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Dr. Jigar V Patel
Department of Livestock Production Management, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Navsari, Gujarat, India

Manoj M Trivedi
Director of Extension Education, Kamdhenu University, Gandhinagar, Gujarat, India

Mahesh P Madhavatar
Pashu Vigyan Kendra, Waghai, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Navsari, Gujarat, India

Rakesh J Modi
Department of Livestock Farm Complex, College of Veterinary Science & Animal Husbandry, Anand, Gujarat, India

Rais M Rajpura
Department of Animal Science, BA College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Dr. Jigar V Patel
Department of Livestock Production Management, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Navsari, Gujarat, India

Effect of chemical litter treatments on ammonia reduction and litter quality improvement in broilers reared in the monsoon season

Jigar V Patel, Manoj M Trivedi, Mahesh P Madhavatar, Rakesh J Modi and Rais M Rajpura

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Abstract
The present experiment was conducted to assess the effect of chemical litter treatments on ammonia emission control and improvement of litter quality in broiler chickens reared during the monsoon season (August-September 2020) at Anand, Gujarat. A total of 144 straight-run, day-old commercial broiler chicks were randomly allocated to six treatment groups, each comprising four replicates with six chicks per replicate, total of 24 chicks per treatment. The six treatments included: T_1-control group with rice husk as litter material; T_2-rice husk treated with alum at 90 g/sq.ft.; T_3-rice husk treated with boric acid (H_3BO_3) at 24 g/sq.ft.; T_4-rice husk treated with sodium bisulfate ($NaHSO_4$) at 25 g/sq.ft.; T_5-rice husk treated with a commercially available probiotic product at 1 g/sq.ft; and T_6-rice husk treated with a liquid formulation of *Yucca schidigera* at 1 mL/sq.ft. The respective litter treatments (T_2 to T_6) were applied uniformly on the 1st, 15th, and 29th days of the experimental period.
The study assessed litter pH, moisture content (%), nitrogen levels, and ammonia emissions (ppm) at weekly intervals up to the sixth week of age under various experimental treatments. At six weeks, T_2 showed significantly lower pH and ammonia concentrations, with the minimum ammonia level recorded in T_2 ($p<0.01$). Although litter moisture (%) was lower in T_2 and nitrogen content was higher compared to other treatments, these differences were statistically non-significant. Overall, the results indicate that broiler birds reared on rice husk litter treated with alum (90 g/sq.ft) had reduced ammonia emissions and improved litter quality.

Keywords: Ammonia emission, broiler chicken, commercial, litter treatment, litter quality, monsoon season

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. The total egg production from commercial poultry is 114.92 billion eggs, and from backyard poultry is 2.7 billion eggs, contributing 80.49% and 19.50% of the total egg production, respectively (BAHS, 2024) [5]. Egg production has increased by 3.17% compared to the previous year, and the current per capita availability of eggs stands at 103 per annum (BAHS, 2024) [5].
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) [19, 20]. 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) [18]. 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) [15].

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) [24, 1]. Despite these options, limited studies in Indian conditions address 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 the monsoon season in Anand, Gujarat.

Materials and Methods

A total of 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 (H_3BO_3) @ 24 g/sq.ft., T_4: husk with Sodium bisulphate ($NaHSO_4$) @ 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 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 the BIS (2007) [6] standard. The experiment was conducted in the monsoon season (August-September 2020) for a six-week duration. The average minimum and maximum temperatures during the Monsoon were 30.4 and 31.54 °C, with minimum and maximum relative humidity of 68.21 and 81.19%, 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 were 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) [2]. Moisture content was determined by drying the litter samples at 100 °C for 18 h (APHA, 2000) [2]. 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) [10]. The strips were first activated by dipping in distilled water, then placed on the litter surface for one minute, 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

Litter pH serves as a critical indicator of its quality, as it has a direct effect on ammonia volatilization. Maintaining pH values below 7 is generally recommended to limit ammonia release. In the present experiment, the weekly pH data are presented in Table 1. By the sixth week, the lowest pH was recorded in the T_2 group ($p<0.01$), followed in ascending order by T_4, T_3, T_5, T_6, and the control group (T_1), which consistently showed the highest pH values. This ranking pattern was largely maintained throughout the trial.

