Broilers’ performance in deep litter house at different floor geometries and stocking densities in humid tropics

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Abstract

The research investigated how broilers’ performances will be affected by the conditions of their droppings in deep litter housing system in humid tropics of south west Nigeria. Two factors were considered, floor geometry and stocking density. Four different levels of floor geometry: F_1 = 2800 cm^2, F_2 = 4200 cm^2, F_3 = 5600 cm^2 and F_4 = 7,000 cm^2 and four different levels of stocking density: S_1 = 4, S_2 = 6, S_3 = 8 and S_4 = 10 birds per pen were used. There were three replicates for each treatment to make a 2× 4 × 3 randomized complete block design. The birds were fed *ad libitum* with all other conditions been equal for eight weeks. Conditions of litter were evaluated via pH, weights, temperatures and relative humidity in and out of the building, temperatures of the litter, temperature of the air just above the litter and the temperatures outside the house, all these were measured for each of the pen at two days intervals. Data were collected and analysed for the period of eight weeks (starting from their two weeks old), using their mean values and the correlation coefficients. Results show the pH range of 8.5 to 8.9, liveweight of the birds increased in the range of 216 to 340 g per bird per week, moisture contents of the litter were between 20.4 and 78.0% with mean temperature of the litter at 30.5 ^oC. The emission of ammonia was high, between 51.67 and 71.30 ppm. There was mortality rate of 10% in the S_3 and S_4 pens, autopsy revealed their cause of death to respiratory diseases which was because of high ammonia emission resulted from high amount of litter. The high temperature of the litter produced increased the level of ammonia and thus produced discomfort in the birds. Birds were uncomfortable in their pens as more litter were produced, thereby their performances were reduced which was evident in their low live weights and high mortality rate.

Keywords: *ad-libitum*, liveweights, mortality rate, floor geometries

Introduction

Poultry owners worldwide look forward to maximize weight of chicken produced per square metre of space (floor geometry) while preventing production losses due to overcrowding (stocking density) to achieve a satisfactory economic return (Abudabos et al., 2013). Overcrowding increases the volume of litter in a pen and therefore the overall conditions of the litter. Such litter when used especially on the soil may easily be leached into the soil or may be useful to crops depending on the soil types, nature of the materials of the litter and time of use (Adeyeye et al., 2017). Birds’ overcrowding and their eventual faeces produced also affect the welfare of birds, cleanness of equipment, durability of the tools in use and birds’ nutrients accumulation for growth (Thomas et al., 2004; Tabler et al., 2009; Payne, 2012; Dunlop and Stuetz, 2016). Other important effects on the litter condition are moisture content of the litter, its greasy capped condition and its nitrogen content (Thaxton et al., 2006; Wheeler et al., 2008; Tabler et al., 2012; 2020). Furthermore, other issues which affect the state of poultry litter are design of drinkers and their handling by the poultry house workers, air change rate, nature of house and its surrounding, make-up of the litter and its depth, stocking density, floor areas, nutrition and flock health (Anupoju, 2021). Litter should be in the range of 30-70% moisture or less than 30% (Collett, 2012). When the litter is too dry, it will be dusty and will affect birds' breathing (Musa et al., 2012; Shao et al., 2015). To prevent this in birds, litter should partially be wet (low moisture content) so that it will not easily crumble or pulverized (Dunlop et al., 2015; Dunlop, 2017). Although, it has been found out that keeping litter dry will enable birds to "play with" it as they scratch, walk, dust bathe and forage (Bernhart et al., 2009; Bernhart and Fasina 2009; Dunlop and Stuetz, 2016), partially wet litter will not provide avenue to be inhaled by the birds. Dry litter with low moisture contents could be better for the birds especially if it is lower than between 27 and 30% as found by Collett (2012). This is also in accordance with AgraPoint's Agric Info Centre (2018) which recommended low water activity in litter for high performance, (Van der Hoeven-Hangoor et al., 2014).

