoCal or DDGS diet as compared to hens fed the control diet. Compared with the control and DDGS hens, the EcoCal hens consumed more feed and had a lower mortality rate, and had a similar feed conversion. The EcoCal hens also tended to have a greater body weight. Egg production was slightly lower for hens fed the DDGS diet (424 eggs hen^{-1} or 58.5 lb hen^{-1}) than that of the Control (435 eggs hen^{-1} or 59.2 lb hen^{-1}) and EcoCal (447 eggs hen^{-1} or 61.9 lb hen^{-1}) hens. The lower egg production by the DDGS hens (during the first cycle) could have resulted from learning management of the new strain birds during the first cycle. The cash returns (revenue – total cost) of each hen were, respectively, \$11.88, \$11.18 and \$12.35 for Control, DDGS and EcoCal regimens over the 91-wk production period.

Introduction

Ammonia (NH_3) emissions from animal feeding operations (AFOs) have been estimated to represent the largest portion of the national NH_3 emissions inventory in the United States. Excessive NH_3 in animal housing adversely affect bird health and production performance. Understanding and mitigating air emissions from production facilities is an important issue for the U.S. livestock and poultry industries. The U.S. egg industry has been proactively looking for practical means to reduce NH_3 generation and/or emissions from egg production facilities. One of the promising NH_3-lowering methods is dietary manipulation. Although lab-scale tests involving small number of birds had shown considerable reduction in NH_3 emissions from manure of laying hens fed EcoCal™ or DDGS diet, field verification and demonstration of the promising dietary strategies are needed before consideration of their wider adoption by the egg industry.

The objective of this field project was to demonstrate, over an extended (2-year) period, the effects of feeding diets containing EcoCal or DDGS on emissions of NH_3 and hydrogen sulfide (H_2S), hen performance, and production economics for commercial high-rise layer facilities.

Materials and Methods

This demonstration project was conducted with three commercial high-rise laying-hen houses located in central Iowa, each measuring 90 × 592 ft with a housing capacity of approximately 260,000 Hy-Line W-36 hens. Each house had 72, 4-ft diameter exhaust fans along the sidewalls of the manure storage level, providing negative-pressure cross ventilation. Manure first fell onto the dropping boards below the cages and was then mechanically scraped into the storage 4 times a day (06:30, 09:00, 12:00, 15:00h). Photoperiod of 16L: 8D was generally used except during the molting period which followed a different lighting program. The three houses received three respective diets, namely, diet containing 7% (by weight) EcoCal (EcoCal), diet containing 10% (by weight) DDGS, and control diet (Control). Weekly bird performance data, including feed and water consumption, egg production, mortality, bird age, and body weight (BW), were collected and provided to the project team by the farm staff.

At the onset of the demonstration monitoring on December 6, 2007, hens for the dietary regimens had the following ages: 41 wk for EcoCal, 30 wk for Control, and 19 wk for DDGS. Monitoring of all the houses started free of manure accumulation (i.e., after a complete removal of manure in the storage). Molting started on June 30, 2008 in the EcoCal house, September 14, 2008 in the Control house, and December 27, 2008 in DDGS house (at age 72 to 75 wk). A molting diet without DDGS or EcoCal™ was used for the molting period. The EcoCal house was depopulated during the period of May 13-21, 2009 and restocked by June 9, 2009; the new flock in this house was fed DDGS diet. The Control house was depopulated during the period of July 16-24, 2009 and restocked by August 6, 2009; the new flock was fed EcoCal diet. Finally, the DDGS house was depopulated during the period of November 6-18, 2009 and restocked by December 17, 2009; and the new flock was fed Control diet.

Feed consumption (g $hen^{-1}d^{-1}$) was measured as feed disappearance from the two bins per house. Egg mass was calculated by multiplying the percentage egg production by the egg weight. Feed conversion was calculated as mass of feed consumed divided by mass of eggs produced. Hen BW was determined monthly by weighing the same 100 hens in each house. Hen-level air temperature was recorded at the 3rd and 5th tiers and averaged by week. The manure storage of each house was cleaned in November 2007 prior to the study. After one year accumulation the manure were removed and weighed separately for each individual house during the period of November 2008 to January 2009. Nine manure samples from each house were collected from nine selected representative locations and analyzed for nutrient, pH, and moisture content by a certified commercial lab.

A state-of-the-art mobile air emissions monitoring unit (MAEMU) housing the measurement and data acquisition systems was used to continuously collect data on NH_3, H_2S, and carbon dioxide (CO_2) concentrations from the three laying hen houses. Air samples were drawn from three composite locations (east, middle, and west parts) in each house as well as from an outside location to provide ambient background data. Ventilation rate (VR) of each house was measured continuously. The gaseous emission rates (ER) were then calculated from the concentration and VR data.

