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Effects of Laying-Hen Strain on Manure Properties and Ammonia Emission

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Abstract

Ammonia (NH3) emissions from laying hens are affected by nutrient content of the diet, manure quantity, and manure properties such as moisture content, nitrogen content, and pH. These production traits may vary with strain of the hen. However, limited information is available concerning the effects of laying-hen genetics on manure properties and NH3 emission. This study was conducted to comparatively quantify production performance, manure properties, and NH3 emissions (through N mass balance) of four white-egg-laying strains (Hy-Line W-36, Hy-Line W-98, Lohmann LSL Lite, and Bovans White) and four brown-egg-laying strains (Hy-Line Brown, Lohmann Brown, ISA Brown, and Bovans Brown) during two production periods of 27-28 weeks (P1) and 35-36 weeks (P2) of age. The diets were formulated to meet the nutritional needs of the brown and white hens. As a result, crude protein contents during P1 and P2 were, respectively, 13.2% and 15.2% for the brown hens but 14.5% and 17.4% for the white hens. The results showed that the brown and white hens had similar hen-day egg production (97.5% to 89.2% for brown hens and 96.0% to 88.2% for white hens) and egg mass output (57.1 to 52.6 g d-1 hen-1 for brown hens and 55.6 to 51.2 g d-1 hen-1 for white hens) but different feed consumption (112 to 98 g d-1 hen-1 for brown hens and 101 to 93 g d-1 hen-1 for white hens, $p < 0.01$) and feed efficiency (1.97 to 1.87 g feed g-1 egg for brown hens and 1.82 g feed g-1 egg for white hens, $p < 0.0001$ and $p = 0.11$). The higher feed consumption for the brown hens stemmed from their heavier body mass (1.81 to 1.78 kg vs. 1.56 to 1.53 kg for white hens). Manure moisture content was higher for the brown hens than for the white hens, although the dry-matter manure production was not significantly different. The results further revealed that under the experimental conditions (i.e., higher CP contents of the diet for the white hens than for the brown hens) the white hens had higher NH3 emissions than the brown hens as expressed per hen (37% to 19% higher, p = <0.001 to 0.016), per animal unit (AU, 500 kg live body mass; 59% to 39% higher, p = 0.0007 to 0.007), per unit of egg mass output (41% to 24% higher, p = 0.01 to 0.09), per unit of feed N consumed (39% to 27% higher, p = 0.01 to <0.0001), and per unit of dry manure (56% to 39% higher, p = 0.001 to 0.007). Certain differences existed in production performance among strains within the brown or white hens, but no differences in NH3 emissions were detected. Because of the relatively small sample size (number of hens involved) and the relatively short monitoring period, the results should be referenced with these limitations in mind. Further larger-scale studies with longer monitoring periods to verify these findings are warranted.

Keywords

Ammonia emission, Laying-hen strain, Nitrogen mass balance

Disciplines

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Comments

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EFFECTS OF LAYING-HEN STRAIN ON MANURE PROPERTIES AND AMMONIA EMISSION

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ABSTRACT. *Ammonia (NH_3) emissions from laying hens are affected by nutrient content of the diet, manure quantity, and manure properties such as moisture content, nitrogen content, and pH. These production traits may vary with strain of the hen. However, limited information is available concerning the effects of laying-hen genetics on manure properties and NH_3 emission. This study was conducted to comparatively quantify production performance, manure properties, and NH_3 emissions (through N mass balance) of four white-egg-laying strains (Hy-Line W-36, Hy-Line W-98, Lohmann LSL Lite, and Bovans White) and four brown-egg-laying strains (Hy-Line Brown, Lohmann Brown, ISA Brown, and Bovans Brown) during two production periods of 27-28 weeks (P1) and 35-36 weeks (P2) of age. The diets were formulated to meet the nutritional needs of the brown and white hens. As a result, crude protein contents during P1 and P2 were, respectively, 13.2% and 15.2% for the brown hens but 14.5% and 17.4% for the white hens. The results showed that the brown and white hens had similar hen-day egg production (97.5% to 89.2% for brown hens and 96.0% to 88.2% for white hens) and egg mass output (57.1 to 52.6 g d^{-1} hen^{-1} for brown hens and 55.6 to 51.2 g d^{-1} hen^{-1} for white hens) but different feed consumption (112 to 98 g d^{-1} hen^{-1} for brown hens and 101 to 93 g d^{-1} hen^{-1} for white hens, $p < 0.01$) and feed efficiency (1.97 to 1.87 g feed g^{-1} egg for brown hens and 1.82 g feed g^{-1} egg for white hens, $p < 0.0001$ and $p = 0.11$). The higher feed consumption for the brown hens stemmed from their heavier body mass (1.81 to 1.78 kg vs. 1.56 to 1.53 kg for white hens). Manure moisture content was higher for the brown hens than for the white hens, although the dry-matter manure production was not significantly different. The results further revealed that under the experimental conditions (i.e., higher CP contents of the diet for the white hens than for the brown hens) the white hens had higher NH_3 emissions than the brown hens as expressed per hen (37% to 19% higher, $p = <0.001$ to 0.016), per animal unit (AU, 500 kg live body mass; 59% to 39% higher, $p = 0.0007$ to 0.007), per unit of egg mass output (41% to 24% higher, $p = 0.01$ to 0.09), per unit of feed N consumed (39% to 27% higher, $p = 0.01$ to <0.0001), and per unit of dry manure (56% to 39% higher, $p = 0.001$ to 0.007). Certain differences existed in production performance among strains within the brown or white hens, but no differences in NH_3 emissions were detected. Because of the relatively small sample size (number of hens involved) and the relatively short monitoring period, the results should be referenced with these limitations in mind. Further larger-scale studies with longer monitoring periods to verify these findings are warranted.*

