RESEARCH ARTICLE

Mitigating Ammonia Emissions and Enhancing Litter Quality in Commercial Broiler Chickens using Chemically Treated Litter during the Winter Season

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Abstract

The experiment was conducted to mitigate ammonia emissions and enhance litter quality in commercial broiler chickens using chemically treated litter during the winter season (December-January, 2020-2021) in Anand, Gujarat. A total of 144 straight-run, day-old commercial broiler chicks were randomly distributed into six treatment groups. Each treatment group consisted of four replicates, each with six chicks, leading to 24 chicks per treatment. The six treatments used were: T_1 - rice husk litter material (control group); T_2 – husk treated with alum @ 90 g/sq.ft.; T_3 - husk treated with boric acid (H_3BO_3) @ 24 g/sq.ft.; T_4 - husk treated with sodium bisulfate ($NaHSO_4$) @ 25 g/sq.ft.; T_5 - husk treated with a commercially available probiotic product @ 1 g/sq.ft.; T_6 - husk treated with a commercially available *Yucca schidigera* liquid solution @ 1.0 mL/sq.ft. The litter treatment (T_2 to T_6) was applied on the 1st, 15th, and 29th days of the experiment. The study evaluated litter pH, moisture (%), nitrogen, and ammonia emissions (ppm) at the 6th week of age across different treatments in experiments. Results showed significantly lower pH, moisture, and ammonia emissions in T_2, with the lowest ammonia levels observed in T_2 ($P<0.01$). Litter nitrogen was significantly higher in T_2 compared to other treatments ($p<0.05$). Based on the overall results of the experiment, it can be concluded that broiler birds reared on rice husk litter treated with alum (@ 90 g/sq.ft) exhibited reduced ammonia emissions and improved litter quality.

Key words: Ammonia emission, Broiler chicken, Commercial, Litter treatment, Litter quality

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Introduction

The Indian poultry industry has emerged as the most dynamic and fast-expanding segment of the agro-animal-based sector. After China, India ranks second in total egg production and fourth in chicken production globally. Litter quality is a key factor in broiler production, directly affecting bird health, growth, and environmental conditions. Accumulation of moisture and nitrogenous waste in the litter increases ammonia (NH_3) emissions, which can impair respiratory health, reduce performance, and contribute to environmental pollution (Miles *et al.,* 2004; Nagaraju *et al.,* 2007). Managing litter through chemical or biological supplements can help control these emissions and improve overall litter conditions. Rice husk is commonly used in India due to its availability and moderate absorbency (Mahmoud *et al.,* 2020). However, it often requires amendments to enhance performance. Acidifying agents like alum, boric acid and sodium bisulfate are known to lower litter pH and reduce ammonia volatilization (Liang *et al.,* 2005). Natural products such as *Yucca schidigera* and probiotics have also been used to improve microbial balance and bind ammonia (Patterson and Burkholder, 2003; Al-Mashhadani and Al-Saadi, 2009). Despite these options, limited studies in Indian conditions addressed the seasonal effects on litter management efficacy. Therefore, this study evaluated the impact of different litter treatments on litter pH, moisture, nitrogen, and ammonia emissions in broiler houses during winter season under Anand, Gujarat climate.

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Materials and Methods

Total 144 day-old commercial straight run broiler chicks from a single hatch acquired from commercial hatcheries, Anand, Gujarat (India) were used for the experiment. Chicks were weighed individually, wing banded, and distributed randomly into six treatment groups; each of four replicates with six chicks in each replicate. The treatments included: T_1 (Control, Rice husk as litter material), T_2 (rice husk mixed with Alum @ 90 g/sq.ft., T_3 (husk with Boric acid (H3BO3) @ 24 g/sq.ft., T_4: husk with Sodium bisulphate (NaHSO4) @ 25 g/sq.ft.), T_5 (husk with commercially available probiotic product @ 1 g/sq.ft), and T_6 (husk with commercially available *Yucca schidigera* liquid solution @ 1.0 mL/sq.ft. The birds were raised in a deep litter type of housing system with the fresh rice husk as litter (bedding) material. The chemical treatment of litter (T_2 to T_6) was done on the 1st, 15th and 29th days of the experimental period. The feed was prepared as per the nutrient specification for the broiler recommended by BIS (2007) standard. The experiment was conducted in the winter season (December 2020-January 2021) for six weeks duration. The average minimum and maximum temperatures during the winter season were 14.40 and 27.08 °C, with minimum and maximum relative humidity of 49.03 and 84.31 %, respectively. The floor space per bird given was @ 0.5 ft^2 for 1-2 weeks of age, 1.0 ft^2 for 3-4 weeks of age, and 1.5 ft^2 for 5-6 weeks of age. All six groups were raised under similar environmental and management conditions, except for the litter treatment/alteration. A digital hanging balance was used to calculate the weight of the litter, and the same amount of litter was used in each replicate. A thickness of 5 to 7 centimeters was maintained throughout the experiment. Proper spreading and timely stirring of the litter material was done to keep the thickness uniform. Vaccination was done at timely intervals to maintain healthy flocks. Biosecurity measures were strictly observed throughout the experimental period. At the entrance of the experimental shed, liquid phenyl solution was added daily as biosecurity measures.

