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Effects of a silica-based feed supplement on performance, health, and litter quality of growing turkeys

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ABSTRACT Poor litter quality is a potential challenge to footpad health as well as the primary cause of ammonia volatilization. High ambient ammonia concentration is one of the most significant factors negatively affecting poultry production today. Some minerals have been reported to reduce ammonia release from poultry litter. Silicon dioxide, a highly pure and natural mineral, shows promise in decreasing ammonia volatilization and improving litter quality. The objective of the current study was to investigate the effects of feed-borne silicon dioxide on litter quality and how this impacts bird performance, general health and footpad health throughout a 12-wk posthatching turkey study. Supplementing the diet with silicon dioxide was found to significantly improve turkey BW gain and the efficiency of feed conversion. The severity of footpad dermatitis was monitored throughout the experimental period but no significant effect of diet was seen. The feeding of silicon dioxide reduced litter pH which decreased the conversion of NH_4^+ to NH_3 thereby reducing nitrogen losses from litter. It was concluded that, under our study conditions, the feeding of 0.02% silicon dioxide offers potential economic benefits to turkey producers.

Key words: silicon dioxide, litter, ammonia, turkey

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INTRODUCTION

Footpad dermatitis (**FPD**) is a common challenge in commercial turkey flocks. It is characterized by inflammation and ulcers on the footpad and toes, which may lead to the abscesses of the underlying tissue and structures (Greene et al., 1985), thereby affecting not only walking ability but also carcass quality (Bradshaw et al., 2002). Mayne et al. (2006) reported that the disease can start at a very early age in turkeys and can occur throughout life. The prevalence of FPD in turkeys can be extremely high, reaching up to 98 to 100% (Hafez et al., 2004). There are several factors which can influence the occurrence of FPD including drinker design, ambient temperature and humidity, and litter type, quality, and quantity (Bray and Lynn, 1986; Collette, 2006).

Since footpads are in constant contact with litter, the potential impact of litter quality on footpad health is significant. Martland (1984) and Collette (2006) observed that poor litter quality was associated with increased incidence and severity of FPD in turkey housing systems. It has also been reported that poor litter quality can increase the microbiological load in litter thereby exposing birds to increased challenges from parasites such as coccidia, other protozoa, fungi, enteric viruses, and environmental bacteria (Ritz et al., 2009). Mycoses and mycotoxicoses can result in increased mortality. Several serious bacterial diseases are known to spread easily in contaminated litter thereby requiring administration of antibiotics. Poor litter quality is also the primary cause of ammonia volatilization which can reduce air quality and is one of the most serious negative factors affecting bird production today (Reece et al., 1980). Many producers underestimate the detrimental effects of ammonia. Birds are sensitive to ammonia and prolonged exposure to high levels (50 to 100 μg/g) can result in blindness and negatively affect production efficiency and flock health (Beker et al., 2004; Miles et al., 2006).

The cost and the difficulty of handling and disposing of used litter have resulted in many poultry companies and turkey producers reusing litter for more than a year of production. There are many treatments that may have potential to improve litter quality and reduce FPD, including organic plant extracts and inorganic minerals. It has been reported that airborne ammonia concentrations can be reduced by the feeding of *Yucca* extract to poultry (Johnston et al., 1981; Headon and Dawson, 1990). Dietary mineral salts are directly related to water intake and urinary output and, therefore, with litter quality and the frequency of FPD. It has been reported that perlite, vermiculite, pumice, and natural zeolite might also reduce odor and ammonia volatilization in poultry litter (Turan, 2009). Silica gel has recently been demonstrated to be an ammonia

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Table 1. Composition of study diets (%).