However, allowing birds on wet litter for long increases the chance of fecal adhesion to their feet, which has been presumed to induce foot pad dermatitis (Abd El-Wahab et al., 2012).

Litter should not exceed 70% moisture in the poultry pen because high litter moisture provides an ideal environment for micro-organisms to grow and multiply since water easily spread across, making it similar to eutrophication on farmlands (Payne et al., 2007; Sharpley et al., 2009). Moreover, in deep litter housing for birds, litters may be named according to where they were found, for instance, mixture of faeces on manure belt is referred to as belt manure and the faeces responsible for fouling of equipment is sometimes referred to as equipment foul-litter (Lamidi, 2014; Abudabos et al., 2013). Their locations may also have effect on their conditions and aftermath especially when used as organic fertilisers (Lamidi et al., 2018).

The temperature of mature birds depends not only on the weather of the local area of production but also on breed, age and their live weights. This is because animals stay over certain range of thermo-comfort value of temperature because they have been biologically equipped to cope with fluctuating temperatures from season to season (Chmelničná, & Solčianska, 2007; Škrbić et al., 2009; Lamidi and Ola, 2021).

There are some factors that are responsible for different conditions of the litter in a poultry house. These factors among others are changes in the temperature and moisture content of the litter and ammonia content of the litter. Ammonia in litters is always dissipated into ambient air causing discomfort for workers and animals in the poultry house. This dissipation occurs in two equilibrium equations:

$$NH_4^+ (l) \longleftrightarrow NH_3 (l) + H^+ \qquad \text{Equation 1}$$

$$NH_4^+ + H_2O \longleftrightarrow NH_3 + H_3O^+ \qquad \text{Equation 2}$$

In these, pH expressed from dissociation constant K_a is found.

Ammonia (NH_3) generation is a major problem with re-used or built-up litter, particularly if the litter gets wet and microbes that are harmful to birds build up in the litter (Thaxton et al., 2006; Chinivasagam et al., 2012; Dunlop and Stuetz, 2016). High ammonia level in broiler house is a concern of the farmer because it often results in poor bird performance and bad health status, as well as loss in profits (Vizzier et al., 2003). Ammonia levels should be kept to 20 ppm or less to prevent production problems (Abd El-Wahab et al., 2012).

When birds consume protein, they are likely to produce uric acid, ultimately converted to NH_3 under favourable conditions (Naseem and King, 2018). It is noteworthy that temperature inside broilers' house directly varies with ammonia concentration. This will have a positive influence on temperature and K_a on NH_3 concentration. The volatisation of water in the litter depends on temperature and air velocity; at their higher rates, water is more volatile. At higher relative humidity, volatisation of water in the litter decreases (Abd El-Wahab et al., 2012; Tabler et al., 2012; Lamidi, 2015). Volatisation can be decreased in the house by reducing the temperature and the velocity of air on the surface of the litter through in-house cooling and increasing the humidity to between 70 and 80% (Feddes et al., 1999). Cooler temperatures and reduced air velocity on litter will reduce the activities of the micro-organisms that are responsible for all the living developments in the litter which help its dry matter not to be actively involved in the promotion of the activities of micro-organisms (Lamidi, 2015). These micro-organisms may affect the lives/welfare of birds. The litter that is produced by birds in different stocking densities at different floor geometries would have an impact on the welfare of workers and birds in the pen and its surroundings under natural conditions, that is, without artificial cooling systems in the house. The goal of this research was to investigate the conditions of litter in a deep litter housing and on the ambient environment and their residual effects on the performances of the broilers.

Materials and Methods

Experimental design

Two factors were considered in the study: floor geometries and stocking densities (assumed to be 100% stocking density for each of the pen). There were four levels of treatment for each of the factors: four different floor geometries (F_1 = 2800 cm^2, F_2 = 4200 cm^2, F_3 = 5600 cm^2 and F_4 = 7,000 cm^2); four different stocking densities (that is, number of bird per pen (S_1 = 4 birds, S_2 = 6 birds, S_3 = 8 birds and S_4 = 10 birds per pen). Each of the treatment was replicated thrice. The experimental set up was a 2 x 4 x 3 randomized complete block design.

