Poultry litter ash as a replacement for dicalcium phosphate in broiler diets

J. P. Blake[1] and J. B. Hess

Department of Poultry Science, Auburn University, Auburn, AL 36849

Primary Audience: Nutritionists, Researchers, Producers

SUMMARY

An experiment was designed to evaluate the nutritional value of poultry litter ash (PLA) under commercial-type conditions. Diets were formulated to meet the nutrient requirements of the broiler utilizing PLA at combinations of 0, 25, 50, 75, or 100% in starter, grower, and finisher diets as a replacement for dicalcium phosphate (DP). No significant effects were observed on BW, feed consumption, FCR, or mortality when broilers were fed PLA to 100% replacement for DP to 41 d of age. Processing performance, as measured by carcass and meat yield, of broilers at 42 d of age was also unaffected ($P > 0.05$). The complete substitution of DP with PLA failed to compromise growth and processing performance in market age broilers and the PLA produced via the combustion of poultry litter can be used as a phosphorus source in poultry diets.

Key words: poultry litter ash, dicalcium phosphate, broiler

2014 J. Appl. Poult. Res. 23:101–107
http://dx.doi.org/10.3382/japr.2013-00838

DESCRIPTION OF PROBLEM

The fertilization of crops with poultry manure is and will continue to be a good agronomic practice. However, alternatives to land application of poultry manure are mandated because, in some areas, the application of poultry manure to agricultural lands has resulted in soil phosphorus levels that exceed the amount that can be removed in the harvested crop [1]. Concerns about P runoff into surface waters where manure is applied at excessive rates or not according to established requirements for crop production also exist [2].

Potential exists for recycling P from poultry manures, especially where poultry litter can be obtained as a feedstock for energy generation [3]. After combustion, the remaining poultry litter ash (**PLA**) has greater value for use as a P supplement for use in poultry diets as compared with its fertilizer value [4]. Feed phosphates are a costly component of the poultry diet and are mirrored by rising costs in the extraction and production of animal feed phosphates [5]. Local sources of products, such as PLA, provide a distinct economic advantage in reducing feed costs. An experiment was designed to evaluate PLA as a substitute for dicalcium phosphate (**DP**) in commercial-type diets for the broiler chicken.

MATERIALS AND METHODS

General Considerations

A total of 1,600 broiler chicks were obtained from a commercial hatchery (Cobb × Ross) and 25 birds were randomly assigned to each of 64 floor pens, each being 1.98 × 2.29 m. The cur-

[1]Corresponding author: blakejp@auburn.edu

Table 1. Composition of poultry litter ash

Nutrient (%, unless otherwise noted)	Analyzed value[1]	Computer value[2]
Calcium	16.68	16.70
Phosphorus	10.08	10.00
Copper	0.165	1,500.00 ppm
Iron	0.593	5,000.00 ppm
Magnesium	2.650	2.70
Manganese	0.209	1,900.00 ppm
Potassium	7.640	7.5
Sodium	4.340	4.2
Chloride	0.990	1.0
Zinc	0.136	1,300.00 ppm
Selenium (ppm)	2.40	2.40

[1]Values obtained from analysis of sample submitted to Eurofins [8].

[2]Values assigned to poultry litter ash when used as an ingredient in the computer feed formulation matrix.

Table 2. Assignment of dietary treatments

	Poultry litter ash (%)		
Treatment[1]	Starter	Grower	Finisher
0/0/0	0	0	0
25/25/25	25	25	25
50/50/50	50	50	50
75/75/75	75	75	75
100/100/100	100	100	100
25/100/100	25	100	100
50/100/100	50	100	100
75/100/100	75	100	100

[1]Percentage of poultry litter ash used as a replacement for dicalcium phosphate in the starter, grower, and finisher diets.

Table 3. Composition of starter diets

Item	Level of poultry litter ash (%)				
(%, unless otherwise noted)	0	25	50	75	100
Ingredient					
Ground yellow corn	55.75	55.44	55.14	54.79	54.47
Soybean meal (48% CP)	35.11	35.12	35.14	35.17	35.19
Poultry oil	4.53	4.65	4.77	4.90	5.02
Dicalcium phosphate[1]	1.73	1.30	0.86	0.43	0.00
Limestone (38% Ca)	1.23	1.12	1.01	0.90	0.79
Poultry litter ash[2]	0.00	0.80	1.60	2.41	3.22
Salt	0.45	0.37	0.28	0.20	0.11
DL-Methionine	0.27	0.27	0.27	0.27	0.27
L-Lysine	0.10	0.10	0.10	0.10	0.10
Vitamin premix[3]	0.50	0.50	0.50	0.50	0.50
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
CP	21.50	21.50	21.50	21.50	21.50
ME (kcal/kg)	3,142.00	3,142.00	3,142.00	3,142.00	3,142.00
Ca	0.93	0.93	0.93	0.93	0.93
Nonphytate phosphorus	0.45	0.45	0.45	0.45	0.45
Met	0.62	0.62	0.62	0.62	0.62
Met + Cys	0.95	0.95	0.95	0.95	0.95
Lys	1.27	1.27	1.27	1.27	1.27

[1]Contains 18.5% P and 24.1% Ca.