Keywords. *Ammonia emission, Laying-hen strain, Nitrogen mass balance.*

Physical and chemical properties of manure, such as moisture content, nitrogen content, and pH, can have significant impacts on ammonia (NH_3) volatilization and emissions. Different strains of laying hens have different production traits, such as feed consumption, water consumption, and egg production, which may lead to different manure properties. For instance, white Hy-Line W-98 hens come into production at a younger age and lay larger eggs than white Hy-Line W-36 hens. Similarly, brown hens have a larger body size and, therefore, a greater feed consumption than white hens. Studies also suggest that higher feed consumption can increase moisture content of the manure, which may increase nutrient loss (Smith et al., 2000) and NH_3 emissions. Studies have fur-

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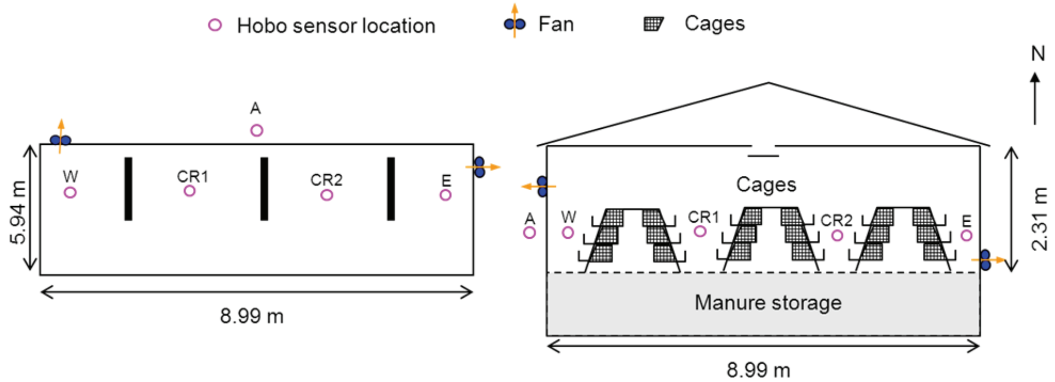

Figure 1. Schematic of the research building showing (left) the floor plan and (right) a cross-sectional view with the Hobo sensor locations: A = ambient, W = west side, CR1 = center row 1, CR2 = center row 2, and E =east side (not to scale).

ther demonstrated that laying-hen genetics influence nutrient requirements (Krautmann, 1971; Christmas and Harms, 1978) and manure properties due to different kidney structures (Wideman and Nissley, 1992).

Ammonia emissions from Hy-Line W-36 hens in commercial high-rise and manure-belt houses have recently been quantified (Liang et al., 2005). However, little research has been done to quantify the differences in manure properties and NH_3 emissions among laying-hen strains commonly used in the U.S. With the increasing need to document and mitigate NH_3 emissions from animal feeding operations, an evaluation of genetic effects on NH_3 emissions from manure of common laying-hen strains is warranted.

Direct measurement of NH_3 emissions is often difficult and requires expensive equipment (Wheeler et al., 2000; Xin et al., 2003; Gates et al., 2005; Liang et al., 2005; Coufal et al., 2006). The National Research Council (NRC, 2003) has recommended the use of mass balance as a tool to estimate nitrogen (N) losses as NH_3 through reliable measurement of N input from feed and N output through animal products. Nitrogen mass balance techniques have been used to calculate NH_3 emissions, assuming that all N not accounted for as manure or animal products is lost as NH_3 to the environment (Coufal et al., 2006; Yang et al., 2000; Liang et al., 2005).