Parameter Studied

Litter quality was evaluated through weekly sampling, with litter collected from five randomly selected points within each replicate pen - four from the corners and one from the center. The samples were thoroughly mixed to obtain a representative composite for each pen. Key parameters assessed included litter pH, moisture content, nitrogen percentage, and ammonia emission. For pH measurement, 10 grams of litter were mixed with 50 mL of distilled water, stirred for 15 min, and filtered; the pH of the filtrate was then measured using a digital pH meter (APHA, 2000). Moisture content was determined by drying the litter samples at 100 °C for 18 h (APHA, 2000). Nitrogen content was estimated weekly using the standard Kjeldahl method. Ammonia emission was assessed on the 42nd day using Hydrion ammonia measurement strips (Dewey *et al.* 2000). The strips were first activated by dipping in distilled water, then placed on the litter surface for one min, and the resulting color change was matched to a standardized scale to determine ammonia levels. The data generated was analyzed statistically using one way ANOVA and Duncan's *post hoc* test.

Results and Discussion

Litter pH

The pH of litter is a key indicator of its quality, as it directly influences ammonia release. Ideally, the pH should remain below 7 to minimize ammonia volatilization. In the present study, weekly pH is depicted in Table 1. At the 6th week, litter pH was significantly ($p<0.01$) lower in the T_2 group, followed by T_4, T_3, T_5, T_6, and T_1 (control), which recorded the highest pH. A similar trend was observed throughout the experimental period.

Overall, litter pH ranged from 4 to 10, and it increased over period in all groups. The alum-treated group (T_2) consistently showed lower pH values, compared to other groups, attributed to the sulfuric acid content in alum (pKa ~3.0). This acidic environment helped reduce ammonia emissions, moisture levels, and microbial activity, consistent with the findings of Smith *et al*. (2001) and Fries *et al.* (2005). During the early weeks, pH remained acidic in T_2 to T_5, while the untreated group (T_1) exhibited a alkaline pH. These results aligned with previous studies by Sims and Luka (2002) and Oliveira *et al.* (2004), who reported significant pH reductions using alum and similar amendments. However, contradictory findings were noted by Onbasilar *et al.* (2013), Avcilar *et al.* (2018), and Toppel *et al.* (2018), who observed no significant pH changes with treatments such as *Yucca schidigera*, sepiolite, or sodium bisulfate.

Litter Moisture Content

Litter condition significantly affects bird performance, directly influencing the profitability of farmers and integrators. Maintaining dry litter is essential for controlling ammonia levels, ensuring bird welfare, and preventing issues like hock and footpad burns, and breast blisters. Therefore, litter management is a vital component of poultry production. Weekly litter moisture percentages up to six weeks of age are presented in Table 2. At the 1st week, the mean litter moisture was significantly ($p<0.05$) lower in T_2, followed by T_4, T_3, T_5, T_6, and highest in T_1 (control). At the 6th week, T_2 again recorded significantly ($p<0.05$) lower moisture, followed by T_3, T_4, T_5, T_6, and T_1. However, differences among T_5, T_6, and T_1, and between T_2 and T_3 were statistically non-significant. Overall, litter moisture ranged from 11% to 34% during the experiment. By the 6th week, values exceeded the acceptable limit of 25% in most groups, leading to wet litter conditions associated with footpad sores and reduced growth (Garrido *et al.,* 2004). Factors such as diet, water intake, ventilation, drinker type, and ambient temperature influenced litter moisture levels (Oliveira *et al.,* 2004).

Alum treatment (T_2) significantly reduced litter moisture, supporting dry litter conditions and improving bird health by reducing hock burns, footpad lesions, and breast blisters, in agreement with Younis *et al.* (2016) and Lonkar *et al.* (2018). However, these findings contradicted with the observations of Sims and Luka (2002), Oliveira *et al.* (2003), and Onbasilar *et al.* (2013), who reported no significant effect of alum on litter moisture.

