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Effects of two litter amendments on air NH_3 levels in broiler closed-houses

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Objective: High NH_3 emissions from poultry houses are reported to have negative impacts on health, welfare and safety of birds and humans, and on the environment. Objective of the present study was to determine the effects of two litter amendments on the NH_3 levels in broiler closed houses under hot-humid conditions.
Methods: Giving a completely randomize design, nine closed houses, each housed 32,500 birds on paddy husk litter, were randomly allocated into two treatment (Mizuho; a bacterial culture mix and Rydall OE; an enzymatic biocatalyst) and control groups. NH_3 levels were determined thrice a day (0600, 1200, and 1800 h), at three heights from the litter surface (30, 90, and 150 cm), at 20 predetermined locations of a house, from day 1 to 41.
Results: Rydall significantly reduced the NH_3 level compared to control and Mizuho. NH_3 levels at 30 cm were significantly higher than that of 90 and 150 cm. The NH_3 levels at 30 cm height were higher than 25 ppm level from day 9, 11, and 13 in Mizuho, control, and Rydall groups, respectively to day 41. NH_3 levels at 150 cm height were higher than maximum threshold limit of 50 ppm for human exposure from day 12, 14, and 15 in Mizuho, control, and Rydall groups, respectively to day 33. Being significantly different among each other, the NH_3 level was highest and lowest at 0600 and 1800 h. Litter amendments had no significant effects on growth performance. Rydall significantly increased the litter N content on day 24.
Conclusion: It was concluded that the NH_3 levels of closed house broiler production facilities under tropical condition are so high that both birds and workers are exposed to above recommended levels during many days of the growing period. Compared to microbial culture, the enzymatic biocatalyst was found to be more effective in reducing NH_3 level.

Keywords: Amendment; Ammonia; Broiler; Litter

INTRODUCTION

Emission of NH_3 from livestock operations has become a serious public concern due to its negative impacts on environment, animal industry and the health and safety of people working in livestock facilities [1-3]. Due to an array of negative impacts on welfare [4-6] and production performance [7-9], it has been recommended that the NH_3 level of a poultry house should not exceed 25 ppm [2,10]. Meanwhile, to minimize the health risk of workers, Occupational Safety and Health Administration has recommended 50 ppm of maximum exposure limit.

In poultry facilities, NH_3 is produced due to the enzymatic or biological degradation of faecal uric acid, in a five step process [11]. NH_3 so formed moves up away from the litter and carried away due to natural or artificial ventilation. Factors that influence the formation of ammonia, such as litter pH, moisture level, environmental temperature and relative humidity, and those that influence the removal of NH_3 such as ventilation rate determine the level of NH_3 in a poultry house [12-14]. NH_3 levels of poultry facilities reported in literature vary widely from 0 to 110 ppm [15]. Studies that report the NH_3 levels of poultry houses under hot-humid conditions are scanty.

Both for poultry and human, the main entry point of NH_3 is the nostrils. Presence of birds obstructs the vertical movement of NH_3 formed in the litter, thus creating high NH_3 zone around the birds nostrils height. Therefore, NH_3 levels of poultry facilities should best be determined at the nostrils heights of the poultry and human. However, NH_3 levels of poultry houses reported in literature do not specify the heights at which the measurements were taken.

Dietary manipulations [16,17] and the use of litter amendments such as alum and sodium bisulfate have been used to minimize the NH_3 emission from poultry litter [2,10,13,19,20]. Karunakaran [18] reported that the application of a selected bacterial culture (MicroTreat P) restricted the action of gram - bacteria which are responsible for the conversion of uric acid into ammonia. In contrast, De Laune et al [19] found no beneficial effects of such an approach. In solid waste management and sludge treatments, enzymatic biocatalysts are widely used to control the odour problems due to gasses including ammonia. Objective of the present study was to determine the effects of two litter amendments; a bacterial culture and an enzymatic biocatalyst on the NH_3 levels of broiler closed houses under hot humid conditions, measured at different heights and times of the day.