The objectives of this study were: (1) to measure the quantity and quality of laying-hen manure produced by eight commercial strains, i.e., four white-egg strains (Hy-Line W-36, Hy-Line W-98, Lohmann LSL Lite, and Bovans White) and four brown-egg-laying strains (Hy-Line Brown, Lohmann Brown, ISA Brown, and Bovans Brown) at 27-28 and 35-36 weeks of age; and (2) to comparatively determine NH_3 emissions from manure of the eight strains during each 2-week accumulation period using the N mass balance method.

Materials and Methods

Hens and Housing

Eight strains of hens were used for this study: four white-egg strains (Hy-Line W-98, Lohmann LSL Lite, Hy-Line W-36, and Bovans White) and four brown-egg strains (ISA Brown, Lohmann Brown, Bovans Brown, and Hy-Line Brown). Day-old chicks (30 per strain) were procured from a Hy-Line hatchery and raised in a pullet facility near Tampico, Illinois. At 17 weeks of age, the pullets were transported to a research building near Dallas Center, Iowa, where they were housed three per cage in wire-bottomed cages (30.5 × 45.7 cm, i.e., 465 cm^2 or 72 $in.^2$ of floor space per bird), each equipped with a nipple drinker and a self-feeder. The research building had dimensions of 9 m × 9 m × 2.3 m (W × L × H) (fig. 1). The daily ambient and indoor temperatures during the monitoring period were (mean ±SD) 21.03°C ±1.81°C and 24.48°C ±1.03°C for the first period (P1, 27-28 weeks of age) and 23.47°C ±2.30°C and 25.81°C ±1.77°C for the second period (P2, 35-36 weeks of age), The corresponding daily indoor relative humidity during the P1 and P2 periods was 58% ±11% and 71% ±7%, respectively.

Hens of different strains were assigned to cages according to a randomized complete block design with 16 blocks (vertical and horizontal locations of the cage tiers) and four cages per block. One cage of three hens represented an experimental unit (EU) for all responses, with 64 total cages or EUs in the experiment. One cage also represented the measurement unit (MU) for all variables except for egg weight (measurement unit was an egg; average egg weight calculated by cage) and hen body weight (measurement unit was a hen; average hen weight calculated by cage). The extra hens were maintained to replace mortalities, as needed. Hens were placed in every other cage to prevent cross feeding. White and brown hens were fed separate diets according to white and brown egg strain energy requirements (table 1). Hens were provided 16 h of light and 8 h of darkness per day, as practiced in commercial production.

Body weights of the hens in each cage were recorded at the start and end of both data collection periods, and body weight change was calculated. Hens were weighed individually, with the average hen body weight per cage considered the EU. Feed consumption was measured as feed disappearance during each 2-week measuring period (i.e., total feed added minus the weighed-back amount). Five portable temperature (T) and relative humidity (RH) loggers (HOBO Pro T/RH logger, Onset Computer Corp., Bourne, Mass.) were used to monitor indoor (four loggers) and ambient (one longer) T and RH (fig. 1). Data were recorded every 10 min and downloaded weekly throughout the study.

Table 1. Diet compositions for the white and brown varieties of hens used in this study.[a]

Diet Component	White Hens 27-28 weeks	White Hens 35-36 weeks	Brown Hens 27-28 weeks	Brown Hens 35-36 weeks
Metabolizable energy (kcal kg^{-1})	2871	2857	2821	2821
Crude protein (%)[b]	14.5	17.4	13.2	15.2
Lysine (%)	0.85	0.80	0.72	0.72
Methionine (%)	0.50	0.46	0.35	0.35
Methionine + cystine (%)	0.76	0.72	0.60	0.60
Crude fat (%)	4.74	4.11	3.07	3.07
Crude fiber (%)	2.29	2.33	2.59	2.59
Calcium (%)	4.25	4.04	3.83	3.83
Available phosphorus (%)	0.46	0.44	0.42	0.42
Total phosphorus (%)	0.68	0.66	0.63	0.63
Sodium (%)	0.19	0.19	0.20	0.20
Chloride (%)	0.28	0.28	0.28	0.28
Ingredient (%)				
Corn	62.22	64.62	69.07	69.07
Soybean meal	22.50	21.50	18.00	18.00
Limestone[c]	10.00	9.50	9.00	9.00
Soybean oil	2.00	1.25	-	-
Dicalcium phosphate	1.95	1.85	1.75	1.75
Dehydrated alfalfa	-	-	1.00	1.00
Methionine	0.24	0.21	0.11	0.11
Lysine	0.10	0.08	0.08	0.08
Other[d]	1.00	1.00	1.00	1.00

[a] Calculated values unless otherwise noted.
[b] Crude protein values were calculated for both brown and white hen diets for the 27-28 week period but were analyzed as 6.25 × N for the 35-36 week period.
[c] 50:50 mixture of course and fine particle sizes, with the large particles averaging 2.27 mm in diameter and the fine particles averaging 0.14 mm.
[d] Includes salt, vitamin and mineral premix, preservative, and mannan oligosaccharide product.