Ingredient	Starter (1 to 3wk)	Grower (4 to 6 wk)	Developer (7 to 9 wk)	Finisher (10 to 12 wk)
Corn, grain	42.80	50.04	57.09	61.50
Wheat, white	10.00	10.00	9.00	9.00
Wheat bran	4.25	1.30	–	–
Soybean meal (48%)	18.91	16.50	12.50	9.00
Pork meal	19.70	18.80	16.10	14.30
Feather meal	2.46	1.50	2.50	2.50
Animal and vegetable fat	–	–	0.56	1.50
Dicalcium phosphate	0.29	0.29	0.28	0.28
Limestone	–	–	0.24	0.22
Iodized salt	0.05	0.08	0.13	0.16
Vitamin and mineral mixture	1.00	1.00	1.00	1.00
DL-Methionine (99%)	0.25	0.22	0.21	0.17
L-Lysine HCl	0.29	0.27	0.39	0.37
Calculated Values				
ME, kcal/kg	2,800	2,900	3,000	3,100
CP (%)	28.00	25.65	23.51	21.17
Lysine (%)	1.59	1.47	1.38	1.21
Methionine (%)	0.65	0.60	0.55	0.48
Calcium (%)	1.38	1.31	1.22	1.09
Phosphorus (total) (%)	1.03	0.97	0.86	0.79
Analyzed Values				
DM (%)	90.82	90.04	90.11	91.99
ME, kcal/kg	2,800	2,750	2,860	3,280
CP (%)	27.64	25.62	21.85	19.81
Calcium (%)	1.48	2.02	1.60	1.47
Phosphorus (total) (%)	1.72	1.23	1.02	0.93

Vitamin-mineral mixture provided per kilogram diet: vitamin A (retinyl palmitate): 8800 IU; cholecalciferol: 3,300 IU; vitamin E (dl-α-tocopheryl acetate): 40 IU; vitamin K: 3.30 mg; thiamin: 4.00 mg; riboflavin: 8.00 mg; pantothenic acid: 15.00 mg; niacin: 50 mg; pyridoxine: 3.30 mg; choline: 600.00 mg; folic acid: 1.00 mg; biotin: 0.22 mg; vitamin B_{12}: 0.012 mg; ethoxyquin: 0.120 mg; manganese: 70 mg; zinc: 70 mg; iron: 60 mg; copper: 10 mg; iodine: 1.00 mg and selenium: 0.3 mg.

absorbent in vitro by Helminen et al. (2000) and in vivo by Pillai et al. (2012). Silicon dioxide is a highly pure and natural mineral which has minimal environmental impact, and also shows promise in reducing off odors due to ammonia and improving the quality of litter. The objective of the current study was to investigate the effects of a silica-based feed supplement on litter quality and how this impacts bird growth, performance, general health, and FPD over 12-wk turkey production cycle.

MATERIALS AND METHODS

Study Birds, Housing, and Diets

A total of 128, 1-day-old, Hybrid Converter male poults were obtained from a commercial hatchery (Cuddy Farms, Strathroy, Ontario, Canada). Poults were individually weighed, neck-tagged, and randomly distributed into groups of 8 birds/floor pen (4.25 m^2) at the Arkell Research Station of the University of Guelph. Eight pens were randomly assigned to each of 2 diets with each diet fed to 64 birds over a 12-wk period. Birds were housed in an environmentally controlled room initially maintained at 32°C and provided with 15 h light daily, and water ad libitum. The temperature was gradually lowered 3°C/week, reaching 21°C by the end of Week 4 and maintained at this temperature for the balance of the study. The diet formulations and nutrient contents are presented in Table 1. Four control standard diets formulated to meet or exceed the minimum nutrient requirements of turkeys according to the NRC (1994) were fed ad libitum for the starter (1 to 3 wk), grower (4 to 6 wk), developer (7 to 9 wk), and finisher (10 to 12 wk) phases. The silicon dioxide diet was prepared by replacing 0.02% of corn in the control diet with silica+ (Ceresco Nutrition, Saint-Urbain-Premier, Quebec, Canada). The dietary inclusion levels of silicon dioxide were the same in all growth phases. At the beginning of each phase, representative feed samples were taken for nutrient analysis. Dietary contents of CP, DM, energy, calcium. and phosphorus were determined according to the Association of Official Analytical Chemists (1980). The experimental procedures were approved by the University of Guelph Animal Care Committee following the guidelines of the Canadian Council on Animal Care. A representative water sample was taken at the beginning of the experiment for pH, dissolved elements (Ca, Mg, and Na), chloride, and sulfate analysis.