MATERIALS AND METHODS

The protocol of the experiment was approved by the Research Ethics Committee of the Faculty of Agriculture, University of Ruhuna, Sri Lanka. The experiment was conducted at Delmo Chicken and Agro (pvt) Ltd. Kappitiwalana, Alawwa (7.32:80.02), Sri Lanka. The mean ambient temperatures and relative humidity during the period of experiment were 29.6°C and 77%, respectively.

Birds and management practices

Giving a completely randomize design experiment, nine closed houses (125 m [L]×12.5 m [W]) were randomly allocated into two treatment groups (Mizuho; SYnegy Bioproducts, Nawala, Sri Lanka and Rydall OE; Apex Engineering Products Corporation, Aurora, IL,USA) and control. On the cross wall of one end of the each closed house, there were seven exhaust fans (1 m diameter), each having 535 m^3/min of air exchange rate. On the opposite end of the each side wall, there were two cooling pads.

The initial thickness of the Paddy husk litter was 6 cm. On day 1, 32,500 male broiler chicks (Cobb 500) were introduced to each house. The initial per bird floor area of 190 cm^2 increased gradually on day 3, 5, 7, and 10 so that each bird got at least 480 cm^2 of floor space from day 10 onward. Each house had 1,650 auto drinker nipples and 160 feeder buckets of an auto feeding system. Brooding was done for 10 days. The temperature of the house on day 1 (34°C) was reduced by 0.5°C daily and from day 18 onward the temperature was maintained at 26°C using programmed exhaust fan operating system in which each 0.5°C increase above the target temperature, one fan turned on. Continuous lighting was provided.

Birds were fed commercial broiler booster feed upto day 21 and broiler finisher feed (New Hope Feeds, Sri Lanka), *ad libitum* (from day 22 onward). Catching started on day 28, but spacing was not reduced with the reduction of the number of birds.

Treatment application

According to the respective manufacturers, Mizuho is a mixture of bacterial culture which suppresses the urease producing bacteria and Rydall OE is a unique enzymatic biocatalyst containing a complex mixture of natural nutrients, vitamins, and trace elements.

According to the manufacturer's recommendation, fifteen mL of Mizuho solution (11% v/v) was sprayed per m^2 litter area on day 8, 16, and 25 and also given with drinking water (2 L with 1,000 L of drinking water) on day 16, 25, and 35. Ninety mL of Rydall (1% v/v solution) was sprayed per 1 m^2 of litter surface on day 8, 16, and 25.

Data collection

NH_3 levels were measured at 30, 90, and 150 cm heights from the litter surface, at 0600, 1200, and 1800 h of the day. At each height plane, measurements were taken at 20 imaginary points in zig-zag arrangement. A portable gas detector (Crowcon Gas-Pro; Crowcon Detection Instruments, Oxfordshire, UK) was used to determine the NH_3 levels. On an imaginary zig-zag line drawn across the litter, twenty litter sample collecting points were randomly selected. Care was taken to maintain a constant distance between sampling points and feeder/drinker lines. Twenty litter samples taken from each closed house on day 12, 24, and 40, were bulked and five subsamples were analyzed for total N content using Kjeldahl procedure. Daily feed/water intakes were determined by dividing the total house feed/water intake by the total number of birds. Live weights of 320 (on day 7, 14) and 90 (on day 21, 28, 35, 40) randomly selected birds from each closed house were used to determine the growth performance parameters.

Statistical analysis

Data were statistically analyzed using SPSS. NH_3 data were analyzed as a completely randomize design in 3×3 factorial arrangement. Treatment factors were three litter amendments (control, Rydall, and Mizuho), three heights (30, 90, and 150 cm) and three time points (0600, 1200, and 1800 h). Tukey test was used for the mean separation when a main effect was significant at $p<0.05$. Growth performance and litter N contents were analyzed as a completely randomize design with three treatments.