Table 1: Effect of different litter treatments on mean (± SE) weekly litter pH of broilers at various ages during the monsoon season

Treatments	1st week	2nd week	3rd week	4th week	5th week	6th week
T_1	7.48^{a}±0.09	7.70^{a}±0.09	7.98^{a}±0.05	8.53^{a}±0.17	9.20^{a}±0.08	9.98^{a}±0.20
T_2	5.15^{d}±0.14	5.80^{d}±0.15	6.23^{c}±0.20	6.65^{d}±0.18	7.33^{d}±0.17	7.95^{d}±0.06
T_3	6.38^{c}±0.14	6.70^{c}±0.17	7.10^{b}±0.11	7.55^{c}±0.17	8.03^{c}±0.22	8.53^{c}±0.25
T_4	6.15^{c}±0.27	5.98^{d}±0.30	6.43^{c}±0.23	6.95^{d}±0.20	7.68^{cd}±0.13	8.18^{cd}±0.05
T_5	6.88^{b}±0.15	7.08^{bc}±0.19	7.40^{b}±0.21	7.90^{bc}±0.18	8.58^{b}±0.13	9.33^{b}±0.11
T_6	7.13^{ab}±0.09	7.43^{ab}±0.11	7.90^{a}±0.04	8.38^{ab}±0.10	9.05^{a}±0.06	9.80^{a}±0.11
SEm	0.16	0.18	0.16	0.17	0.14	0.15
CD at 5%	0.47	0.53	0.47	0.50	0.41	0.45
CV%	4.86	5.34	4.44	4.47	3.38	3.35

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

Across the study period, pH values ranged between 5 and 10. The alum-treated group (T_2) consistently maintained a more acidic environment, likely due to the sulfuric acid component of alum (pKa ≈ 3.0). This acidic condition effectively suppressed ammonia release, reduced litter moisture, and inhibited microbial proliferation, in agreement with earlier findings by Smith *et al.* (2001) [29] and Fries *et al.* (2005) [11]. In the initial weeks, treatments T_2 to T_5 showed acidic pH levels, whereas the control (T_1) remained alkaline. These trends are comparable to reports by Sims and Luka (2002) [28] and Oliveira *et al.* (2004) [21], who also documented marked pH reductions using alum and related amendments. On the other hand, studies by Onbasilar *et al.* (2013) [23], Avcilar *et al.* (2018) [4], and Toppel *et al.* (2018) [30] found no significant pH changes when employing additives such as *Yucca schidigera*, sepiolite, or sodium bisulfate.

Litter Moisture Content

Litter quality plays a crucial role in poultry performance, directly impacting both farm profitability and bird welfare.

Maintaining dry litter is essential for minimizing ammonia production and preventing welfare issues such as hock and footpad burns or breast blisters. Consequently, effective litter management is a key aspect of successful poultry production. Weekly litter moisture data up to six weeks of age are shown in Table 2. By week six, the lowest moisture level was observed in T_2, followed by T_3, T_4, T_5, T_6, and T_1, although differences were statistically non-significant. Throughout the trial, moisture content ranged from 11% to 34%. In most treatments, values exceeded the recommended 25% limit by the sixth week, creating wet litter conditions linked to footpad dermatitis and reduced growth (Garrido *et al.*, 2004) [12].

Table 2: Effect of different litter treatments on mean (± SE) weekly litter moisture (%) of broilers at various ages during the monsoon season

Treatments	1st week	2nd week	3rd week	4th week	5th week	6th week
T_1	15.50±0.65	19.50±0.65	23.25±0.75	28.50±0.87	33.00±1.08	43.50±1.26
T_2	11.50±0.87	15.00±0.41	18.50±0.65	23.50±0.87	27.50±1.04	35.50±1.32
T_3	13.75±0.63	16.25±0.85	20.00±1.08	25.25±1.18	30.00±1.58	38.25±1.65
T_4	13.25±1.38	16.75±0.95	21.25±0.48	26.25±0.63	31.00±1.08	39.25±1.75
T_5	15.00±0.58	18.75±0.75	22.00±0.91	27.50±1.41	32.00±1.38	39.75±2.17
T_6	15.25±1.31	18.50±1.85	23.00±2.08	28.00±1.87	32.50±1.32	41.00±1.78
SEm	0.95	1.01	1.12	1.21	1.35	1.68
CD at 5%	NS	NS	NS	NS	NS	NS
CV%	13.66	11.63	10.51	9.18	8.74	8.52

NS-Non-significant

Moisture variation was influenced by factors such as feed composition, water consumption, ventilation efficiency, drinker design, and environmental temperature (Oliveira *et al.*, 2004) [21]. The alum-treated group (T_2) maintained comparatively drier litter, contributing to improved leg and breast health by reducing hock burns, footpad lesions, and breast blisters. These observations are consistent with the findings of Younis *et al.* (2016) [31] and Lonkar *et al.* (2018) [16], but contrast with reports by Sims and Luka (2002) [28], and Onbasilar *et al.* (2013) [23], who found no significant effect of alum on litter moisture.