Performance, Litter Quality, and Footpad Dermatitis

Turkey poults were individually weighed at the end of each growth phase. Feed consumption was measured weekly. General health and mortality were monitored daily. BW gain, feed intake, and feed conversion ratio (**FCR**) were calculated on a per-day basis with corrections for mortality.

A litter sample composed of 3 subsamples taken from different parts of each pen (drinking and eating area) was collected at the end of each production phase (8 samples/diet). Litter samples were analyzed for DM (percent), pH, ammonium-N (NH_4^+), total Kjeldahl nitrogen, and total carbon. DM was determined by drying samples for 24 to 48 h at 105°C until a constant weight mass was obtained. Total Kjeldahl nitrogen and NH_4^+ were determined using the Recommended Methods of Manure Analysis–Extension A3769 (Peters et al., 2003) and the Methods for Chemical Analysis of Waters and Wastes, U.S. Environmental Protection Agency 600/4-79-020 (USEPA, 1983). Total carbon analysis was based on the combustion and oxidation of carbon to form CO_2 by burning the sample at 1,350°C in a stream of purified O_2. The amount of evolved CO_2 was measured by infrared detection and used to calculate the percentages of carbon in the sample according to Nelson and Sommers (1996).

At the end of each phase, litter samples were visually scored on a scale of 1 to 5 (1 driest to 5 wettest) adapted from Hooge et al. (2012) with some modifications, as follows:

1. Dry, friable material throughout the pen.
2. Predominantly dry material and mostly acceptable but with some areas of wet shavings.
3. Poor quality litter material with a large proportion of wet areas.
4. Unacceptable litter quality, wet but with a few areas of dry material remaining.
5. All litter wet and soggy, no dry areas left.

FPD was evaluated at the end of each growth phase over the 12-wk study. Each turkey poult was evaluated by observation for FPD and scored on a scale of 1 to 5 as described by Michel et al. (2012).

1. No lesion or enlargement of scales and erythema, whatever the size.
2. Hypertrophic and hyperkeratotic scales covered by yellowish/brownish exudates, <50% footpad.
3. Hypertrophic and hyperkeratotic scales covered by yellowish/brownish exudates, ≥50% footpad.
4. Depressed lesion, ulceration, with/without dark thick adherent crust, <50% footpad.
5. Depressed lesion, ulceration, with/without dark thick adherent crust, ≥50% footpad.

Plasma Biochemistry

Blood samples were collected from the wing vein of 1 bird/pen (8 birds/diet) for plasma chemistry analysis at the end of each phase. Plasma concentrations of Ca, P, Na, K, Cl, albumin, albumin-to-globulin ratio, glucose, cholesterol, bile acid, and uric acid, and activities of amylase, lipase, aspartate aminotransferase, γ-glutamyltransferase, lactate dehydrogenase, glutamate dehydrogenase, and creatine kinase were determined using a Roche Cobas 6000 c50 Biochemistry Analyzer (Roche Diagnostics, Laval, Quebec, Canada).

Statistical Analysis

Origin 8.0 (OriginLab Corporation, Northampton, MA) was used for data processing. Data for all response variables was reported as means ± SEM and subjected to one-way ANOVA.

RESULTS

Bird Performance

The feeding of the silica-based supplement significantly increased average daily BW gain and improved FCR (gram feed consumed per gram weight gain) compared with controls during the grower (P = 0.001 and 0.001, respectively) and finisher phases (P = 0.047 and 0.034, respectively) (Table 2). Average daily

Table 2. Effects of a silica-based supplement on feed intake, weight gain, and feed conversion ratio.