RESULTS AND DISCUSSION

NH_3 levels over the production period

NH_3 was first detected as early as day 8 in control group whereas

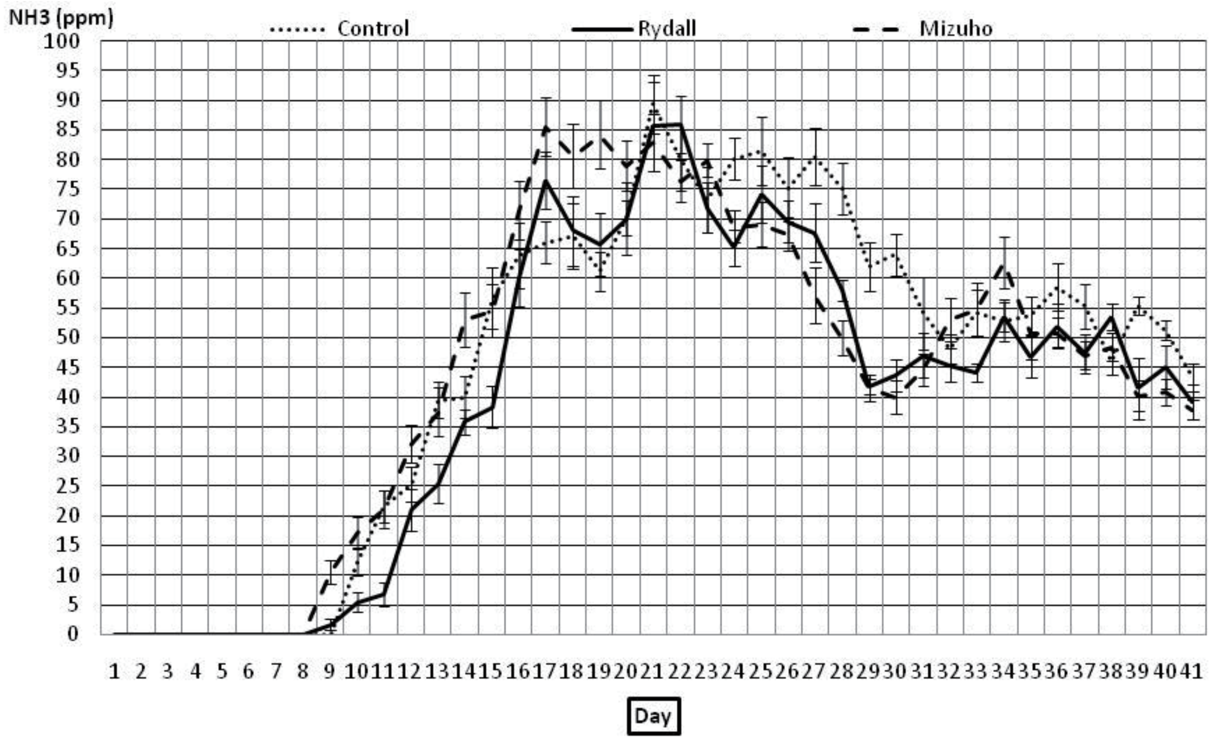

Figure 1. Air NH_3 levels of boiler closed houses treated with three litter amendments, over the production period.

NH_3 was not detected until day 10 in litter amended groups (Figure 1). The NH_3 level in Mizuho amended closed-houses reached maximum level of 85.6 ppm as early as day 17 whereas control and Rydall recorded their maximum levels (89.4 ppm and 85.9 ppm) on day 21 and 22, respectively. The significant quadratic relationships of air NH_3 levels over the production period, in control ($p = 0.001$, $R^2 = 0.83$), Rydall ($p = 0.001$, $R^2 = 0.73$) and Mizuho amended groups ($p = 0.001$, $R^2 = 0.74$) showed that irrespective of the liter amendment, the NH_3 level reached its maximum level when birds were around 25 days old and then declined. Our results are in agreement with those of Redwine (15) who found an increase in ammonia levels up to day 35 and subsequent reduction in fan ventilated broiler closed houses in which the targeted temperature being maintained (20°C) was lower than that of the present study (26°C). Therefore, as shown by other studies [12-14,20,21], high temperature conditions under which this study was conducted may be the reasons for higher ammonia level and its earlier peak observed in the present study.