Litter Nitrogen (%)

Poultry litter serves as a valuable nitrogen source for crop production. However, recent shifts in litter management practices, including the adoption of chemical amendments, may alter nitrogen availability. Weekly nitrogen percentages measured up to six weeks of age are presented in Table 3.

Table 3: Effect of different litter treatments 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	2.15±0.13	2.19±0.11	2.26±0.11	2.36±0.13	2.56±0.10	2.94±0.11
T_2	2.25±0.08	2.34±0.08	2.42±0.07	2.62±0.09	2.77±0.10	3.41±0.05
T_3	2.19±0.09	2.24±0.05	2.41±0.05	2.56±0.10	2.74±0.16	3.24±0.10
T_4	2.22±0.05	2.31±0.11	2.41±0.07	2.40±0.10	2.65±0.10	3.14±0.15
T_5	2.19±0.17	2.25±0.09	2.29±0.10	2.37±0.16	2.60±0.11	3.02±0.11
T_6	2.17±0.06	2.27±0.13	2.36±0.05	2.49±0.14	2.65±0.09	3.12±0.11
SEm	0.10	0.10	0.08	0.12	0.11	0.10
CD at 5%	NS	NS	NS	NS	NS	NS
CV%	9.94	8.76	6.66	10.01	8.41	6.86

From weeks 1 to 4 and again at week 6, the highest mean nitrogen content was recorded in T_2, followed by T_6, T_4, T_3, T_1, and T_5. These differences were not statistically significant. Across all treatments, litter nitrogen values ranged from 2.15% to 3.41%, which is comparable to the ranges reported by Lonkar *et al.* (2018) [16], Sahoo *et al.* (2017) [27], and Younis *et al.* (2016) [31]. The acidic environment in alum-treated groups likely suppressed the conversion of ammonium ions to gaseous ammonia, thereby improving nitrogen retention. This mechanism aligns with the findings of Burgess *et al.* (1998) [7], who demonstrated that alum application reduced ammonia volatilization and increased nitrogen concentration in litter.

NS-Non-significant

Enhanced nitrogen retention not only improves litter quality but also boosts its fertilizer value, as ammoniacal nitrogen is more efficiently absorbed by plants. These results are consistent with previous observations by Sims and Luka (2002), Younis *et al.* (2016) [31], Sahoo *et al.* (2017) [27], and Chakravati *et al.* (2019) [8], all of whom reported elevated nitrogen levels in alum-treated litter compared to untreated controls. In contrast, studies by Karamanlis *et al.* (2008) [13], Madrid *et al.* (2012) [17], and Atapattu *et al.* (2017) [3] found no significant differences in nitrogen content between treated and control groups.

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_4, T_3, T_6, and T_5. A lower mean was also observed in T_1; however, there was no statistically significant difference among T_1, T_3, T_4, T_5, and T_6.

Ammonia levels in the present study ranged from 6 to 20 ppm, which is consistent with the findings of Karamanlis *et al.* (2008) [13], Madrid *et al.* (2012) [17], Rashid *et al.* (2017) [26], and Lonkar *et al.* (2018) [16]. Ammonia volatilization is influenced by several factors, including temperature, litter pH, moisture content, and air movement (Li *et al.*, 2013) [14]. The control group, which exhibited higher pH and moisture levels, showed elevated ammonia emissions. These results supported the findings of Oliveira *et al.* (2003) [22], who reported

reduced ammonia emissions in gypsum-treated litter, and Choi and Moore (2008) [9], 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) [13] and Purswell *et al.* (2013) [25]. However, the present findings contradict those of Onbasilar *et al.* (2013) [23], 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	7.50^{c}±1.44
T_3	15.00^{ab}±2.89
T_4	12.50^{bc}±2.50
T_5	20.00^{a}±0.00
T_6	17.50^{ab}±2.50
SEm	1.95
CD at 5%	5.87
CV%	25.35

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

Conclusion

Overall, broilers raised on rice husk litter with alum at 90 g/sq.ft. Had much lower ammonia emissions and better litter quality, creating a welfare-friendly, healthier, and more comfortable environment during the monsoon season.

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Conflict of interest

Not available

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Not available

Reference

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