Long Term Studies of Nitrogen Balance in Broiler Production

J. B. Carey, C. D. Coufal, C. Chavez, and P.L. Niemeyer

Corresponding author: John B. Carey, Poultry Science Department, Texas A&M University, 2472 TAMU, College Station, TX 77843-2472; phone: 979-845-4319; fax: 979-845-1921; email: jcarey@poultry.tamu.edu.

Abstract. *An experiment was conducted to quantify nitrogen loss via volatilization (ammonia) from a broiler grow-out facility. Nitrogen loss was quantified over eighteen consecutive flocks using a mass balance approach. In flocks 1 -9 (560 birds/flock), caked litter was removed after each flock and the remaining litter was recycled for subsequent flocks. In flocks 10-18 (840 birds/flock), the effects of top-dressing of litter (treated) with a thin layer (1-2 cm) of new litter before each flock of birds was placed was compared to untreated litter (control). Total nitrogen content of day-old chicks and all feeds was measured to account for nitrogen entering the facility. Nitrogen not accounted for from analysis of litter, caked litter, broiler carcasses and mortality was assumed to be lost from the facility (volatilized). Significant seasonal effects were observed regarding percent nitrogen loss when treatment was not considered. Nitrogen loss was generally higher in flocks reared in warmer months. Percent of total nitrogen lost due to volatilization was significantly greater for treated pens compared to the controls in flocks 10 and 12, but was significantly lower for flock 11. Results of this experiment show that seasonality greatly influences nitrogen loss from the broiler rearing facility, and top-dressing of litter tends to increase nitrogen loss on average. Quantification of nitrogen loss via nitrogen balance studies provides a basis to evaluate other direct measures of ammonia emissions and enhances the knowledge base for implementation of policy regarding broiler production facilities.*

Keywords. *Ammonia, nitrogen mass balance, broilers*

Introduction

The poultry industry is currently facing new challenges with respect to environmental impacts of nutrient loss from poultry facilities. The gaseous emission of primary concern is nitrogen in the form of ammonia. The objectives of this research were to 1) perform an accurate nitrogen mass balance to measure the amount of nitrogen loss, 2) determine the effects of season on nitrogen loss and 3) determine what effects the litter management technique of top-dressing has on nitrogen volatilization.

Materials and Methods

At the beginning of the study, rice hulls were added to 4 pens (10’ x 10’) to a depth of approximately 7.5-10 cm. For Flocks 1-9, after each flock of birds was removed, caked litter was removed from the pens using a silage fork. Loose litter remained in the pens and subsequently used for the next flock. No additional litter material or amendments were added to the recycled litter. For Flocks 10-18, 2 additional pens were added to the project. Recycled litter was evenly distributed from the original 4 pens into the 6 pens. Three pens continued to be managed as before with no additional litter added (untreated controls). The other 3 pens were “top-dressed” with a thin layer (1-2 cm) of new rice hulls before the placement of each flock of chicks. Samples of beginning, ending and caked litter were collected for each pen for each flock. The mass of all litter, birds and feed entering and leaving the facility was measured. In Flocks 2-18, 12 day-old chicks and 12 market-age broilers were selected at random, euthanized and retained for laboratory analysis. Samples of all feeds (multiple phases) for Flocks 2-18 were collected for laboratory analysis.

Results and Discussion

Nitrogen mass balance

Day-old chicks represented <1% of all nitrogen inputs, while feeds were calculated to be >99% of all nitrogen inputs (data not shown). Measurable nitrogen outputs were marketed broilers, mortalities, caked litter, and loose litter that remained in the pens after caked litter was removed. Nitrogen partitioned into the various outputs are presented in units of grams of nitrogen per kg of live marketed broiler (g N/kg) in Tables 1 and 2.

Table 1. Nitrogen partitioning and nitrogen emission in broiler production[1], flocks 1-9.