The conditions of litter were evaluated via the pH, weights, temperatures and relative humidity of air immediately above the surface of the litter and temperatures and humidity of the litter. The data were collected for the period of eight weeks. The breed of birds used was a popular *cornish* cross broilers and they were raised from day old to the age of ten weeks. Within that period, they were fed *ad libitum* with grower mash (for the first 4 weeks), then finisher for the next six weeks. Wood shavings were provided as litter and were removed at a week interval to analyse the dry matter and moisture contents.

For the collection of the gas escaping from the surface of the litter, an improvised glass cylindrical chamber, opened at its base, closed at its top with pen-sized glass calibrated calorimetric tube was used (Figure 1). Colorimetric tubes give assured and replicative technology for rough estimation of ammonia emitted in animal environments (Fabian, 2019). There are two broad kinds of colorimetric tubes, namely, pull tubes and

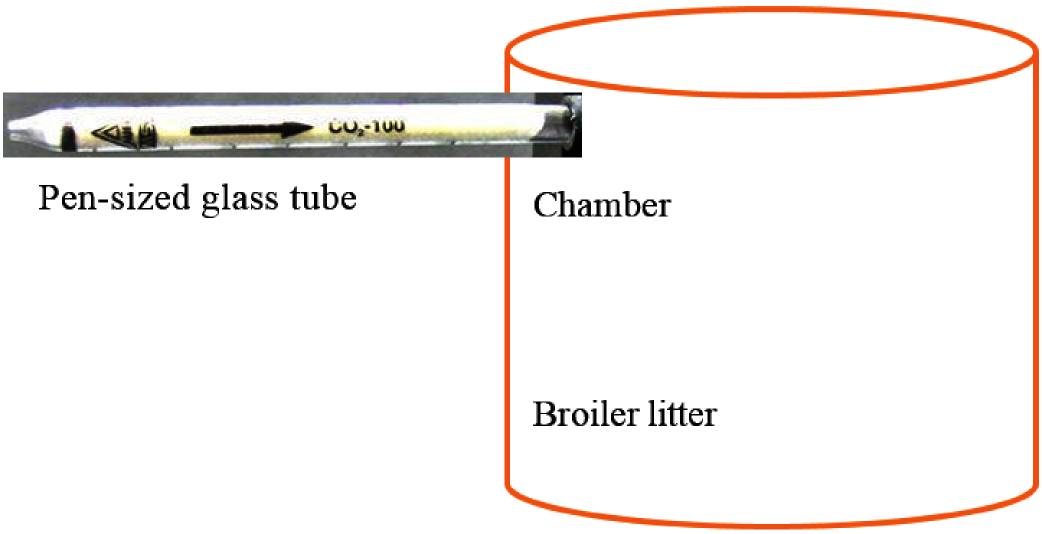

Figure 1 Pen-sized glass tube arrangement with chamber for measuring ppm of ammonia in the litter and just above the litter (that is, at the immediate surface of the litter)

diffusion tubes. Diffusion tube (sometimes called passive tube or dosimeter tube) was used in the experiment, it was calibrated at its side. It is a low-cost option to monitor ammonia gas in animal's vicinity (Fabian, 2019). Ambient air slowly diffused into the pen-sized glass calorimetric tube, there was change in colour along its length after exposure to ammonia just as the air in the tube reacted with NH_3. The length of change in colour in the pen-tube revealed the amount of ammonia gas (Miles et al., 2004; Miles, 2012; Fabian, 2019). The ammonia concentration was read using the scale along the tube at a location where the tube colour stopped to change. This concentration-time reading is divided by the number of hours of exposure to the air to get the average ppm over that measuring period. The tube was positioned near (but out of reach of) the birds for welfare concerns and to sincerely observe the code of ethics in animal handling (Thomas et al., 2004). It was assumed that there was no any other emission in the building. There were two visits to the animal environment daily with 3-4 hours apart, to place the tube and retrieve the reading.