Sample Collection and Analyses

Manure Collection and Analysis

The N mass balance was conducted for 27-28 and 35-36 weeks of age, denoted as period 1 (P1) and period 2 (P2), respectively. Manure from each cage was collected weekly during the 2-week measuring periods in an aluminum pan placed underneath each cage. For manure collection and analyses, one cage represented both the EU and the MU. The empty pan weight was recorded before manure collection. After one week, the manure and pan were weighed, the manure mixed, and a 400-500 g subsample was collected and placed in a sealed Ziploc bag for subsequent analyses (e.g., moisture content, N content, and pH). A new pan was placed underneath each cage for the second week of collection. Manure samples were placed in ice-chilled coolers and transported to Iowa State University for analyses. Moisture content of the manure sample from each cage was analyzed by drying 10 g of the sample in a 105°C oven for 24 h on the day of collection. A 100 g subsample of the remaining manure was placed in a plastic capped jar and stored at -20°C until subsequent analyses. Manure from each cage from the first and second week of each collection was combined in the plastic jar to make a 200 g composite sample. The 200 g composite sample was thawed at 4°C, and 150 g was blended with 1 M sulfuric acid to produce homogenous slurry and minimize NH_3 volatilization. The N content of the slurry was measured in duplicate using the micro-Kjeldahl method (method 990.03; AOAC, 2006) on a Kjeltech 1028 distilling unit (U.S. Tecator, Inc., Herndon, Va.). The pH of the remaining manure, which was not mixed with acid, was measured (Accumet AR-15, Fisher Scientific, Pittsburgh, Pa.) by mixing one part manure (approximately 1 g) with ten parts double-distilled water with a vortex mixer.

Egg Production Monitoring

Eggs from each cage were collected daily during each 2-week measuring period and weighed together. The average hen-day egg production (EP) was calculated as the number of eggs during the 2-week period divided by the number of hens divided by 14 days. Seven eggs were randomly chosen from each cage during each 2-week period for moisture and N analyses. The eggs were broken into an aluminum dish, mixed, and dried at 70°C for 72 h in a forced convection oven (Yamato DKN 810, Yamato Scientific America, Inc., Gaithersburg, Md.) and subsequently ground through a 1 mm screen using a Wiley mill (Thomas Wiley Model 4, Thomas Scientific, Swedesboro, N.J.). Moisture content of the egg was measured as weight loss during drying, and N content was determined using a Leco TruSpec analyzer (Leco Corp., St. Joseph, Mich.).

Nitrogen Mass Balance

Nitrogen mass balance was performed for each 2-week measuring period. Nitrogen consumption of the hen was calculated from the N content of the feed and the average daily feed consumption per cage. Nitrogen output in eggs was calculated from the N content of the eggs and egg mass output (egg weight × EP). The N output in the manure was calculated from the average daily manure production and the N content of the manure. Nitrogen gain or loss in body composition was not considered because of the negligible change in body weight during the 2-week test periods.

The mean daily N loss as NH_3, NH_3-N, was calculated as:

$$NH_3\text{-}N_{loss} = N_{feed} - (N_{manure} + N_{egg}) \qquad (1)$$

where N_{feed} is the N input from feed, N_{manure} is the N output as manure, and N_{egg} is the N output as eggs. To account for the differences in body mass, feed consumption, crude protein content, manure production, and egg mass output among the hen strains, NH_3 loss was expressed in various units, including per hen per day, per animal unit (AU, 500 kg live body weight) per day, per unit mass of N consumed, per unit mass of egg produced, and per unit mass of dry manure produced. Although the method of N mass balance over a period of time cannot delineate the dynamic profiles of gaseous emissions, it allows for estimation of N loss over a certain time period. The National Research Council (NRC, 2003) has recommended the use of the N mass balance method to estimate total loss. Liang et al. (2005) applied the N balance method to ammonia emissions from high-rise layer houses and compared the results with those from real-time measurement of ammonia emissions. They reported a residual error of -1.1% to 5.6% (2.7% overall) between the two methods.