Begin Date (m/y)	Flock	Litter	Caked Litter	All Litter	Mortality	Marketed Broilers	Loss	--- Emission --- (g N/d/bd)[3]	% of N inputs
		(g N/kg)[2]							
7/01	1	11.20^{a}	0.52^{e}	11.72^{abc}	0.49^{ab}	29.05^{d}	9.21^{cd}	0.486^{cd}	18.24^{cde}
9/01	2	10.73^{ab}	3.80^{a}	14.53^{a}	0.37^{b}	28.99^{e}	8.65^{cd}	0.471^{cd}	16.38^{de}
11/01	3	8.50^{abc}	4.22^{a}	2.72^{ab}	0.54^{ab}	30.29^{a}	7.34^{d}	0.417^{d}	14.42^{e}
1/02	4	10.23^{ab}	3.60^{ab}	13.84^{a}	0.81^{ab}	28.99^{de}	9.43^{cd}	0.534^{cd}	17.73^{cde}
2/02	5	10.53^{ab}	1.80^{d}	12.32^{abc}	0.85^{a}	29.77^{b}	10.33^{cd}	0.539^{cd}	19.40^{cde}
4/02	6	6.70^{bc}	2.78^{bc}	9.48^{bc}	0.34^{b}	28.66^{f}	12.45^{bc}	0.690^{bc}	24.43^{bc}
6/02	7	2.56^{d}	1.88^{cd}	4.44^{d}	0.48^{ab}	29.18^{c}	19.72^{a}	1.035^{a}	36.63^{a}
7/02	8	10.23^{ab}	1.24^{de}	11.48^{abc}	0.43^{ab}	29.21^{c}	11.98^{bc}	0.613^{bcd}	22.63^{bcd}
9/02	9	4.88^{cd}	3.50^{ab}	8.39^{cd}	0.33^{b}	29.17^{c}	14.65^{b}	0.830^{ab}	27.78^{b}
Average		8.40	2.59	10.99	0.52	29.26	11.53	0.624	21.96

[1] All analyses and calculations performed on dry matter basis.
[2] Values calculated as grams of N/kg of live marketed broiler.
[3] Values calculated as grams of N/day/marketed broiler.
[a, b, … f] Means within columns with no common superscripts differ significantly (P<0.05).

Table 2. Nitrogen partitioning and nitrogen emission in broiler production[1], flocks 10-18.

Begin Date (m/y)	Flock	Trt.[2]	Litter	Caked Litter	All Litter	Mortality	Marketed Broilers	Loss	Emission (gN/d/bd)[4]	Emission % of N Inputs
			(g N/kg)[3]							
11/02	10	C	15.02*	3.14*	18.16*	0.68	28.55	4.12*	0.229*	7.88*
		T	7.78*	1.56*	9.34*	1.32	28.55	13.50*	0.759*	25.59*
1/03	11	C	14.62*	3.43	18.05*	1.45	29.00	7.79*	0.426*	13.81*
		T	19.92*	2.37	22.29*	1.12	29.00	3.32*	0.181*	5.94*
2/03	12	C	13.95*	4.91*	18.86*	0.97*	29.16	5.20*	0.297*	9.59*
		T	6.59*	2.40*	8.99*	1.80*	29.16	14.09*	0.810*	26.08*
4/03	13	C	2.25*	4.48*	6.73*	0.41	28.90	15.47	0.834	30.10
		T	8.39*	2.49*	10.88*	0.50	28.90	12.25	0.642	23.29
6/03	14	C	-0.32	4.55*	4.23	0.18	28.86	18.71	0.985	36.03
		T	3.20	2.24*	5.44	0.31	28.86	18.69	0.941	34.93
8/03	15	C	3.36	2.44	5.80	0.76	28.47	16.18	0.841	31.59
		T	5.62	1.91	7.53	0.65	28.47	14.05	0.718	27.72
9/03	16	C	5.37	5.09*	10.46	0.38	28.47	14.53	0.801	27.00
		T	7.50	2.37*	9.87	0.50	28.46	14.38	0.799	27.02
11/0	17	C	9.15	5.37*	14.52	0.88	28.79	8.21	0.470	15.67
		T	9.70	2.80*	12.50	0.55	28.80	10.31	0.597	19.75
1/04	18	C	4.72*	11.32*	16.04	2.65*	30.57	5.00	0.293	9.14
		T	8.90*	6.82*	15.72	1.63*	30.57	5.98	0.347	11.08
Average		C	7.57	4.97*	12.54*	0.93	28.97	10.58	0.575	20.09
		T	8.62	2.77*	11.40*	0.93	28.98	11.84	0.644	22.38

[1] All analyses and calculations performed on dry matter basis.
[2] C = control group, T = top-dressed group (3 pens/treatment)
[3] Values calculated as grams of N/kg of live marketed broiler.
[4] Values calculated as grams of N/day/marketed broiler.
* Means between treatment within flock differ significantly (P<0.05).