Diet	Starter (1 to 3wk)	Grower (4 to 6 wk)	Developer (7 to 9 wk)	Finisher (10 to 12 wk)	Overall (1 to 12 wk)
			Feed intake (g/bird/d)		
Control	37[1] ± 1	139 ± 2	254 ± 5	418 ± 11	209 ± 3
Silica	39 ± 1	137 ± 4	246 ± 6	419 ± 9	212 ± 4
			weight gain (g/day)		
Control	26 ± 0	73 ± 2	127 ± 4	161 ± 4	96 ± 2
Silica	27 ± 1	83[2] ± 2	121 ± 2	174[2] ± 4	103[2] ± 2
			Feed conversion ratio (g feed/g gain)		
Control	1.43 ± 0.02	1.91 ± 0.05	2.02 ± 0.08	2.61 ± 0.07	2.19 ± 0.04
Silica	1.42 ± 0.02	1.64[2] ± 0.03	2.03 ± 0.04	2.41[2] ± 0.05	2.07[2] ± 0.03

[1]Values are presented as means ± SEM.

[2]Values are significantly different from control ($P < 0.05$).

Table 3. Visual scoring of the litter quality and footpad dermatitis.

Diet	Starter (1 to 3wk)	Grower (4 to 6 wk)	Developer (7 to 9 wk)	Finisher (10 to 12 wk)
	Litter Scoring (from 1 to 5)			
Control	1.25[1] ± 0.16	2.13 ± 0.13	2.13 ± 0.13	2.25 ± 0.16
Silica	1.13 ± 0.13	2.00 ± 0.00	2.13 ± 0.13	2.25 ± 0.16
	Footpad Dermatitis (from 1 to 5)			
Control	1.16 ± 0.05	1.12 ± 0.04	1.18 ± 0.06	1.18 ± 0.05
Silica	1.08 ± 0.03	1.10 ± 0.04	1.22 ± 0.05	1.13 ± 0.04

[1]Values are means ± SEM.

weight gain of supplemented birds (103 g/bird/d) was also significantly higher than controls (96 g/bird/d) ($P = 0.0269$) throughout the 12-wk study. A positive effect was also obtained when the overall FCR of supplemented birds (2.07) was compared with control birds (2.19) ($P = 0.0278$). No significant effect of diet was observed on feed intake, however, throughout the study ($P > 0.05$). Mortalities were similar in the 2 diet groups in the starter and grower phases (1 bird/diet due to round-heart disease). During developer and finisher phases, 3 of 63 supplemented birds and 4 of 63 control birds were euthanized due to crooked legs.

Plasma Biochemistry

No significant effect of diet was found on any plasma parameters throughout the 12-wk study ($P > 0.05$) (data not shown).

Litter Quality and Footpad Dermatitis

Litter quality was visually scored at the end of each growth phase (Table 3). The litter quality from birds fed both diets gradually reduced from the grower phase to the end of the study. The feeding of the silica-based supplement made litter drier and more friable during the starter and grower phases. This difference was, however, found not to be statistically significant ($P > 0.05$).

FPD was also assessed at the end of each growth phase. The feeding of silica-based supplement resulted in lower FPD scores (1.08 ± 0.03) compared to controls (1.16 ± 0.05) at the end of the starter phase. It should be noted that Score 3 was only recorded on 2 control birds during the developer phase (3%). Although differences in FPD scores between birds fed the supplemented and control diets were observed throughout the study, no statistically significant effect of diet was observed ($P > 0.05$).