[2]Poultry litter ash was added to the diet at the expense of dicalcium phosphate.

[3]Supplied the following per kilogram of complete feed: vitamin A, 8,000 IU (vitamin A acetate); vitamin D, 2,000 IU (cholecalciferol); vitamin E, 8 IU (DL-α tocopheryl acetate); menadione, 2 mg (menadione sodium bisulfite complex); riboflavin, 5.5 mg (riboflavin); pantothenic acid, 13 mg (D-calcium pantothenate); niacin, 36 mg (niacinamide); choline, 500 mg (choline chloride); vitamin B_{12}, 0.02 mg (cyanocobalamin); folacin, 5 mg (folic acid); thiamine, 1 mg (thiamine mononitrate); pyridoxine, 2.2 mg (pyridoxine hydrochloride); biotin, 0.05 mg (D-biotin); ethoxyquin, 125 mg.

[4]Supplied the following per kilogram of complete feed: manganese, 125 mg (manganous oxide); iodine, 1 mg (ethylene diamine dihydriodide); iron, 55 mg (iron carbonate); copper, 6 mg (copper oxide); zinc, 55 mg (zinc oxide), selenium, 0.3 mg (sodium selenite).

[5]Monensin sodium [12].

Table 4. Composition of grower diets

Item (%, unless otherwise noted)	Level of poultry litter ash (%) 0	25	50	75	100
Ingredient					
Ground yellow corn	63.00	62.70	62.31	62.01	61.62
Soybean meal (48% CP)	29.70	29.71	29.81	29.82	29.93
Poultry oil	3.28	3.41	3.53	3.65	3.77
Dicalcium phosphate[1]	1.60	1.20	0.80	0.40	0.00
Limestone (38% Ca)	1.09	0.99	0.89	0.80	0.70
Poultry litter ash[2]	0.00	0.74	1.48	2.22	2.96
Salt	0.45	0.37	0.30	0.22	0.14
DL-Methionine	0.23	0.23	0.23	0.23	0.23
L-Lysine	0.07	0.07	0.07	0.07	0.07
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
CP	19.50	19.50	19.50	19.50	19.50
ME (kcal/kg)	3,153.00	3,153.00	3,153.00	3,153.00	3,153.00
Ca	0.84	0.84	0.84	0.84	0.84
Nonphytate phosphorus	0.42	0.42	0.42	0.42	0.42
Met	0.56	0.56	0.56	0.56	0.56
Met + Cys	0.86	0.86	0.86	0.86	0.86
Lys	1.10	1.10	1.10	1.10	1.10

[1]Contains 18.5% P and 24.1% Ca.

[2]Poultry litter ash was added to the diet at the expense of dicalcium phosphate.

[3]Supplied the following per kilogram of complete feed: vitamin A, 8,000 IU (vitamin A acetate); vitamin D, 2,000 IU (cholecalciferol); vitamin E, 8 IU (DL-α tocopheryl acetate); menadione, 2 mg (menadione sodium bisulfite complex); riboflavin, 5.5 mg (riboflavin); pantothenic acid, 13 mg (D-calcium pantothenate); niacin, 36 mg (niacinamide); choline, 500 mg (choline chloride); vitamin B_{12}, 0.02 mg (cyanocobalamin); folacin, 5 mg (folic acid); thiamine, 1 mg (thiamine mononitrate); pyridoxine, 2.2 mg (pyridoxine hydrochloride); biotin, 0.05 mg (D-biotin); ethoxyquin, 125 mg.

[4]Supplied the following per kilogram of complete feed: manganese, 125 mg (manganous oxide); iodine, 1 mg (ethylene diamine dihydriodide); iron, 55 mg (iron carbonate); copper, 6 mg (copper oxide); zinc, 55 mg (zinc oxide), selenium, 0.3 mg (sodium selenite).