Effects of Rydall and Mizuho on air NH_3 levels

None of the two way interactions between amendment, time of the day and the height of the measurements and the three way interaction among them was significantly different. Rydall amendment significantly reduced the NH_3 level compared to control but there were no significant difference between the NH_3 levels of control and Mizuho groups (Table 1). Rydall resulted in 12.5% and 14.7% reductions in NH_3 level compared to control and Mizuho, respectively. The per bird cost of Rydall application (0.48Rs) was also calculated to be two times lower than that of Mizuho (0.97Rs). Effectiveness of Rydall was higher than that of $Ca(OH)_2$ (6% reduction) and comparable with Ferrous sulfate at 100 g/kg litter [22]. Meanwhile effectiveness of Rydall was found to be lower than some commonly used litter amendments such as alum at 100 g/kg litter (36% reduction), sodium bisulfate (21%

Table 1. The air NH3 levels of broiler closed house as affected by the height and the time of measurement and the litter amendments

Items	Closed house air NH_3 level±SE[1)]
Height	
30	43.7 ± 1.3^a
90	38.6 ± 1.3^b
150	35.0 ± 1.3^b
p value	0.001
Time	
0600	46.3 ± 1.0^a
1200	39.4 ± 1.3^b
1800	23.6 ± 1.5^c
p value	0.001
Litter amendment	
Control	40.7 ± 1.2^a
Rydall	35.3 ± 1.3^b
Mizuho	41.4 ± 1.3^a
p value	0.01

SE, standard error.
[1)] Means within a column bearing same superscripts are not statistically different at 5% probability level.

reduction) [22] and PLT at 20 kg/100 m_2 litter (upto 50% reduction) [23]. Our results with Mizuho agree with others (19) who also used microbial amendments

Air NH_3 levels compared to the threshold value for poultry

Taking animal performance and health aspects into consideration, it has been recommended [24] that, NH_3 level of a poultry house should not exceed 25 ppm. However, broilers in control, Rydall and Mizuho groups were exposed to more than above limit from day 11, 12, and 11 onward, respectively, up to the day 41. Though air NH_3 levels showed a quadratic relationship over the growing cycle, even at the end of the production period, the NH_3 level was around 40 ppm.

The number of days that broilers were exposed to levels above the maximum recommended NH_3 level of 25 ppm was more or less similar across all the treatments; 30, 29, and 30 days in control, Rydall and Mizuho groups, respectively. In contrast, Moore et al [22] reported that when no amendment was used, air NH_3 levels of broiler houses were above the maximum recommended level throughout the 42 day growing period and alum reduced the birds' exposure to above the critical limit for 12 days (29 to 40 d). Results of the present experiment clearly suggest that under hot humid conditions NH_3 level of broiler closed houses were higher than the maximum recommended level for broilers for around two thirds of the growing period.

Taking the animal welfare aspects into consideration, some studies [6,25], recommend that broilers should not be exposed to more than 10 ppm of atmospheric ammonia. However, birds in Mizuho, control, and Rydoll group were exposed to more than the said limit from as early as day 9, 10, and 11, respectively.

Occupational Safety and Health Administration (OSHA) sets 50 ppm as the permissible exposure limit for human. The NH_3 level exceeded the threshold of 50 ppm on day 14, 15, and 16 in Mizuho, control, and Rydall groups, respectively. Moreover, the unsafe time windows for human were shorter for Rydall (13 days; from 15 to 27 day) than for control (16 days) and Mizuho (17 days) groups, in two time windows (14 to 28 d and 32 to 35 d). Highlighting the grave concerns on human health hazards, the NH_3 level was higher than 50 ppm for about 25 days. However, analysis on the level of NH_3 at three heights indicated that the possible adverse impacts of high NH_3 level are more serious on birds than on human.