Statistical Analysis

Statistical analyses were performed using JMP statistical software (version 6.0, SAS Institute, Inc., Cary, N.C.). Data were analyzed by ANOVA with the model including the effects of strain and block as indicated below:

$$Y_{ijk} = \mu + B_i + S_j + \varepsilon_k \quad (2)$$

where Y_{ijk} is the observed response, μ is the overall mean, B is the variation due to block, S is the variation due to strain, and ε_k is the experimental error.

Responses from each of the eight strains were compared to responses from every other strain using Tukey's honestly significant difference (HSD) test; and responses from brown and white hens were compared using contrasts. A p-value of ≤0.05 was considered significant.

Results and Discussion

Production Parameters

Production parameters for P1 (hen age of 27-28 weeks) are shown in table 2. The brown hens had a heavier body weight, consumed more feed, and laid larger eggs than the white hens. Although the white hens produced smaller eggs than the brown hens, the white hens had a more favorable feed efficiency. Bovans Brown, Hy-Line Brown, and Lohmann LSL Lite produced larger eggs than Hy-Line W-36. However, Hy-Line W-36 consumed less feed than all other strains except for Hy-Line W-98. Consequently, Hy-Line W-36 had a more favorable feed efficiency than ISA Brown, Lohmann Brown, and Bovans Brown. Within the brown strains, Lohmann Brown had a greater body weight than Hy-Line Brown, and within the white strains, Hy-Line W-98 had a greater body weight than Hy-Line W-36.

Production parameters for P2 (hen age of 35-36 weeks) are shown in table 3. Again, the brown hens had a heavier body weight and consumed more feed than the white hens. However, egg production, egg weight, and feed efficiencies were not different between the brown and white strains. Similar to P1, Bovans Brown, Hy-Line Brown, Lohmann LSL Lite, and Hy-Line W-98 produced heavier eggs than Hy-Line W-36. Within the brown varieties, Hy-Line Brown produced heavier eggs than Lohmann Brown and ISA Brown. Within the white strains, Lohmann LSL Lite and Hy-Line W-98 produced heavier eggs than Hy-Line W-36. Although Hy-Line W-36 consumed less feed, the hens produced smaller eggs and, consequently, had similar feed efficiency to all other white varieties. Bovans Brown had a less favorable feed efficiency than Hy-Line Brown or Hy-Line W-98.

Table 2. Production parameters for the eight strains of laying hens during test period P1 (27-28 weeks of age).[a]

	Variety	Hen-Day Egg (%)	Egg Weight (g egg^{-1})	Egg Mass (g d^{-1} hen^{-1})	Feed Consumption (g d^{-1} hen^{-1})	Feed Efficiency (kg feed kg^{-1} egg)	Body Weight (kg hen^{-1})
Brown	ISA Brown	95.9	58.2 ab	55.8	111 ab	2.00 ab	1.78 ab
	Lohmann Brown	97.1	58.2 ab	56.5	112 b	1.99 ab	1.91 a
	Bovans Brown	98.6	58.3 a	57.5	115 a	2.02 a	1.82 ab
	Hy-Line Brown	98.5	59.8 a	58.7	111 ab	1.89 abc	1.75 bc
White	Hy-Line W-98	95.3	58.1 ab	55.3	102 de	1.86 abc	1.64 cd
	Lohmann LSL Lite	96.0	58.6 a	56.3	104 bcd	1.85 abc	1.57 de
	Hy-Line W-36	98.0	54.9 b	53.7	95 e	1.77 c	1.50 e
	Bovans White	98.3	57.9 ab	56.8	103 cd	1.82 bc	1.51 de
SEM[b]		1.6	0.8	1.18	2	0.04	0.03
Mean	Brown	97.5	58.6 y	57.1	112 y	1.97 y	1.81 y
	White	96.9	57.4 z	55.6	101 z	1.82 z	1.56 z
	SEM	0.8	0.4	0.6	1	0.02	0.02
	p-value[c]	0.56	0.023	0.067	<0.0001	<0.0001	<0.0001

[a] Means within a column followed by different letters (a, b, c, d, e) differ at p ≤ 0.05 by Tukey's HSD test. Means within a column followed by different letters (x, y, z) differ at p ≤ 0.05 by the contrast of brown vs. white.

[b] SEM = standard error of the mean.

[c] p-value for the contrast of brown vs. white.