Litter was analyzed for NH_4^+, DM, pH, total Kjeldahl nitrogen, and total carbon (for the calculation of carbon-to-nitrogen ratio) (Table 4). NH_4^+ concentrations were higher in litter samples collected from birds fed the supplemented diet compared to controls during the grower (1,457 versus 1,227 ppm, $P = 0.006$), developer (1,750 versus 1,525 ppm, $P = 0.024$) and finisher phases (2,376 versus 1,906 ppm, $P = 0.016$). The pH of litter was 4.8 on Day 0 of the experiment and increased to 7.36 or 7.01 in control and supplemented litter, respectively. The feeding of 0.02% silica-based supplement tended to reduce pH of treated litter (7.01 to 6.73) compared with controls (7.36 to 7.05). Difference in pH comparing control and treated litters were significant during the developer ($P = 0.0218$) and finisher phases ($P = 0.0148$). No significant differences in DM, total Kjeldahl nitrogen, and C:N ratio were seen comparing control and treated litter in any of the growth phases ($P > 0.05$).

Wet droppings appeared in birds fed both diets and were counted from Week 8 to the end of the study. There was no significant effect of diet on the frequency of wet droppings during the developer (9 and 8%, respectively) and finisher phases (23 and 24%, respectively).

Table 4. Effects of silica-based supplement on litter composition.

Diet	Week 0	Starter (1 to 3wk)	Grower (4 to 6 wk)	Developer (7 to 9 wk)	Finisher (10 to 12 wk)
		DM (%)			
Control	89.90	73.75[1] ± 2.29	79.09 ± 2.21	79.20 ± 0.48	79.64 ± 0.87
Silica		72.38 ± 1.75	79.54 ± 1.27	79.68 ± 1.15	79.43 ± 0.52
		pH			
Control	4.8	7.36 ± 0.13	7.11 ± 0.14	7.23 ± 0.06	7.05 ± 0.08
Silica		7.01 ± 0.12	6.96 ± 0.10	6.92[2] ± 0.10	6.73[2] ± 0.07
		Ammonium-N (mg/kg wet)			
Control	12	1080 ± 127	1227 ± 62	1525 ± 70	1906 ± 121
Silica		1029 ± 83	1457[2] ± 36	1750[2] ± 53	2376[2] ± 117
		Total Kjeldahl Nitrogen (% wet weight)			
Control	<LOD[3]	1.00 ± 0.09	2.10 ± 0.10	2.83 ± 0.12	2.91 ± 0.09
Silica		0.85 ± 0.06	2.14 ± 0.08	2.65 ± 0.15	2.91 ± 0.09
		Carbon-to-Nitrogen Ratio			
Control	NA[4]	50.63 ± 4.41	21.72 ± 0.45	15.66 ± 0.81	14.37 ± 0.34
Silica		57.61 ± 3.91	22.53 ± 0.91	16.91 ± 0.92	14.60 ± 0.41

[1]Values are presented as means ± SEM.

[2]Values are significantly different from control ($P < 0.05$).

[3]<LOD = Below the method limit of detection.

[4]NA = Not applicable.

DISCUSSION

Performance

The supplement fed was a dioxide of silicon mineral powder, micronized to 40 microns and supplemented in the feed at a level of 200 mg/kg. The positive effects of this compound on daily BW gain and FCR were significant during the grower and finisher phases of the study. This finding was in accord with a study in roosters fed 100 mg sodium meta-silicate for 25 d (Carlisle, 1972). The average daily weight gain for the control and treated roosters was respectively 2.57 and 3.85 g. This author also reported a beneficial effect of dietary silicon on leg and skeletal development. Short et al. (2011) also recently reported that dietary silicon supplements had the capacity to reduce lameness in broilers. Silica-based supplements might, therefore, have the potential to improve poultry welfare.

Plasma Chemistry

Plasma biochemistry parameters are important tools for health assessment in many species and are often used as biomarkers for pathologies of organs such as liver, kidney, biliary tract, and so on. No effect of diet, however, was found on any plasma parameters throughout this current study. This indicated that the silica-based supplement did not have any negative effects on turkey health during the 4 turkey growth phases.