Air NH_3 levels at three heights from the litter surface

The NH_3 levels were significantly different at 30, 90, and 150 cm heights, giving the highest value at 30 cm level (Table 1). Since the main entry site of NH_3 is the nostrils, NH_3 level at 30 cm height was compared with the maximum exposure level for poultry. The NH_3 levels at 30 cm height exceeded 25 ppm level on day 9, 11, and 13 in Mizuho, control, and Rydall groups, respectively (Figure 2). Irrespective of the amendment used, throughout the production cycle NH_3 levels at 30 cm height were higher than 25 ppm level. Probably the presence of birds might have reduced the air circulation below 30 cm height thereby preventing NH_3

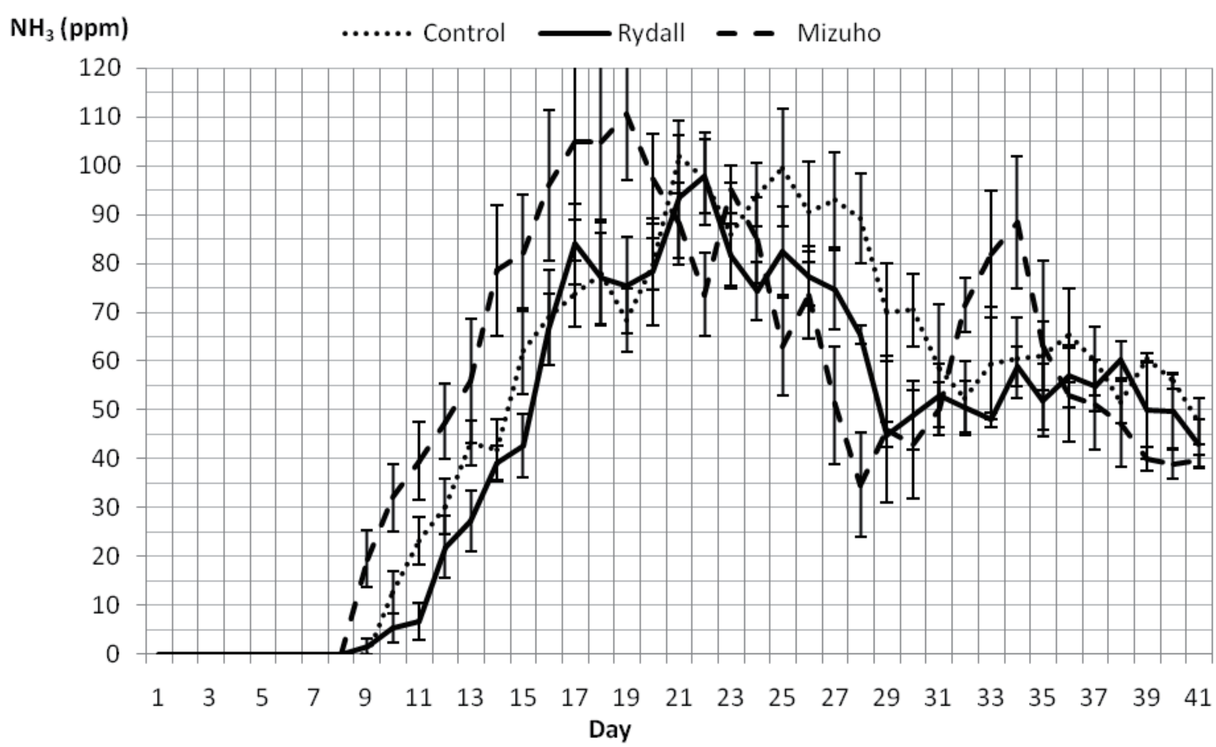

Figure 2. NH_3 level at 30 cm height in broiler closed houses treated with either no (control), Rydall, or Mizuho as litter amendments, over the production period.

being removed by exhaust fans. NH_3 level recorded at 90 and 150 cm levels were 11.6% and 18.6% lower than that at 30 cm level. In contrast, Lahav et al [26] have reported a sharp increase in NH_3 level upto 20 cm height from the manure surface and no change thereafter, in a layer housing facility. Results of this study highlight the importance of taking NH_3 level measurements at the birds' height in order to predict the possible impacts. Furthermore, strategies are needed to maintain a safer NH_3 level at the birds' height. Since the presence of birds and other obstructions such as feeders and drinkers may restrict the horizontal air movement close to the floor, it may be worthy of studying the effectiveness of the means of better vertical air circulation (for example, a fan arrangement on the roof) alone or in combination with side wall-fixed fan arrangement. Alternatively, Lahav et al [26] suggested to separate NH_3 withdrawal from the ventilation system and, devising a separate low flow-rate air capturing system to collect NH_3 rich air in the litter.