The body weight and nitrogen content of broiler carcasses were relatively consistent values. Therefore, the amount of nitrogen partitioned into the broiler carcasses was relatively constant, ranging between 28.47 and 30.57 g N/kg. Broiler carcasses contained between 7.8

and 8.7% nitrogen on a dry matter basis (data not shown). Nitrogen partitioned into mortalities displayed little variation due to the few numbers of bird carcasses involved in each calculation. Since the two bird carcass categories were relatively constant, any change in the amount of nitrogen retained in the litter and caked litter (referred to collectively as "all litter") resulted in an opposite partitioning of nitrogen into the loss category. Therefore, when nitrogen retention in the litter was significantly lower in summer compared to winter flocks, the amount of nitrogen loss was significantly greater in summertime and lower in wintertime. These findings are supported by the fact that ammonia volatilization has been shown to increase greatly as temperatures increase from 20C to 35C (Elliott and Collins, 1982). Redwine *et al* (2002) observed similar results when comparing emission rates of summer and winter broiler flocks in Texas. Increased summertime nitrogen losses can easily be delineated in Flocks 7, 14 and 15 which were reared in the hottest months of the two summers encompassed by this study. A summary of nitrogen emissions for Flocks 1-18 control pens only is presented in Table 3. These findings demonstrate that older litter may not necessarily release more ammonia than newer litter due strictly to litter age in a wintertime scenario. Cooler temperatures and decreased microbial activity are factors that may support this reasoning (Flocks 3-4 vs 10 and 18).

Nitrogen balance data comparing top-dressed pens to untreated control litter pens for Flocks 10-18 is presented in Table 2. Significant differences were observed for nitrogen retention in the litter for the first 4 flocks. However, these differences were not consistent. In Flocks 10 and 12, top-dressing of litter significantly reduced nitrogen retention compared to control pens; while in Flocks 11 and 13, top-dressing significantly increased nitrogen retention in the litter compared to control pens. These results can not be fully explained at this time. Explanation of these results may lie in the relationship of C:N ratios in the litter, microbial activity, litter moisture, litter temperature and other environmental factors such as humidity and ventilation rate. The effects of these factors on ammonia volatilization have been discussed by Nahm (2003). Nahm (2003) suggested that the C:N ratio and the type of carbon source (rice hulls in this case) in litter can greatly influence ammonia retention and/or volatilization.

Significant reductions in caked litter production and caked litter nitrogen content in top-dressed pens resulted in significantly reduced nitrogen partitioned into caked litter for 7 of the 9 flocks compared to control pens. However, overall average nitrogen retained in all litter was significantly higher in the control litter pens vs. the top-dressed pens. Although not statistically significant, more nitrogen was lost as ammonia and dust for the top-dressed pens (11.84 g N/kg) compared to the control pens (10.58 g N/kg) for all 9 flocks (P=0.096). As a percentage of nitrogen inputs, nitrogen loss was 20.09 and 22.38% for control and top-dressed pens, respectively. Therefore, these findings do not support the theory that top-dressing recycled litter can reduce ammonia loss in broiler litter.

Nitrogen emissions rates

Nitrogen emission rates resulting from the current research are presented in Tables 1, 2 and 3. The difference between total nitrogen loss and ammonia loss is due to other nitrogenous losses such as dust and other nitrogenous gases (nitrous oxide, nitric oxide, etc.). These other nitrogen losses are generally known to be very small. Therefore, total nitrogen loss is approximately equal to ammonia loss, and the nitrogen emission rates presented would represent the maximum amount of ammonia emission. Nitrogen losses have been calculated as grams of nitrogen per kg of live marketed broiler (g N/kg), grams of N per day per bird (g N/d/bd) and as a percentage of nitrogen inputs. The latter two units have previously appeared in the literature (Burns, 2004; Patterson *et al*, 1998). We believe the novel unit g N/kg would be easier to compare across studies that may utilize different broiler body weights and management systems. Average nitrogen emission rates calculated for Flocks 1-9 and Flocks 10-18 are similar to those reviewed by Burns (2004). In Flocks 1-9, an average of 0.624 g N/d/bd was lost to the environment as ammonia and dust. Significant differences were observed for nitrogen emission rates between control and top-dressed pens for Flocks 10-13. Ammonia emissions were significantly lower in the control pens in flocks 10 and 12 compared to the top-dressed pens, while ammonia emissions were significantly lower for

Table 3. Nitrogen emissions for untreated litter, flocks 1-18.