Litter Quality and Footpad Dermatitis

To perform to their genetic potential, poultry need to grow in a good environment and this is highly dependent upon litter quality. Litter DM was not affected by dietary treatment in any of the growth phases of the current study but was always at a high level ranging from 73.75 to 79.64% for controls, and from 72.38 to 79.68% for the treated group. This compared with 89.9% on Day 0 of the study. Çabuk et al. (2004) also previously reported that the feeding of natural zeolite and *Yucca* extract to broilers for 42 d did not result in any significant effect of diet on litter DM.

Chemical and physiochemical characterizations of turkey litter often include pH, NH_4^+, total Kjeldahl nitrogen, and carbon-to-nitrogen ratio. Poor litter quality is the primary cause of ammonia volatilization which can result in many negative environmental and caretaker health conditions, and is one of the most serious factors negatively affecting bird production today (Reece et al., 1980). Sims and Wolf (1994) indicated that more than 50% of the total nitrogen in poultry may be lost by ammonia volatilization. Unlike mammals, birds excrete excess nitrogen as uric acid. Uric acid in poultry litter can be converted to urea by uricase. Urea can be subsequently hydrolyzed to ammonium ($NH4^+$) by urease, with the process consuming H^+ ions and raising pH (Ferguson et al., 1984). A fraction of $NH4^+$ is then converted into ammonia (NH_3). The potential for volatilization of NH_3 can, therefore, be indirectly estimated by NH_4^+ concentration in litter. This process is believed to start around pH 7 and is pH-dependent (Court et al., 1964; Reece et al., 1979). The pH of poultry litter is an important factor because it determines the NH_3 to NH_4^+ ratio. Increasing pH increases this ratio causing high NH_3 volatilization and vice versa. In the current study, the pH of control litter varied from 7.36 to 7.05 during the 12-wk study. This parameter in supplemented litter, however, declined from 7.01 at the end of the starter phase to 6.73 at the end of the finisher phase. It was likely, therefore, that the silica-based supplement decreased the conversion of NH_4^+ to NH_3 thereby helping to reduce nitrogen losses from litter. This is supported by the findings of Li et al. (2008) and Doydora et al. (2011) in studies in which aluminum sulfate, ferric sulfate, sodium bisulfate, and acidified bio-charcoals, respectively, were used as poultry feed supplements to decrease NH_3 volatilization from the poultry litter.

The feeding of the silica-based supplement in the current study also significantly increased litter NH_4^+ concentrations compared to controls during the grower, developer, and finisher phases. This greatly increased the amount of litter nitrogen available for soil fertilizer applications while decreasing NH_3 emissions in the turkey house. Similar results were reported by Moore et al. (1996) who fed alum sulfate, ferrous sulfate, and sodium bisulfate to determine the effects of these compounds on NH_3 volatilization and nitrogen content in broiler litter. In another study, Moore (1998) reported that the majority of NH_3 loss from broiler and laying hen litter probably occurred when the litter was still in the poultry houses because NH_3 was rapidly converted from uric acid following excretion. It should also be noted that the FCR increased linearly with increasing litter NH_4^+ from both supplemented and control birds (Figure 1). These linear equations suggest, however, that the higher the NH_4^+ concentration (x), the lower the feed conversion ratio obtained (y) from supplemented birds compared with controls. This means that trapping effect of the silica-based supplement results in reduced NH_3 volatilization in turkey litter, thereby improving feed efficiency. This finding is in agreement with previous studies which demonstrated negative effects on bird performance caused by high atmospheric NH_3 concentrations in poultry facilities (Reece et al., 1980; Kristensen and Wathes, 2000; Beker et al., 2004).