Mean height of an adult Sri Lankan was 157 cm [27]. Therefore, NH_3 level at 150 cm was compared with the maximum exposure levels for human. NH_3 levels at 150 cm height exceeded the maximum threshold limit of 50 ppm for human exposure on day 12, 14, and 15 in Mizuho, control and Rydall groups, respectively (Figure 3). In general, after about day 33 NH_3 levels were lower than the recommended level, in all three groups and thus the unsafe periods were 21, 19, and 18 for Mizuho, control, and Rydall group, respectively.

NH_3 levels at different times of the day

Due to high ambient temperature conditions, higher NH_3 levels were expected during mid day. Contrary, being significantly different among each other, the NH_3 level was highest and lowest at 0600 and 1800 h, respectively and intermediate at midday (Table 1). Meanwhile Zhu et al [28] found no significant variation in NH_3 emission in animal facilities within a day. The NH_3 level at 1200 and 1800 h were 15% and 50% lower than that at early morning. Therefore, results of this study suggest that workers could be exposed to high NH_3 levels when they enter the poultry houses in morning. Since cooling fans had been programmed to operate to control the in house temperature build up, more fans were in operation during daytime, than night in which temperature was low. Consequently, NH_3 build up might have happened during night, giving a higher NH_3 level in the morning. Due to poor ventilation higher NH_3 levels was reported in winter season than in summer during which more fans are operated to reduce the temperature [29]. Though the programming of fans to operate according to the NH_3 level could reduce the NH_3 level, a number of studies [30,31] showed that improvements in ventilation incurred a significant additional cost.

Litter amendments on growth performance

Several studies [7-9], have reported better growth performance when air NH_3 levels were low in broilers houses. Contrary to those studies, in the present experiment, none of the growth performance parameters was significantly different among the treatments (Table 1), probably due to two reasons. Firstly, as discussed earlier, the duration of the exposure to higher NH_3 levels