Table 3. Production parameters for the eight strains of laying hens during test period P2 (35-36 weeks of age).[a]

	Variety	Hen-Day Egg (%)	Egg Weight (g egg^{-1})	Egg Mass (g d^{-1} hen^{-1})	Feed Consumption (g d^{-1} hen^{-1})	Feed Efficiency (kg feed kg^{-1} egg)	Body Weight (kg hen^{-1})
Brown	ISA Brown	92.5	58.0 bc	53.7	101 a	1.89 ab	1.74 a
	Lohmann Brown	88.4	58.1 bc	51.3	95 ab	1.85 ab	1.86 a
	Bovans Brown	86.9	58.7 ab	51.1	100 a	1.97 a	1.78 a
	Hy-Line Brown	89.0	61.2 a	54.4	96 ab	1.76 b	1.72 ab
White	Hy-Line W-98	85.6	60.1 ab	51.5	90 ab	1.76 b	1.59 bc
	Lohmann LSL Lite	91.4	58.8 ab	53.7	95 ab	1.78 ab	1.54 c
	Hy-Line W-36	85.4	55.6 c	47.5	85 b	1.82 ab	1.45 c
	Bovans White	90.4	57.8 bc	52.3	99 a	1.91 ab	1.53 c
SEM[b]		2.9	0.7	1.8	3	0.05	0.03
Mean	Brown	89.2	59.0	52.6	98 y	1.87	1.78 y
	White	88.2	58.1	51.2	93 z	1.82	1.53 z
	SEM	0.01	0.43	0.92	2	0.02	0.02
	p-value[c]	0.63	0.06	0.29	0.01	0.12	<0.0001

[a] Means within a column followed by different letters (a, b, c, d, e) differ at p ≤ 0.05 by Tukey's HSD test. Means within a column followed by different letters (x, y, z) differ at p ≤ 0.05 by the contrast of brown vs. white.

[b] SEM = standard error of the mean.

[c] p-value for the contrast of brown vs. white.

Between the brown and white strains, only Hy-Line Brown and Hy-Line W-98 had similar body weights. Average production parameters during P2 were slightly lower than during P1 and are likely attributable to the warmer environment (hence lower feed intake) and older age of the hens.

Manure Production and Properties

Manure excretion and moisture content are shown in table 4 for P1 and in table 5 for P2. During P1, the white hens excreted less manure (as-is basis) than the brown hens, which was expected because the white hens consumed less feed. However, the dry-matter manure excretion was not different between the white and brown hens (p = 0.14), indicating that the higher as-is manure excretion from the brown hens was due to the higher moisture content.

During P2, the white hens again excreted less manure than the brown hens, and the manure from the white hens was again drier. When the manure excretion was compared on a dry-matter basis, no difference was detected between the white and brown strains (p = 0.70). During both measuring periods, Hy-Line W-36 hens always had less manure excretion and drier manure than the brown strains, indicating that the differences between the white and brown hens in manure excretion and manure moisture were primarily attributed to the responses of Hy-Line W-36 hens.

Manure pH values are shown in tables 4 and 5 for P1 and P2, respectively. Manure from the white strains tended to have a lower pH than that from the brown strains during P1. Hy-Line W-36 had more acidic manure than Bovans Brown and Lohmann Brown during this period. During P2, no significant differences in manure pH were detected among the eight strains (p = 0.27).

Ammonia Emissions

Results for N balance and NH_3 emissions are shown in table 4 for P1 and table 5 for P2. During P1, the white hens

Table 4. Manure production and nitrogen balance for eight strains of laying hens during test period P1 (27-28 weeks of age).[a]