The data were analyzed for the period of December 6, 2007 to December 5, 2009. Analysis of variance of the data was performed using JMP (version 6.0, SAS Institute, Inc., Cary, NC). The dietary effect was considered significant at P-values ≤ 0.05.

Results and Discussion

Monthly means (± SE) NH_3 and H_2S ER for the DDGS, EcoCal, and Control houses are summarized in Tables 1 and 2. The monthly mean NH_3 ER was the lowest for the EcoCal diet (0.58 ± 0.05 g d^{-1} hen^{-1}), followed by the DDGS diet (0.82 ± 0.04 g d^{-1} hen^{-1}), and highest for the Control (0.96 ± 0.05 g d^{-1} hen^{-1}) ($P<0.01$). The efficacy of NH_3 emission reduction by the DDGS or EcoCal diet was season dependent during the 2-year monitoring period ($P<0.01$). The 2-year overall NH_3 emission reduction rate was 13.8% and 39.2% for DDGS and EcoCal diets, respectively. The outcome of seasonal variations in the dietary efficacy could have stemmed from changes in the manure properties, especially moisture content, as the climatic conditions and VR varied considerably with the season. The monthly mean H_2S ER for the EcoCal diet (5.39 ± 0.46 mg d^{-1} hen^{-1}) was significantly higher than that of the DDGS (1.91 ± 0.13 mg d^{-1} hen^{-1}) or Control (1.79 ± 0.16 mg d^{-1} hen^{-1}) ($P<0.001$). However, no difference in H_2S ER was observed between DDGS and Control ($P=0.23$). The mean H_2S ER increased 6.7% and 202% for the DDGS and EcoCal diets, respectively. It should be noted that the magnitude of H_2S ER was rather small in all cases. Hence, the 202% increase caused by the EcoCal diet, as compared to the Control, should have little negative impact on the practicality of the dietary strategy.

The feed consumption, egg production, and egg mass for the 1st cycle were estimated as the sum of the weekly feed consumption and egg production from weeks 20 to 69. The second cycle was defined as weeks 1–42 wk after molting. Hens in the EcoCal regimen consumed 6.7 and 4.3 lb, respectively, more feed than hens in the Control and DDGS regimens for the periods of two production cycles of the first flock. The increased feed consumption might have led to the larger BW for the EcoCal hens. The mean BW over this period was 3.54, 3.52, and 3.69 lb for the Control, DDGS, and EcoCal hens, respectively. The greater BW for the EcoCal hens would in turn require higher energy for metabolic maintenance. Furthermore, air temperature was somewhat cooler in the EcoCal house (73.5^{o}F) than in the Control (75.1^{o}F) or DDGS (75.3^{o}F) house, which could also contribute to the higher feed consumption. The overall feed conversions were 1.99, 2.06, and 2.02 for the Control, DDGS, and EcoCal regimens, respectively. Egg production was slightly lower for the DDGS hens (424 eggs hen^{-1} or 58.5 lb hen^{-1}) than for the Control (435 eggs hen^{-1} or 59.2 lb hen^{-1}) or EcoCal (447 eggs hen^{-1} or 61.9 lb hen^{-1}) hens during the two production cycles. Mean egg weights were 60.6, 61.3, and 61.7 g, respectively, for the Control, DDGS, and EcoCal hens.

The prices of feed ingredients (corn, soybean meal, DDGS, meat and bone meal, fat and salt) were the 2007-2009 average prices for Minneapolis, Chicago and Kansas City as published in the Feedstuffs newspaper. Ecocal was priced at 8 cents per cwt and micronutrients were priced at \$1,000 ton^{-1} (personal communication between Ibarburu and industry nutritionist). The feed prices throughout the two-year period were estimated from the feed formulas provided by the producer and were \$184.3, \$182.2, and \$189.0 per US ton (2000 lbs) for Control, DDGS and EcoCal diets, respectively. The manure values were \$5.87, \$7.35, and \$8.95 per 1000 hens per week for Control, DDGS and EcoCal diets, respectively. The egg price paid to producers was estimated using 2007–2009 Urner Barry prices minus a discount for washing, grading, packaging, etc. The pullet cost was assumed to be \$2.96 $bird^{-1}$ and all the pullets were paid in the 1st cycle and the starting cost of the birds in the 2nd cycle was the cost of feeding them throughout the molting period. The other costs, including labor, utilities, depreciation, insurance, etc., were assumed to be 27.2 cents per month per hen housed. The returns (revenue – total cost) per hen were, respectively, \$11.88, \$11.18 and \$12.35 for Control, DDGS and EcoCal dietary regimens over the 91-wk period (49 wks pre-molt and 42 wks post-molt). Hence, EcoCal provides a viable means for reducing ammonia emissions and improving production economic efficiency.