Total Kjeldahl nitrogen plays an important role in determining litter quality with respect to the NH_3 to NH_4^+ ratio. total Kjeldahl nitrogen in poultry litter can be defined as the sum of free-NH_3, NH_4^+, and organic nitrogen compounds which can be converted to ammonium sulfate. Nitrogen may also be present in nitrate or nitrite forms although these are normally present in trace amounts due to the highly anaerobic conditions existing in poultry litter. Although decreases in total

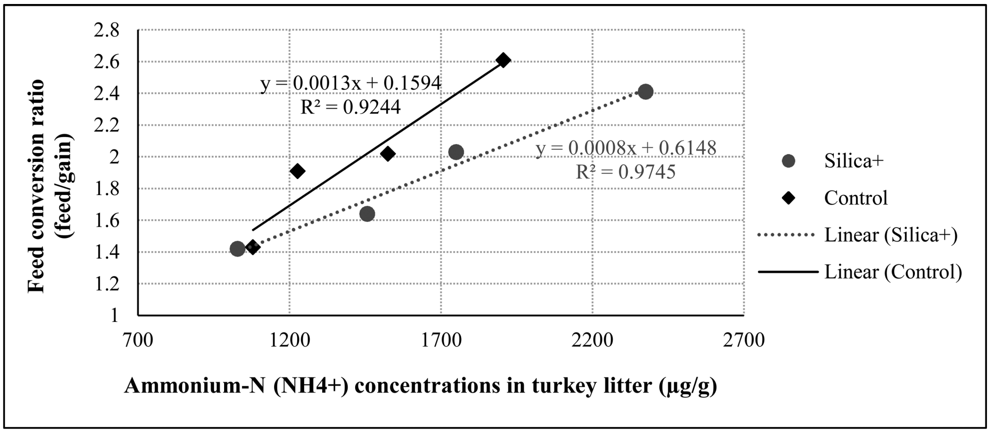

Figure 1. Correlation between feed conversion ratio and NH_4^+ concentration in turkey litter.

Kjeldahl nitrogen in treated litter were seen during the starter and developer phases in the current study, the differences were not statistically significant. This might have been due to increased organic nitrogen resulting from spilled feed and feathers in litter from control birds.

When poultry litter is used as animal compost, the carbon to nitrogen ratio (C:N) is a critical parameter in evaluating its value as compost. The C:N ratio in litter from supplemented birds was higher than in control litter (up to 14%) during the starter phase but no significant difference was observed through the balance of the 12-wk study (Table 4). In a previous study, Nahm (2003) stated that the organic fraction of poultry had a C:N ratio from 1 to 27 and poultry litter with a C:N ratio of 25 to 30 was ideal for composting. The C:N ratio in the current study, however, ranged from 14.37 to 50.63 for control litter and from 14.60 to 57.61 for treated litter, and decreased during each growth phase. A high initial C:N ratio may cause a slower beginning of the composting process thereby causing a longer than usual composting time (Tuomela et al., 2000). Tiquia and Tam (2000) suggested that a low initial C:N ratio results in high volatilization of NH_3. The loss of N through NH_3 volatilization during composting of poultry litter leads to a reduction of the fertilizer value and constitutes an important economic loss.

An increased risk of skin burns and a high incidence of contact dermatitis due to NH_3 may result in a serious threat to the health of the birds and footpads of turkeys were, therefore, checked for dermatitis at the end of each growth phase in the current study. It should be noted that the density of turkeys/pen (8 birds/ 4.25 m^2) in this current study was not as high as is common under commercial conditions. Although no significant variation of FPD score was found between treated and control birds throughout the 12-wk study, it should be noted that Score 3 was only recorded on 2 control birds during the developer phase (3%). This might have been due to higher NH_3 volatilization from control litter because the pH of control litter was higher compared to that of the treated litter. This would support the concept that the silica-based supplement has a high NH_4^+ capturing capacity thereby reducing NH_3 volatilization from treated litter.

It can be concluded that the silica-based supplement improved turkey performance including BW gain and the efficiency of feed conversion, reduced litter pH, and increased adsorbed NH_4^+ in turkey litter. It was also concluded that there is a significant correlation between NH_4^+ concentrations in litter and the efficiency of feed conversion. Under our test conditions, therefore, the feeding of a silica-based supplement offers potential economic benefits to turkey producers.

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