		Manure Production				Nitrogen Balance				
	Variety	Excretion (g d^{-1} as-is)	Moisture (%)	Excretion (g DM d^{-1})	pH	N Cons. (g d^{-1} hen^{-1})	N in Eggs (g d^{-1} hen^{-1})	N in Manure (g d^{-1} hen^{-1})	N Loss[b] (g d^{-1} hen^{-1})	NH_3 ER (g d^{-1} AU^{-1})[c]
Brown	ISA Brown	95.8 a	78.1 a	20.4 a	7.81 ab	2.34 ab	1.13	0.87	0.34	115
	Lohmann Brown	92.4 a	77.4 ab	20.3 a	7.88 a	2.37 ab	1.21	0.91	0.25	80
	Bovans Brown	90.8 a	77.5 ab	20.0 a	7.88 a	2.43 a	1.23	0.92	0.28	92
	Hy-Line Brown	95.3 a	78.0 a	20.7 a	7.80 ab	2.33 ab	1.15	0.88	0.29	103
White	Hy-Line W-98	84.3 ab	76.6 ab	19.3 a	7.67 ab	2.38 ab	1.10	0.85	0.42	158
	Lohmann LSL Lite	76.1 ab	72.4 c	20.8 a	7.72 ab	2.41 a	1.08	0.91	0.42	160
	Hy-Line W-36	62.8 b	70.9 c	18.2 a	7.53 b	2.21 b	1.03	0.93	0.35	141
	Bovans White	76.0 ab	74.1 bc	19.5 a	7.78 ab	2.40 a	1.10	0.89	0.41	163
SEM[d]		6.1	0.9	0.9	0.06	0.04	0.05	0.04	0.06	23
Mean	Brown	93.6 y	77.7 y	20.4	7.84 y	2.37	1.18 y	0.90	0.29 z	98 z
	White	74.8 z	73.5 z	19.4	7.68 z	2.35	1.08 z	0.89	0.40 y	156 y
	SEM	3.1	0.5	0.4	0.03	0.02	0.02	0.02	0.03	11
	p-value[e]	<0.0001	<0.0001	0.142	0.0008	0.46	0.003	0.381	0.0160	0.0004

[a] Means within a column followed by different letters (a, b, c, d, e) differ at p ≤ 0.05 by Tukey's HSD test. Means within a column followed by different letters (x, y, z) differ at p ≤ 0.05 by the contrast of brown vs. white.
[b] N loss calculated as: N consumption – (N in eggs + N in manure).
[c] AU = animal unit = 500 kg live body weight.
[d] SEM = standard error of the mean.
[e] p-value for the contrast of brown vs. white.

Table 5. Manure production and nitrogen balance from eight strains of laying hens during period P2 (35-36 weeks of age).[a]

		Manure Production				Nitrogen Balance				
	Variety	Excretion (g d^{-1} as-is)	Moisture (%)	Excretion (g DM d^{-1})	pH	N Cons. (g d^{-1} hen^{-1})	N in Eggs (g d^{-1} hen^{-1})	N in Manure (g d^{-1} hen^{-1})	N Loss[b] (g d^{-1} hen^{-1})	NH_3 ER (g d^{-1} AU^{-1})[c]
Brown	ISA Brown	86.6 a	77.6 ab	18.8 ab	7.48	2.46 abc	1.00	0.79	0.66 b	231 cde
	Lohmann Brown	77.4 a	75.9 ab	17.8 ab	7.37	2.30 c	0.99	0.75	0.56 b	181 e
	Bovans Brown	82.2 a	75.6 ab	18.7 ab	7.64	2.43 abc	0.96	0.82	0.65 b	219 de
	Hy-Line Brown	87.2 a	78.9 a	18.1 ab	7.41	2.32 bc	1.02	0.73	0.65 b	200 de
White	Hy-Line W-98	65.1 ab	72.2 bc	17.7 ab	7.52	2.52 abc	0.99	0.80	0.73 ab	277 bcd
	Lohmann LSL Lite	63.7 ab	71.6 bc	18.0 ab	7.43	2.65 ab	1.05	0.78	0.83 ab	323 abc
	Hy-Line W-36	50.7 b	67.2 c	16.5 b	7.29	2.37 bc	0.91	0.67	0.79 ab	331 ab
	Bovans White	75.3 ab	73.0 abc	20.3 a	7.37	2.76 a	1.02	0.78	0.96 a	382 a
SEM[d]		5.9	1.5	0.80	0.09	0.08	0.03	0.04	0.06	22
Mean	Brown	83.3 y	77.0 y	18.3	7.47	2.38 z	0.99	0.77	0.61 z	209 z
	White	63.7 z	71.0 z	18.1	7.40	2.58 y	0.99	0.76	0.83 y	329 y
	SEM	3.1	0.8	0.42	0.05	0.04	0.02	0.02	0.03	12
	p-value[e]	<0.0001	<0.0001	0.70	0.27	0.0013	0.98	0.58	<0.0001	<0.0001

[a] Means within a column followed by different letters (a, b, c, d, e) differ at p ≤ 0.05 by Tukey's HSD test. Means within a column followed by different letters (x, y, z) differ at p ≤ 0.05 by the contrast of brown vs. white.
[b] N loss calculated as: N consumption – (N in eggs + N in manure).
[c] AU = animal unit = 500 kg live body weight.
[d] SEM = standard error of the mean.
[e] p-value for the contrast of brown vs. white.

lost more N from manure than the brown hens. Although the brown and white hens consumed similar amounts of feed N and excreted similar amounts of manure N, the brown hens deposited more N in eggs, which contributed to the lower N loss from manure. Interestingly, eggs of the brown hens contained more N than the eggs of the white hens (2.07% and 1.94% N on a wet basis, respectively; $p = 0.005$). During P2, the white hens again lost more N from manure than the brown hens. However, during P2, the greater N loss might be due to a greater N consumption by the white hens (higher dietary CP content of 17.4% vs. 15.2%) than by the brown hens. There were no significant differences in N deposition in eggs between the brown and white hens during P2. Bovans White hens lost more N than any of the brown strains.