[5]Monensin sodium [12].

tain-sided house had thermostatically controlled heating and cross ventilation. Pens were separated by wire partitions and the floor and isles were concrete. Each pen was equipped with an electric brooder and ceiling-mounted forced-air furnaces were used to maintain a brooding temperature of 95°F (35°C) for the first week; thereafter, brooding temperature was reduced 5°F (2.8°C) weekly through 4 wk of age. Each pen had fresh pine shavings (5 cm) and was equipped with 1 hanging feeder (22.5-kg capacity) and nipple water line system. Chicks were vaccinated for Marek's disease at the hatchery. Feed and water were provided ad libitum, accompanied by an L:D cycle of 23:1 for the 41-d experimental period.

Body weight was recorded initially and at 14, 28, and 41 d of age to determine BW gain. Mortalities were weighed daily and recorded before disposal. Feed consumption (**FC**) was calculated by the difference in feed offered and feed remaining on a pen basis at 14, 28, and 41 d. Mortality-corrected FCR (FC:BW) was determined as the ratio of the FC divided by the pen weight plus BW of mortality during the 14-, 28-, and 41-d periods. Statistical analysis was conducted using JMP software [6]. Animal transport, housing, and handling procedures were in accordance with guidelines of Auburn University's Institutional Animal Care and Use Committee.

Experimental Diets

The PLA was obtained from a pilot plant test of an Energy Products of Idaho [7] fluidized

Table 5. Composition of finisher diets

Item (%, unless otherwise noted)	Level of poultry litter ash (%) 0	25	50	75	100
Ingredient					
Ground yellow corn	72.55	72.24	71.95	71.63	71.32
Soybean meal (48% CP)	21.76	21.82	21.87	21.92	21.97
Poultry oil	1.98	2.08	2.18	2.30	2.41
Dicalcium phosphate[1]	1.38	1.03	0.69	0.35	0.00
Limestone (38% Ca)	1.02	0.94	0.85	0.76	0.68
Poultry litter ash[2]	0.00	0.64	1.28	1.92	2.56
Salt	0.45	0.39	0.32	0.26	0.20
DL-Methionine	0.24	0.24	0.24	0.24	0.24
L-Lysine	0.12	0.12	0.12	0.12	0.12
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
CP	16.50	16.50	16.50	16.50	16.50
ME (kcal/kg)	3,175.00	3,175.00	3,175.00	3,175.00	3,175.00
Ca	0.75	0.75	0.75	0.75	0.75
Nonphytate phosphorus	0.37	0.37	0.37	0.37	0.37
Met	0.54	0.54	0.54	0.54	0.54
Met + Cys	0.79	0.79	0.79	0.79	0.79
Lys	0.92	0.92	0.92	0.92	0.92

[1]Contains 18.5% P and 24.1% Ca.

[2]Poultry litter ash was added to the diet at the expense of dicalcium phosphate.

[3]Supplied the following per kilogram of complete feed: vitamin A, 8,000 IU (vitamin A acetate); vitamin D, 2,000 IU (cholecalciferol); vitamin E, 8 IU (DL-α tocopheryl acetate); menadione, 2 mg (menadione sodium bisulfite complex); riboflavin, 5.5 mg (riboflavin); pantothenic acid, 13 mg (D-calcium pantothenate); niacin, 36 mg (niacinamide); choline, 500 mg (choline chloride); vitamin B_{12}, 0.02 mg (cyanocobalamin); folacin, 5 mg (folic acid); thiamine, 1 mg (thiamine mononitrate); pyridoxine, 2.2 mg (pyridoxine hydrochloride); biotin, 0.05 mg (D-biotin); ethoxyquin, 125 mg.

[4]Supplied the following per kilogram of complete feed: manganese, 125 mg (manganous oxide); iodine, 1 mg (ethylene diamine dihydriodide); iron, 55 mg (iron carbonate); copper, 6 mg (copper oxide); zinc, 55 mg (zinc oxide), selenium, 0.3 mg (sodium selenite).

bed system designed to combust poultry litter with the intent to produce process steam. Initial analyses [8] were completed to determine its mineral composition and establish feed formulation values (Table 1). For diet formulation, PLA (16.70% Ca, 10.00% P) was substituted for DP (24.1% Ca, 18.5% P) where the mineral contribution of Ca, P, and Na were used in the feed formulation matrix. The 8 dietary treatments were 0, 25, 50, 75, or 100% PLA as a replacement for DP in the starter, grower, and finisher diets or 25, 50, or 75% in the starter diet followed by 100% PLA in the grower and finisher diets (Table 2). Each diet was fed to 8 pens with 25 birds/pen. The corn-soybean meal pelleted diets were formulated based on available information to meet or exceed NRC recommendations [9] and birds were allocated a specified amount of starter (1.8 lb/bird), grower (3.5 lb/bird), and finisher (ca. 6.7 lb/bird) on a pen basis during the 41-d experimental period (Tables 3, 4 and 5).