Litter Nitrogen (%)

Poultry litter is an excellent source of nitrogen for crop production. However, recent modifications in poultry litter management practices and the increased use of chemical amendments/treatments may influence nitrogen availability. In the present study, litter nitrogen percentage estimated on a weekly basis up to six weeks of age is presented in Table 3. During the experiment, from the 1st to 4th week and at the 6th week, the mean litter nitrogen percentage was highest in treatment T_2, followed by T_6, T_4, T_3, T_1, and T_5; however, the differences among treatments were not statistically significant. At the 5th week, the nitrogen content in the litter was significantly higher ($p<0.05$) in T_2, followed by T_6, T_3, T_4, T_1, and T_5.

In the current study, the litter nitrogen content ranged from 2.24% to 3.41%, which is in agreement with the findings of Lonkar *et al.* (2018), Sahoo *et al.* (2017), and Younis *et al.* (2016). The acidic nature of the litter, particularly in alum-treated groups, likely inhibited the conversion of ammonium ions to ammonia, thereby enhancing nitrogen retention. This is consistent with the findings of Burgess *et al.* (1998), who reported that alum treatment increased nitrogen concentrations in litter by reducing ammonia volatilization. Improved nitrogen retention enhances the fertilizer value of poultry litter, as nitrogen in the ammonical form is more readily absorbed by plants (Rashid *et al.,* 2020). These results aligned with those reported by Sims and Luka (2002), Younis *et al.* (2016), Sahoo *et al.* (2017), and Chakravati *et al.* (2019), all of whom observed significantly higher nitrogen concentrations in alum-treated litter compared to untreated controls. However, the present findings are in contrast with the observations of Karamanlis *et al.* (2008), Madrid *et al.* (2012), and Atapattu *et al.* (2017), who did not report significant differences in nitrogen content between treated and control groups.

Table 1: Effect of different litter treatment on mean (± SE) weekly litter pH of broilers at different ages of broilers

Treatments	1st week	2nd week	3rd week	4th week	5th week	6th week
T_1	$7.41^{a}\pm0.15$	$7.73^{a}\pm0.11$	$8.02^{a}\pm0.06$	$9.06^{a}\pm0.17$	$9.59^{a}\pm0.19$	$10.35^{a}\pm0.19$
T_2	$4.13^{d}\pm0.17$	$4.70^{e}\pm0.17$	$5.28^{d}\pm0.18$	$5.83^{e}\pm0.26$	$6.88^{e}\pm0.21$	$7.88^{e}\pm0.23$
T_3	$6.13^{c}\pm0.32$	$6.63^{cd}\pm0.33$	$7.13^{b}\pm0.36$	$7.80^{c}\pm0.35$	$8.40^{c}\pm0.22$	$9.15^{c}\pm0.10$
T_4	$5.85^{c}\pm0.13$	$6.20^{d}\pm0.11$	$6.55^{c}\pm0.12$	$7.15^{d}\pm0.13$	$7.50^{d}\pm0.15$	$8.48^{d}\pm0.09$
T_5	$6.78^{b}\pm0.14$	$7.18^{bc}\pm0.17$	$7.53^{ab}\pm0.15$	$7.98^{bc}\pm0.15$	$8.75^{bc}\pm0.22$	$9.65^{bc}\pm0.17$
T_6	$7.00^{ab}\pm0.17$	$7.48^{ab}\pm0.17$	$7.98^{a}\pm0.15$	$8.55^{ab}\pm0.13$	$9.08^{ab}\pm0.15$	$9.79^{b}\pm0.20$
SEm	0.19	0.19	0.19	0.21	0.19	0.17
CD at 5%	0.56	0.56	0.57	0.63	0.57	0.51
CV%	6.12	5.68	5.46	5.48	4.59	3.75

Means bearing with different superscripts within a column differ significantly ($p<0.01$)

Table 2: Effect of different litter treatment on mean (± SE) weekly litter moisture (%) of broilers at different ages

Treatments	1st week	2nd week	3rd week	4th week	5th week	6th week
T_1	$13.75^{a}\pm0.75$	$16.25^{a}\pm0.63$	$20.00^{a}\pm0.91$	24.00±1.41	28.00±1.47	$34.25^{a}\pm1.31$
T_2	$10.75^{b}\pm0.48$	$12.00^{c}\pm0.41$	$15.50^{c}\pm0.65$	20.50±0.65	24.50±0.65	$29.25^{d}\pm0.48$
T_3	$12.25^{ab}\pm0.48$	$13.25^{bc}\pm0.85$	$16.50^{bc}\pm0.65$	21.50±0.87	25.25±0.85	$30.25^{cd}\pm0.85$
T_4	$11.50^{b}\pm0.65$	$15.50^{ab}\pm0.65$	$18.75^{ab}\pm0.75$	22.75±0.75	26.25±0.85	$31.25^{bcd}\pm0.85$
T_5	$13.50^{a}\pm0.65$	$15.50^{ab}\pm0.65$	$19.75^{a}\pm0.48$	22.75±0.48	26.50±0.65	$32.25^{abc}\pm0.45$
T_6	$13.50^{a}\pm0.87$	$15.75^{a}\pm1.31$	$19.75^{a}\pm1.31$	23.50±1.32	27.25±1.49	$33.25^{ab}\pm1.49$
SEm	0.65	0.80	0.83	0.98	1.05	0.99
CD at 5%	1.96	2.38	2.48	NS	NS	2.94
CV %	10.51	10.90	9.09	8.67	8.03	6.23