On the basis of per AU, manure NH_3-N loss for the white hens was 59% and 58% higher than for the brown hens during P1 and P2, respectively. The difference arose from the higher N loss from the manure and the lighter body weight of the white hens as compared to the brown hens. When NH_3-N losses were compared among the strains, no differences were detected during P1, but differences existed during P2. This was likely due to differences in ambient and room temperatures during the P1 and P2 periods. Under the given conditions, Hy-Line W-36 and Bovans White hens had more NH_3-N loss than any of the brown strains; and Lohmann Brown hens had less NH_3-N loss than any of the white strains.

During P1 and P2, the white hens lost 41% and 40% more NH_3 per unit mass of egg output than the brown hens, respectively ($p = 0.01$ and <0.0001); 53% and 45% more NH_3 per kg of feed consumed, respectively ($p = 0.0012$ and <0.0001); 39% and 27% more NH_3 per unit of N consumed, respectively ($p = 0.01$ and <0.0001); and 42% and 38% more NH_3 per kg of dry manure excretion, respectively ($p = 0.008$ and <0.0001).

Different manure moisture contents could have influenced the differences in NH_3 emissions observed between the brown and white hens. Typically, drier manure leads to lower NH_3 emission, as observed by Yang et al. (2000). However, manure moisture content in the present study was approximately 2 times that measured by Yang et al. (2000). The drastic difference in manure moisture content between the current study and the study by Yang et al. (2000) was due to the fact that the manure in the current study was collected in a manure pan for one week and it had a little chance to dry, whereas the manure in the Yang et al. (2000) study was stored in commercial high-rise barns for approximately one year, and it had gone through considerable drying by the ventilation air and stirring fans. The high moisture content of the manure from the brown hens, as compared to the white hens in the present study, may have created a more anaerobic environment, which would have inhibited the bacteria primarily responsible for conversion of uric acid and undigested proteins to NH_3. Indeed, Pratt et al. (2004) found that manure with very high moisture content lost less N than manure with more moderate moisture content.

Hen manure pH also influences NH_3 emission (Roberts et al., 2007). As pH drops and the manure becomes more acidic, the NH_3-N is converted to NH_4-N, which is more water soluble and tends to stay in the manure rather than becoming volatilized to the atmosphere. Manure of the white hens had a lower pH than that of the brown hens during P1, but the white hens still lost more NH_3, somewhat contrary to our expectations. The lower manure moisture content of the white hens may have favored aerobic bacterial metabolism and increased NH_3 emission in spite of the significantly lower pH. The higher dietary CP contents for the white hens could have been the main driving factor for the higher NH_3 volatilization from the manure, although NH_3 emission expressed as per unit of feed N intake was still higher for the white hens compared to the brown hens. A previous field study by Liang et al. (2005) indicated that an average 1% reduction in dietary CP would lead to about 10% reduction in NH_3 emissions from high-rise layer houses.

CONCLUSIONS

The impact of laying-hen strains on manure properties and ammonia-N loss was comparatively assessed with four white-egg strains and four brown-egg strains, each strain involving 24 hens in groups of three hens, during the hen's production ages of 27-28 weeks and 35-36 weeks. While the scale of the experiment was relatively small with a relatively short monitoring period, and thus the results should be taken with these limitations in mind, the study revealed some interesting findings that are of scientific and practical values.

The study shows that hen strain can have considerable impact on ammonia emissions from the hen manure, resulting from differences in dietary nutrition, production traits, and manure properties. In this study, it was shown that ammonia (NH_3) emissions from the white-egg hen manure were greater than from the brown-egg hen manure when the hens were fed respective production diets, with the white-hen diets having higher crude protein (CP) contents. The magnitude of the differences revealed in this study ranged from 19% (per hen basis) to 59% (per animal unit or AU basis), depending on the units used to express NH_3 emissions. The lower NH_3 emission for the brown-egg hens might be partially attributed to greater N deposition in eggs, lower dietary CP content, and possibly higher (bacteria-inhibiting) moisture content of the manure as compared to the white-egg hens. Further larger-scale studies with longer monitoring periods to verify these findings are warranted.

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