Processing and Yield Determination

Carcass yield was evaluated at 42 d of age for 10 broilers randomly selected, wing-banded, and placed back in the pens at terminal weighing (d 41) with their pen mates and maintained on full feed. Feed and water withdrawal was introduced 8 h (2300 h) before processing. Marked birds were weighed before processing following the 8-h feed withdrawal period. Carcass and abdominal fat weight were determined after a 2-h ice chilling to slightly less than 4.4°C (40°F). Following chilling, the front half and rear half were separated, weighed, and the respective yield of each component calculated as a percent of preslaughter live weight.

Table 6. Performance of mixed sex broilers fed graded levels of poultry litter ash

	BW[2] (g)		BW (kg)		Feed consumption (kg/bird)				FCR (FC:BW)				Mortality (%)[3]
Item[1]	0 d	14 d	28 d	41 d	0–14 d	14–28 d	28–41 d	0–41 d	0–14 d	14–28 d	28–41 d	0–41 d	0–41 d
0/0/0	46.73	452.2	1.476	2.557	0.516	2.041	2.295	4.852	1.141	1.993	2.123	1.898	2.50
25/25/25	47.05	469.6	1.517	2.567	0.511	2.081	2.294	4.886	1.088	1.988	2.185	1.896	1.50
50/50/50	46.88	465.6	1.500	2.603	0.514	2.085	2.334	4.933	1.104	2.016	2.116	1.895	2.50
75/75/75	47.60	464.0	1.495	2.562	0.521	2.059	2.240	4.820	1.123	1.997	2.099	1.881	2.50
100/100/100	47.50	461.2	1.452	2.517	0.486	2.037	2.261	4.784	1.054	2.055	2.123	1.901	2.50
25/100/100	46.18	473.5	1.452	2.537	0.521	2.065	2.213	4.799	1.100	2.109	2.040	1.892	2.50
50/100/100	46.80	466.9	1.462	2.555	0.512	2.051	2.307	4.870	1.097	2.061	2.111	1.906	2.50
75/100/100	46.75	464.9	1.477	2.596	0.519	2.087	2.394	5.000	1.117	2.062	2.139	1.926	2.50
Pooled SEM	0.35	5.47	0.017	0.044	0.009	0.026	0.074	0.056	0.019	0.044	0.034	0.014	—
P-value	0.130	0.258	0.076	0.894	0.100	0.771	0.770	0.315	0.092	0.281	0.054	0.794	0.136

[1]Percentage of poultry litter ash used as a replacement for dicalcium phosphate in the starter, grower, and finisher diets fed as an allocation of 1.8, 3.5, and ca. 6.7 lb/bird during the 41-d experimental period.

[2]Values are grand means involving 64 pens each with 25 chicks at placement.

[3]Total mortality percentages were transformed to the arcsine, whereas no valid SEM exists, as data were transformed and subject to analysis.

Table 7. Processing performance of broilers at 42 d of age fed graded levels of poultry litter ash

			Chilled carcass[4]		Abdominal fat[5]		Front half		Rear half	
Start/Grow/Finish[1]	Preslaughter live weight[2] (g)	Carcass yield[3] (%)	Weight (g)	Yield[6] (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)
0/0/0	2,648	71.39	1,938	73.20	48.00	1.81	1,072	40.49	818	30.90
25/25/25	2,686	74.19	2,045	76.00	48.50	1.81	1,109	41.25	887	32.94
50/50/50	2,701	70.07	1,945	71.92	50.00	1.86	1,072	39.60	823	30.46
75/75/75	2,649	71.36	1,944	73.23	49.63	1.87	1,048	39.45	847	31.90
100/100/100	2,654	72.85	1,983	74.77	51.13	1.93	1,075	40.47	857	32.37
25/100/100	2,707	71.69	1,993	73.66	53.25	1.97	1,100	40.62	840	31.07
50/100/100	2,641	70.45	1,912	72.38	51.13	1.94	1,057	39.99	804	30.46
75/100/100	2,688	70.83	1,955	72.75	51.63	1.92	1,087	40.43	817	30.40
Pooled SEM	66.74	1.16	61.29	1.16	1.78	0.051	32.56	0.419	33.55	0.978
P-value	0.993	0.251	0.862	0.265	0.487	0.263	0.897	0.080	0.721	0.446

[1]Percentage of poultry litter ash used as a replacement for dicalcium phosphate in the starter, grower, and finisher diets fed as an allocation of 1.8, 3.5, and ca. 6.7 lb/bird during the 41-d experimental period.