Means bearing with different superscripts within a column differ significantly ($p<0.01$)

Table 3: Effect of different litter treatment on mean (± SE) weekly litter nitrogen (%) of broilers at different ages of broilers

Treatments	1st week	2nd week	3rd week	4th week	5th week	6th week
T_1	2.25±0.14	2.29±0.08	2.35±0.13	2.44±0.08	2.62^{c}±0.09	2.73±0.13
T_2	2.35±0.10	2.39±0.06	2.42±0.09	2.61±0.12	3.04^{a}±0.05	3.13±0.11
T_3	2.29±0.09	2.33±0.06	2.40±0.10	2.54±0.21	2.80^{abc}±0.11	2.84±0.12
T_4	2.28±0.04	2.32±0.08	2.40±0.05	2.59±0.07	2.75^{bc}±0.08	2.92±0.10
T_5	2.24±0.07	2.30±0.09	2.35±0.14	2.48±0.08	2.64^{bc}±0.09	2.74±0.15
T_6	2.31±0.11	2.35±0.06	2.39±0.13	2.59±0.11	2.88^{ab}±0.05	2.91±0.10
SEm	0.09	0.07	0.11	0.12	0.08	0.12
CD at 5%	NS	NS	NS	NS	NS	NS
CV %	8.54	6.27	9.42	9.44	5.81	8.36

Means bearing with different superscripts within a column differ significantly ($p<0.05$).

Litter Ammonia (ppm)

High levels of ammonia in poultry houses have detrimental effects on bird health and performance. In the present study, litter ammonia concentration was estimated at the end of the experiment (42nd day), and the results are presented in Table 4. The mean litter ammonia emission was significantly lower ($p<0.01$) in treatment T_2 compared to T_6, T_3, T_4, T_5 and T_1, however, there was no statistically significant difference among the latter groups.

Ammonia levels in the present study ranged from 6 to 20 ppm, which is consistent with the findings of Karamanlis *et al.* (2008), Madrid *et al.* (2012), Rashid *et al.* (2017), and Lonkar *et al.* (2018). Ammonia volatilization is influenced by several factors, including temperature, litter pH, moisture content, and air movement (Li *et al.,* 2013). The alum treated litter group (T_2) exhibited lower pH and moisture levels followed by boric acid (T_3) and sodium bisulphate (T_4) groups, with reduced ammonia emissions compared to the control and other probiotics groups. These results supported the findings of Oliveira *et al.* (2003), who reported reduced ammonia emissions in gypsum-treated litter, and Choi and Moore (2008), who found significantly decreased ammonia volatilization with aluminum chloride. Similar reductions in ammonia emissions due to litter treatments were reported by Karamanlis *et al.* (2008) and Purswell *et al.* (2013). However, the present findings contradict those of Onbasilar *et al.* (2013), who observed no significant effect on ammonia levels with Yucca schidigera supplementation.

Overall, the alum-treated group (T_2) exhibited significantly lower ammonia emissions compared to the untreated control, indicating the efficacy of alum as a litter treatment for ammonia mitigation.

Table 4: Mean ± SE of litter ammonia emission (ppm) of broilers in different treatments at the end of the experiment

Treatments	Ammonia (ppm)
T_1	20.00^{a}±0.00
T_2	6.25^{b}±1.25
T_3	17.50^{a}±2.50
T_4	17.50^{a}±2.50
T_5	20.00^{a}±0.00
T_6	15.00^{a}±2.89
SEm	1.93
CD at 5 %	5.74
CV %	24.09

Means bearing with different superscripts within a column differ significantly ($p<0.05$).

Conclusion

Based on the overall findings of the present study, it can be concluded that broiler birds reared on rice husk litter treated with alum at 90 g/sq.ft. experienced significant mitigating effect on ammonia emissions and enhanced litter quality, contributing to a more favourable rearing environment.

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