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Table 1. NH_3 emission rates (g hen^{-1} d^{-1}) of three diets and emission reduction relative to Control diet.

Month, Year	Mean T_{out}, °F	NH_3 ER (Mean)			NH_3 ER (S.E.)			Reduction, %	
		Control	DDGS	EcoCal	Control	DDGS	EcoCal	DDGS	EcoCal
Dec, 07	28.4	1.11	0.60	0.48	0.04	0.05	0.04	45.9	56.7
Jan, 08	20.4	1.29	0.92	0.40	0.06	0.03	0.02	28.9	69.4
Feb, 08	20.8	0.99	0.72	0.35	0.04	0.02	0.01	27.6	65.2
Mar, 08	37.4	1.02	0.76	0.39	0.05	0.04	0.02	25.6	61.5
Apr, 08	47.5	1.32	1.19	0.62	0.04	0.07	0.02	9.7	52.8
May, 08	60.4	1.15	1.05	0.71	0.05	0.05	0.04	8.7	38.1
Jun, 08	72.3	1.25	1.07	0.92*	0.07	0.05	0.04	14.4	26.5*
July, 08	75.9	1.38	1.18	0.90*	0.07	0.04	0.05	14.3	34.9*
Aug, 08	71.2	1.12	1.16	1.06	0.04	0.04	0.03	-3.9	5.0
Sep, 08	64.6	0.94*	1.09	1.00	0.06	0.05	0.04	-16.3*	-7.1*
Oct, 08	53.2	0.81*	0.85	0.69	0.04	0.04	0.04	-5.1*	14.0*
Nov, 08	41.2	0.88	0.66	0.58	0.04	0.05	0.03	25.1	33.5
Dec, 08	21.8	0.91	0.73*	0.58	0.02	0.04	0.04	20.2*	36.3
Jan, 09	19.6	0.6	0.80*	0.36	0.05	0.06	0.01	-31.8*	39.6
Feb, 09	29.4	0.78	0.96	0.22	0.04	0.03	0.01	-23.4	72.2
Mar, 09	40.0	0.91	0.8	0.26	0.03	0.02	0.01	12.3	71.6
Apr, 09	48.4	0.58	0.6	0.46	0.04	0.04	0.02	-2.0	21.8
May, 09	61.9	0.70	0.76	0.68†	0.04	0.02	0.06	-8.2	4.0
Jun, 09	69.8	1.01	0.94	-	0.06	0.06	-	6.8	-
July, 09	69.9	1.01†	0.61	-	0.14	0.03	-	39.5	-
Aug, 09	69.9	0.53§	0.72	-	0.03	0.03	-	-36.2§	-
Sep, 09	64.4	0.73§	0.58	0.67	0.08	0.02	0.05	19.9§	7.4§
Oct, 09	46.0	-	0.47	0.47	-	0.02	0.02	51.0‡	50.7‡
Nov, 09	45.7	-	0.56†	0.40	-	0.02	0.01	41.5‡	58.2‡
Overall	**49.2**	**0.96**	**0.82**	**0.58**	**0.05**	**0.04**	**0.05**	**13.8**	**39.2**

*Molting diet was used.
† Flock was depopulated.
§ The new flock was considered as control before the EcoCal diet was fed.
‡ Reduction rate was based on average ER of control diet from Dec, 2007 to Sep, 2009.
- No meaningful comparison due to flock changing

Table 2. H_2S emission rate (ER, mg hen^{-1} d^{-1}) of three diets and ER increases relative to the Control diet.