Relative humidity in and out of the building, litter temperatures, temperature of the air just above the litter and the temperatures outside the house were measured for each pen at one-week interval. The weights and volume of the litter starting from the day the litter was introduced into the pen to the day of its removal were also measured at one-week interval. Triple beam balance (0.1 g Accuracy) of capacity 2610±0.1g was used throughout for all the weight measurements. The pH of the litter was measured daily with the pH scale.

Statistical Analysis

One-way ANOVA was used for the statistical analysis and the mean values were separated using Duncan multiple range test at 5% level of significance.

Results

Table 1a shows the mean weight values of the litter and broilers' mean liveweights produced at different floor geometries and at different stocking densities. The cumulative live weights means were significantly different (p = 0.0071 at $p \leq 0.05$ for floor geometry; and p = 0.0001 at $p \leq 0.05$ for stocking density) from one another. Also, the average weekly weight gains (g) in 8 weeks at both floor geometry and stocking density were significantly different from one another (p = 0.0001 at $p \leq 0.05$ for floor geometry; and p = 0.0001 at $p \leq 0.05$ for stocking density), Table 1b.

Table 2 shows that there were significant differences (p = 0.0001 at $p \leq 0.05$ for ammonia emission) among the pens for the mean values of the part per million (ppm) of ammonia emitted in the floor geometries. However, the concentrations of ammonia were not significantly different in the stocking density pens. Moreover, from these mean values in ppm of ammonia released in different pens, it could be seen that the high stocking density pens have low rate of ammonia gas emitted while higher floor geometries also have low rate of ammonia emitted. It could be seen that ammonia emission in ppm were the same in high floor geometry and high stocking density for the birds.

Table 3 shows the low moisture content (minima) as 20.4% and 78% maximum moisture content for the litter. This high dry matter of the litter produced was as high as 2,166.70 g (average) per pen of 10 birds, Table 1a and 3,400 g (maximum in the research) Table 3. This was to the range of 216 to 340

TABLE 1a

Mean weights of the litter and broiler liveweight produced at different floor geometries and at different stocking densities

Factors	Weight, g	S_1	S_2	S_3	S_4
Stocking densities	Mean litter weight	250.00d±10.00	713.30c±11.50	906.70b±11.50	1526.70a±41.60
	Cumulative broiler liveweight	1482a ± 6.00	1407ab ± 6.65	1342 b± 15.75	1482a ± 1.35
Floor geometries		F_1	F_2	F_3	F_4
	Mean litter weight	340.00d±72.10	780.00c±20.00	1526.70b±46.20	2166.70a±152.70
	Cumulative broiler liveweight	1480ab ± 4.03	1482a ± 10.35	1382c ± 10.00	1245d ± 8.00

abcd -Mean values with the same letters along same row are not significantly different at ($p \leq 0.05$)

TABLE 1b

Average weekly liveweight gains (g) in 8 weeks at both floor geometry and stocking density

Factors	Pens	Weekly mean weight gains, g
Stocking densities	S_1	180.30a ± 25.19
	S_2	149.01b ± 21.03
	S_3	138.50d ± 18.63
	S_4	148.20c ± 12.02
Floor geometries	F_1	154.43d±20.26
	F_2	167.50c±19.25
	F_3	171.33b±12.28
	F_4	179.41a±24.19

abcd -Mean values with the same letters on same column for a factor are not significantly different at ($p \leq 0.05$)

TABLE 2

Mean values (ppm) of ammonia produced in litter in broilers at different floor geometries and at different stocking densities

Factors	Pens	ppm of ammonia
Stocking densities	S_1	65.00a ± 10.00
	S_2	63.80ab ± 16.00
	S_3	59.70b ± 10.65
	S_4	62.56ab ± 16.90
Floor geometries	F_1	52.67d ± 12.00
	F_2	71.30 a± 16.00
	F_3	62.00 b± 26.00
	F_4	60.60c± 11.50

abcd -Mean values with the same letters on same column for a factor are not significantly different at ($p \leq 0.05$)