[2]All values represent least squares means of 8 pens, each providing data from 10 carcasses.

[3]Statistical analysis employed transformed values (arcsine), whereas the respective SEM values were estimates derived from actual percentages.

[4]Carcass without neck and giblets after 2 h of slush ice chilling and removal of abdominal fat expressed on an absolute basis and relative to the full-fed live bird. Depot fat removed from the abdominal cavity of carcasses without neck and giblets after 2 h of slush ice chilling expressed on an absolute basis and relative to the full-fed live weight.

[5]Abdominal fat expressed on an absolute basis and relative to the chilled carcass.

[6]As a percent of preslaughter live weight.

RESULTS AND DISCUSSION

This experiment was designed to evaluate the use of PLA as a substitute for DP under commercial-type conditions. No significant effects ($P > 0.05$) were observed on BW, FC, FCR, or mortality when broilers were fed graded levels of PLA to 100% replacement for DP, as represented by the 100/100/100 treatment (Table 6). Also, no significant differences ($P > 0.05$) were observed in the processing performance of broilers at 42 d of age due to the substitution of DP with PLA (Table 7).

The use of PLA as a replacement for DP has been met with limited investigation in the past with turkeys [10] and broilers [11]. Both investigators concluded that PLA obtained from the combustion of turkey or broiler litter could be used as a P supplement for poultry. In the current study, the complete substitution of DP with PLA failed to compromise growth and processing performance in market age broilers. Therefore, the PLA evaluated in this and previous experiments confirms that the PLA produced via the combustion of poultry litter can be used as a phosphorus source in poultry diets.

CONCLUSIONS AND APPLICATIONS

1. The use of PLA as a replacement for DP in commercial-type broiler diets had no negative effects on growth or processing characteristics of market age broilers.
2. The PLA produced by the combustion of poultry litter and used in this evaluation can be used as a substitute for DP in broiler diets without consequence.

REFERENCES AND NOTES

1. Codling, E. E., R. L. Chaney, and J. Sherwell. 2002. Poultry litter ash as a potential phosphorus source for agricultural crops. J. Environ. Qual. 31:954–961.

2. Sharpley, A. N., S. H. Chapra, R. Wedepohl, J. T. Sims, T. C. Daniel, and K. R. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: Issue and options. J. Environ. Qual. 23:437–451.

3. Power Plant Research Program. 1998. Engineering and economic feasibility of using poultry litter as a fuel to generate electric power at Maryland's Eastern Correctional Institute. PPES-96–1. Dept. of Natural Resources, Annapolis, MD. Accessed June 6, 2013. http://esm.versar.com/pprp/eci/poultry.htm.

4. USDA. 2009. Manure use for Fertilizer and for Energy: Report to Congress. USDA, Economic Research Service, Washington, DC. Accessed June 6, 2013. http://www.ers.usda.gov/media/156155/ap037_1_.pdf.

5. Auman, S. 2010. Phosphorus Availability—When will we run out of phosphorus? In Proc. 2010 Natl. Poult. Anim. Waste Manag. Sym. J. B. Hess, J. P. Blake, and K. S. Macklin, ed. Natl. Poult. Waste Manag. Sym. Comm., Auburn, AL.

6. Data were subjected to or one-way analysis of variance and, where significant, means were separated by Tukey's honestly significant difference test at the probability level of 0.05 using JMP software (JMP The Statistical Discovery Software, 2005, SAS Institute Inc., Cary, NC). All percentage data were subjected to arcsine square root transformation prior to analysis; however, actual data are reported.

7. Energy Products of Idaho, Coeur d'Alene, ID.

8. Eurofins, Memphis, TN.

9. NRC. 1994. Nutrients Requirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.

10. Apke, M. P., P. E. Waibel, and R. V. Morey. 1984. Bioavailability of phosphorus in poultry litter biomass ash residues for turkeys. Poult. Sci. 63:2100–2102.

11. Muir, F., R. M. Leach Jr., and B. S. Heinrichs. 1990. Bioavailability of phosphorus from broiler litter ash for chicks. Poult. Sci. 69:1845–1850.

12. Elanco Animal Health Inc., Indianapolis, IN.