Month, Year	Mean T_{out}, °F	H_2S ER (Mean)			H_2S ER (S.E.)			Increase, %	
		Control	DDGS	EcoCall	Control	DDGS	EcoCall	DDGS	EcoCal
Dec, 07	28.4	1.66	1.46	2.23	0.06	0.13	0.14	-11.7	34.8
Jan, 08	20.4	2.43	1.89	4.25	0.14	0.11	0.14	-22.2	75.0
Feb, 08	20.8	2.03	1.80	6.99	0.10	0.04	0.33	-11.2	245
Mar, 08	37.4	2.4	1.81	8.97	0.09	0.07	0.28	-24.7	273
Apr, 08	47.5	2.89	1.99	7.59	0.07	0.07	0.21	-31.1	163
May, 08	60.4	2.39	1.90	5.8	0.08	0.09	0.40	-20.7	142
Jun, 08	72.3	3.17	2.12	7.36*	0.11	0.15	0.59	-33.0	132*
July, 08	75.9	2.97	3.68	2.04*	0.13	0.24	0.11	23.7	-31.3*
Aug, 08	71.2	2.27	3.44	2.24	0.10	0.19	0.07	51.3	-1.5
Sep, 08	64.6	1.45*	2.52	5.93	0.18	0.13	0.32	73.9*	309*
Oct, 08	53.2	0.76*	1.46	4.46	0.06	0.05	0.24	91.4*	485*
Nov, 08	41.2	0.85	1.50	4.11	0.10	0.18	0.45	76.8	385
Dec, 08	21.8	1.05	1.95*	3.98	0.11	0.23	0.44	85.8*	280
Jan, 09	19.6	1.78	0.97*	6.33	0.13	0.13	0.37	-45.7*	256
Feb, 09	29.4	1.38	1.17	7.45	0.05	0.05	0.29	-15.6	438
Mar, 09	40.0	0.93	1.34	7.10	0.04	0.06	0.46	44.5	665
Apr, 09	48.4	1.06	1.7	5.39	0.05	0.09	0.2	59.7	406
May, 09	61.9	0.80	1.57	4.79†	0.08	0.08	0.2	95.9	499
Jun, 09	69.8	1.35	1.71	-	0.10	0.21	-	27.0	-
July, 09	69.9	1.85†	1.59	-	0.47	0.07	-	-13.9	-
Aug, 09	69.9	2.03§	2.47	-	0.10	0.11	-	21.4§	-
Sep, 09	64.4	1.94§	2.06	2.30	0.09	0.05	0.09	6.5§	18.7§
Oct, 09	46.0	-	1.31	2.59	-	0.08	0.26	-26.5‡	44.8‡
Nov, 09	45.7	-	1.48†	3.57	-	0.07	0.1	-17.3‡	99.8‡
Overall	**49.2**	**1.79**	**1.91**	**5.39**	**0.16**	**0.13**	**0.46**	**6.7**	**202**

*Molting diet was used.
† Flock was depopulated.
§ The new flock was considered as control before the EcoCal diet was fed.
‡ Reduction rate was based on average ER of control diet from Dec, 2007 to Sep, 2009.
- No meaningful comparison due to flock changing

Table 3. Summary of production data and economic analysis of three flocks* with two production cycles separated by molting (1st cycle: 21 to 69 wk of age; 2nd cycle: 1 to 42 wk of post-molting).

Parameters		Control	DDGS	EcoCal
Feed consumed, lb hen^{-1}	1st cycle	69.3	70.4	72.0
	2nd cycle	46.6	47.9	50.6
	Overall	115.9	118.3	122.6
Eggs produced, eggs hen^{-1}	1st cycle	283	270	279
	2nd cycle	152	154	168
	Overall	435	424	447
Egg mass, lb hen^{-1}	1st cycle	37.6	36.4	37.4
	2nd cycle	21.6	22.2	24.4
	Overall	59.2	58.6	61.9
Egg weight, g egg^{-1}	1st cycle	60.1	61.0	60.9
	2nd cycle	61.3	61.6	62.6
	Overall	60.6	61.3	61.7
Feed conversion, lb lb^{-1}	1st cycle	1.81	1.94	1.92
	2nd cycle	2.60	2.60	2.42
	Overall	1.99	2.06	2.02
Egg price, cents dozen^{-1}	1st cycle	84.5	84.5	85.2
	2nd cycle	85.1	84.9	85.8
	Overall	84.7	84.7	85.4
Manure Value, $ hen^{-1}	1st cycle	0.29	0.36	0.44
	2nd cycle	0.25	0.31	0.38
	Overall	0.53	0.67	0.81
Egg Value, $ hen^{-1}	1st cycle	19.94	19.03	19.77
	2nd cycle	10.74	10.91	12.00
	Overall	30.68	29.94	31.78
Feed Cost, $ hen^{-1}	1st cycle	6.39	6.41	6.80
	2nd cycle	4.29	4.36	4.78
	Overall	10.68	10.78	11.59
Pullet cost, $ hen^{-1}	1st cycle	2.96	2.96	2.96
	2nd cycle	-	-	-
	Overall	2.96	2.96	2.96
Other cost, $ hen^{-1}	1st cycle	3.07	3.07	3.07
	2nd cycle	2.63	2.63	2.63
	Overall	5.70	5.70	5.70
Revenue - Feed Cost, $ hen^{-1}	1st cycle	13.85	12.98	13.41
	2nd cycle	6.69	6.86	7.60
	Overall	20.54	19.84	21.01
Revenue - Total Cost, $ hen^{-1}	1st cycle	7.82	6.95	7.38
	2nd cycle	4.06	4.23	4.97
	Overall	11.88	11.18	12.35

* The number of hens per barn was estimated for each week if all started with 260,000 hens per barn using each week mortality rate.