Begin Date (m/y)	End Date (m/y)	Flock	g N/kg[1]	g N/d/bd[2]	% of N inputs[3]
7/01	8/01	1	9.21^{efghi}	0.486^{def}	18.24^{efg}
9/01	10/01	2	8.65^{efghi}	0.471^{ef}	16.38^{fgh}
11/01	12/01	3	7.34^{ghij}	0.417^{efg}	14.42^{ghi}
1/02	2/02	4	9.43^{efgh}	0.534^{de}	17.73^{efg}
2/02	4/02	5	10.33^{defg}	0.539^{de}	19.40^{defg}
4/02	5/02	6	12.45^{cde}	0.690^{cd}	24.43^{bcde}
6/02	7/02	7	19.72^{a}	1.035^{a}	36.63^{a}
7/02	9/02	8	11.98^{cdef}	0.613^{cde}	22.63^{cdef}
9/02	10/02	9	14.65^{bc}	0.830^{abc}	27.78^{bc}
11/02	12/02	10	4.12^{j}	0.229^{g}	7.88^{i}
1/03	2/03	11	7.79^{fghij}	0.426^{efg}	13.81^{ghi}
2/03	4/03	12	5.20^{hij}	0.297^{fg}	9.59^{hi}
4/03	6/03	13	15.47^{abc}	0.834^{abc}	30.10^{abc}
6/03	7/03	14	18.71^{ab}	0.985^{ab}	36.03^{a}
8/03	9/03	15	16.18^{abc}	0.841^{abc}	31.59^{ab}
9/03	10/03	16	14.53^{bcd}	0.801^{bc}	27.00^{bcd}
11/03	12/03	17	8.21^{efghij}	0.470^{efg}	15.67^{fghi}
1/04	2/04	18	5.00^{ij}	0.293^{fg}	9.14^{hi}
average			11.05	0.603	21.02

[1] Values calculated as grams of N/kg of live marketed broiler.
[2] Values calculated as grams of N/day/marketed broiler.
[3] N inputs = feed N + day-old chick N
[a, b, … i] Means within columns with no common superscripts differ significantly ($P<0.05$).

top-dressed pens in Flock 11. As previously discussed, neither treatment group exhibited consistently lower nitrogen emission rates when compared to the other, and the average emission rate over the 9 flocks for the two litter management strategies was not significantly different (Table 2). It is interesting to note that when the control groups were lower in nitrogen loss (Flocks 10 and 12), the difference between the groups was more than double size of the difference in Flock 11 when the top-dressed group was lower in nitrogen loss. This suggests that large amounts of ammonia were lost from the top-dressed pens due to a dramatic shift in some factor(s) regulating ammonia volatilization (pH, temperature, moisture, C:N, microbial activity, etc.) Nitrogen emission rates are presented for Flocks 1-18 control pens only in Table 3. The average nitrogen (ammonia) emission rate was calculated to be 0.603 g N/d/bd or 11.05 g N/kg, which represented about 21% of the nitrogen inputs. Seasonality appears to be a key factor for nitrogen emissions, with summertime flocks exhibiting significantly greater emission rates than wintertime flocks.

Results of this experiment show that seasonality greatly influences nitrogen loss from the broiler rearing facility, and top-dressing of litter tends to increase nitrogen loss on average. Quantification of nitrogen loss via nitrogen balance studies provides a basis to evaluate other direct measures of ammonia emissions and enhances the knowledge base for implementation of policy regarding broiler production facilities.

Acknowledgements

This research supported in part by U.S Poultry and Egg Association research project #495 – Quantification of the fate of nitrogen in commercial broiler production systems.

References

Burns, R. T., 2004. Poultry broiler ammonia emission factor comparisons. Proceedings of 2004 National Poultry Waste Management Symposium, Memphis, Tennessee.

Elliott, H. A. and N. E. Collins, 1982. Factors affecting ammonia release in broiler houses. Transactions of the ASAE 25(2): 413-424.

Nahm, K. H., 2003. Evaluation of the nitrogen content in poultry manure. World's Poultry Science Journal 59: 77-88.

Patterson, P. H., E. S. Lorenz, W. D. Weaver, Jr. and J. H. Schwartz, 1998. Litter production and nutrients from commercial broiler chickens. Journal of Applied Poultry Research 7: 247-252.

Redwine, J. S., R. E. Lacey, S. Mukhtar and J. B. Carey, 2002. Concentrations and emissions of ammonia and particulate matter in tunnel-ventilated broiler houses under summer and winter conditions in Texas. Transactions of the ASAE 45(4): 1101-1109.