TABLE 3

Mean values, range of different parameters of litter

Parameters	Minimum	Maximum	Mean
pH	8.5	8.9	8.70 ± 0.28
Moisture content (g/kg)	204 (20.4%)	780 (78%)	492.00 ± 5.63 (49.2%)
Dry matter content (%)	67.5	76	72.00 ± 6.01
Density, g/cm^3	0.09	0.5	0.30± 0.10
Thickness of layer of litter (cm)	0.8	2.75	1.30 ± 10.67
Weight of litter (g)	320	3400	1360 ± 14.71
Temperature of the litter (^{o}C)	29	32	30.5 ± 0.70
Temperature inside the house (^{o}C)	28	32	30.0 ± 2.83
Temperature at the immediate outside of the house (^{o}C)	28	32	30.0 ± 2.83
Temperature of the air just above the litter (^{o}C)	29	31	30.0 ± 1.42
Relative humidity inside the house (%)	53	75	66.0 ± 8.32
Relative humidity at the immediate outside the house (%)	54	76	68.0 ± 8.91

g per bird per week. The moisture contents of the litter increased between the range 204 and 780 g/kg (20.4 and 78% respectively) (Table 3) which undoubtedly happened in all the pens but especially the thicker litter layer pens. There was more ammonia released, at 32 ^{o}C maximum temperature, the moisture content reached 78% maximum with 35.4% increase in ammonia from 52.67 to 71.30. Even though the temperature in the pens was around the room temperature of 30 ^{o}C, nevertheless, the more litter in the poultry house, the higher the ppm of ammonia released (range 52.67 to 71.30 ppm).

There was mortality rate of 10% in the S_3 and S_4 pens. This rate is high in animal production as 1.0-5.0% mortality was recommended (Voslarova et al., 2007). The birds, prior to their deaths, were noticed to show up-and-down bob of their tails with each breath. This was a sign of difficulty in breathing (Yang et al., 2019; Swelum et al., 2021). The result of autopsy done on the dead birds revealed that they were dead because of respiratory diseases from ammonia emission they inhaled. This could be so because the litter was not too friable or dry for the birds to have been affected by litter flying particles which was presumed to have caused their respiratory issues that led to their death.

The ranges of temperature and the humidity of the litter shown in Table 3 were moderate, 28 - 32 ^{o}C. High temperature will automatically increase the level of ammonia and then alter the birds' comfort zone, this is because their thermo-comfort zone would have been tampered with. Such may not happen to the birds in this experiment as the values are within the moderate, room temperature for animals and workers in the pens.

Discussion

The statistical differences among the cumulative live weights' means for the floor geometries per birds and the stocking densities could have resulted from factors like the floor geometries of the pens and number of birds per floor space. This is inferred because some other factors like breed, age, sex and the environmental factors were all the same and common to all the birds in the pens during the research.

The mean litter weight that increased with the birds' age, feeds consumed and stocking rate is in agreement with earlier experiment where it was found that the extent of litter/faeces produced in the birds is a factor of their rate of feeding (Feddes et al., 1999; Lamidi, 2014, 2015). The mean litter weights in Table 1a increase not only with the birds' age, or feeds but with the rate of stocking, S_4 pen has 10 birds, it may not be expected that the amount of litter produced by 10 birds per week will be equal to the amount produced by 4 birds because of their rate of feeding, their age, sex or ambient environment. The thickness of the layer of litter produced in each pen depends on the number of birds in the pen, thus the range of thickness of litter layer in Table 3. The litter weights increment with the age of the birds may not be good for the farmers as the feeds consumed by them could have been converted to carcass that is needed as table meat (Park et al., 2002). Other factors may be their health status and management as provided by the poultry workers, but since there were no changes in these factors in the experiment, it could be that the stocking density and pen's floor geometry accounted for the thickness and size of the litter as recorded.