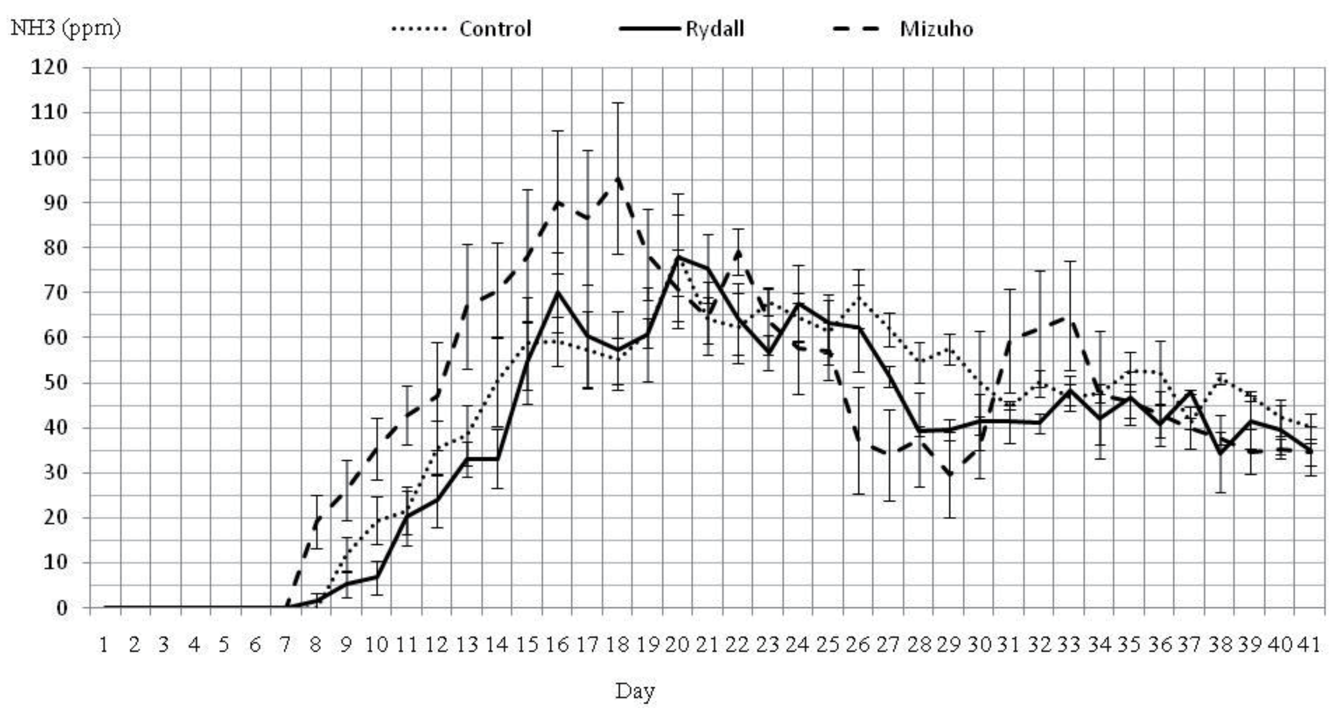

Figure 3. NH_3 level at 150 cm height in broiler closed houses treated with either no (control), Rydall or Mizuho as litter amendments, over the production period.

Table 2. Effects of two litter amendments on growth performance of broiler chicken form day 1-41

Growth performance parameter	Liter amendment			SEM	Probability
	Control	Rydall	Mizuho		
Live weight on day (g)					
1	50.6	51.3	53	1.8	NS
7	154.6	161.6	156.6	9.4	NS
14	456	474.3	466.3	14.4	NS
21	956.3	919.6	925.6	48.7	NS
28	1,407.3	1,389.3	1,410.6	42.4	NS
35	1,850.6	1,842.6	1,780.6	61.5	NS
41	2,157.3	2,255.3	2,209.6	54.6	NS
Total weight gain (g)	2,106.6	2,204	2,156.6	53.1	NS
Total feed intake (g)	3,568.3	3,499.9	3,535.2	124.8	NS
Feed conversion ratio	1.69	1.58	1.64	0.04	NS
Total water intake (L)	6.20	6.12	6.29	0.37	NS
Mortality %	2.0	3.6	3.3	0.9	NS
Amendment cost (Rs)/bird	0	0.48	0.97	-	-

SEM, standard error of the mean.
NS, $p > 0.05$.

were more or less similar across all three groups. Secondly, the magnitude of reduction of NH_3 level in Rydall group was just 12.5%, compared to control and, thus might not have been strong enough to evoke a positive response. Given the higher NH_3 levels experienced in the present experiment, more effective litter amendments are suggested under hot humid conditions.

Litter N contents as affected by the amendments

As suggested by others [19,22], higher litter N content was expected in Rydall treated litter. Behaviour of the air NH_3 level showed that the effects of Rydall over Mizuho and control was stronger up to day 22 and became weaker thereafter. Probably due to the above reason, Rydall amendment resulted in a higher litter N content on day 24, but not on day 12 or at the end of the growing period; on day 42. The final N contents of the litters were more or less similar to that reported by Moore et al [22] for 42 days old paddy husk based broiler litter (Table 2, 3).

CONCLUSION

It was concluded that birds and people working in tropical broiler closed houses are exposed to NH_3 levels above the maximum recommended levels during a substantial number of days of the growing cycle. NH_3 level was found to be higher around the birds' height. Compared to microbial culture Mizuho, the enzymatic biocatalyst Rydall was found to be more effective in reducing broiler closed house NH_3 levels at lower amendment cost. In order to maintain the NH_3 levels below the recommended threshold limits for broilers and workers, more effective NH_3 formation reduction strategies need to be combined with a ventilation system which operates according to the in house NH_3 level.

Table 3. Effects of litter amendments on litter N contents (mean±SE)

Day	Control	Rydall	Mizuho	Probability
12	2.7 ± 0.25	2.4 ± 0.33	3.0 ± 0.11	NS
24	2.2 ± 0.21^{b}	3.4 ± 0.3^{a}	2.6 ± 0.11^{ab}	*
40	3.1 ± 0.08	3.0 ± 0.08	3.1 ± 0.14	NS

SE, standard error.
NS, $p > 0.05$; *, $p < 0.05$.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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