The low moisture content, 20.4% in the litter could be adjudged better for the birds as it was far lower than 27-30% as found by Collett (2012) which he recommended for the available water activity (Aw) that should be in the litter for the birds not to develop sores in their feet in case there is invasion of micro-organisms. The pH of 8.5-8.9 (Table 3) shows that the litter was alkaline, which implies that the litter was more of organic form of dry matter.

The low rate of ammonia gas emitted in low stocking density per pen could be as a result of lower litter thickness on the floor as evident in pen F_4. That is, the floor geometries of 10 birds' litter in 7000 cm^2 which translated to

700 cm^2 per bird did not have thicker litter on the floor and consequently low ppm of emitted ammonia. The pen S_1 with 4 birds, had thicker litter on its floor, that is, more volume of litter, denoting that the floor space could be responsible for the mean values of the high ppm of ammonia. Simply put, less space attracted more thickness of litter on the floor, thus, there could have been more metabolic activities of microorganisms within the litter and more emission of ammonia. It could be surmised that as much feed as consumed by each bird in these pens, less feed was digested and assimilated for carcass development and then the evident higher litter accumulation. Another reason why more ammonia built up on the floor space was due to the fact that more thicknesses of litter were built up in F_1 and F_2 and S_1 and S_2, thus moisture contents of the litter increased. With more moisture content built up, there was more ammonia released. This is in agreement with a report by Fabian (2019) who reported that a slight 5% increase in water content of the litter from 20 to 25% at 75^{o}F, will yield about 140% increment in ammonia emission.

Moreover, since the volatility rate of ammonia in poultry litter depends on its pH, humidity, rate of ventilation, velocity of air, nitrogen (N) and temperature, the comfort of the birds may be affected negatively leading to poor growth performances. The pH of the litter is an important factor that regulates the volatilization of NH_3 because it specifies the volatile ammonium (NH_4^+)/NH_3 ratio between their ionic and non-volatile forms. High NH_3 levels destroy respiratory systems in birds and mucous membranes of their respiratory tracts (Swelum et al., 2021).

Even though the rate of emission of ammonia was not as high in S_3 and S_4 pens compare to S_1 and S_2 pens to have caused death of birds, the amount of NH_3 emitted could cause respiratory issues (Yang et al., 2019; Swelum et al., 2021).

Research has shown that there was a one-half pound body weight reduction at 7-weeks of age for broilers raised in 25-50 ppm ammonia environment compared to birds kept in environment below 25 ppm (Miles et al., 2004; Miles, 2012). This indicates that birds in all these pens (F_1 through to F_4, S_1 through to S_4) were not comfortable as the level of NH_3 emission was far greater than 25 ppm and 50 ppm (52.67 -71.30 ppm). This level of emission resulting in discomfort in birds is attributable to the low cumulative liveweights of the broilers in the pens and especially the pen containing 10 birds, (Tables 1a and 1b). The performance of the birds was low which was evident in their low liveweight after 8 weeks.

The farmers may do well by spreading lime evenly over the chicken manure. This is acceptable as liming decreased N_2O emissions but increased ammonia volatilisation in the soil (Mkhabela et al., 2006). Liming to pH ≥ 6.3 can reduce N_2O emissions, thereby reduction follows by substantial amount in loss of NH_3. This has been found as the most effective method to reduce ammonia odours and at the same time such action has been found not be detrimental to the health of the birds simply due to change in ecosystem (Naseem and King, 2018).

Conclusion

The low cumulative broilers' liveweights in the pens containing highest number of birds, which signified low performances in growth, was a result of their discomfort ability as a result of moisture build-up in the litter due to the thickness of the litter on the floor geometries. Also, the mortality rate recorded in pens S_3 and S_4 were as a result of ammonia emission which was detrimental generally to birds' ecosystem.

Acknowledgements

This study was supported by authors. We thank staff of the Obafemi Awolowo University, Ile-Ife, Nigeria Teaching and Research Farms for their support during the period of the research.

Data Availability

All data have been included in the manuscript.

This data will be made available upon reasonable request.

Conflict of Interest/Competing Interest

The authors have no financial or competing interests to declare that are relevant to the content of this article.

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