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Ammonia levels during broiler rearing cycle

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ABSTRACT

The evaluated ammonia volatilization rates and its association with humidity, temperature, and pH in broiler litter in conventional and dark house rearing systems. Evaluations were performed at 0.01, 1.00, and 1.50 m high, using a completely randomized design, at a weekly frequency for 12 weeks—from the sanitary void to the end of the 42-day cycle. Litter temperature had no significant difference for different types of house. Humidity and pH levels varied according to houses and evaluation periods. No ammonia volatilization was detected during initial periods. However, up from the 21st day of rearing, rates started to increase, showing higher concentrations at 0.01 m height. At 1.00 and 1.50 m, values around 20 $mL \cdot m^{-3}$, were obtained and considered an acceptable exposure level for the broilers and employees directly working in this sector. Yet, broiler breeders should target lower levels due to environmental impacts.

Keywords: poultry litter; volatilization; environment; employee health.

INTRODUCTION

Air quality in environments of poultry production raises concern in zootechnical, environmental, and human aspects, as the flock spends its entire life confined to the house, and employees work 4 to 8 h a day within this environment (NÄÄS et al., 2007).

Among gases produced in poultry farms, ammonia—primarily originated from the decomposition of uric acid present in birds excretes—stands out for compromising the performance and health of broilers and rural employees (OLIVEIRA et al., 2003; MEDEIROS, 2007; OVIEDO-RONDÓN, 2008) if $N\text{–}NH_3$ reaches concentration levels above 20 $mL \cdot m^{-3}$, considered the minimum requirement for acceptable air quality in poultry houses (WATHES et al., 1997; GLOBALGAP, 2007; BRAZIL, 2008; COBB-VANTRESS BRASIL, 2008).

Ammonia is also a precursor of volatile particles (PM2.5, that is, particulate matter 2.5 μm), both sources of air pollution, in and outdoors, that cause irritation to the mucous membranes in the eyes and the respiratory tract, affecting food intake and conversion (MEDEIROS, 2007; OVIEDO-RONDÓN, 2008).

In broiler litters, 83 g of ammonia is produced per broilers per year (FRANCO, 1998), and factors such as temperature, pH, and humidity may increase ammonia volatilization within poultry farms (TERZICH, 1997; CAFÉ et al., 2009; LIMA, 2014).

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High temperatures (> 32 °C) potentiate ammonia volatilization (FRANÇA, 2014). In broilers management, litter surface presents higher temperatures close to heaters (CARVALHO et al., 2011). In the first week of rearing, the ideal temperature range is from 32 to 33 °C, reducing gradually throughout the rearing cycle to reach 18 °C on day 42. Using brooders, as recommended for the first days of life, induces a floor temperature of 40.5ºC (COBB-VENTURES, 2008). To provide poultry thermoneutrality and, consequently, better levels of production, management is overall set between 15–28 °C (BAÊTA, 1998).

A pH higher than nine also potentiates ammonia volatilization (FRANÇA, 2014), but a pH lower than 5.5 entails $N–NH_3$ loss. In the literature there are studies that employ the use of additives to adjust pH values to acidity for allowing this control (OLIVEIRA et al., 2003; MEDEIROS et al., 2008).

Humidity is another important variable for ammonia volatilization. Relative humidity of the air above 70% and litter humidity between 40–60%, considering laying hens, potentiates the process (FRANÇA, 2014). Relative humidity between 50–70% is considered ideal for improving rearing conditions, depending on poultry age (OLIVEIRA et al., 2006; ABREU; ABREU, 2011). As litter is responsible for absorbing moisture from feces and providing the necessary conditions for poultry to express their natural behavior of sponging and scratching, its moisture is a concern for rearing conditions. Litter may present high humidity levels related to its thin thickness or eventual leaks in the waterer, promoting microbial growth and volatilization. The dynamics involved within its evaporation may also compromise poultry heat loss by respiratory evaporation (FREITAS et al., 2011).

Depending on the poultry farm technological level, the amount of volatilized N may reach 50 $mL{\cdot}m^{-3}$ (JONES et al., 2005) or even exceed 60 $mL{\cdot}m^{-3}$, predisposing both poultry and people to respiratory diseases (SIMIONI JR. et al., 2009). Fans or range hoods are used to mitigate such problem (TINÔCO, 2001), although not effectively, as concentration above 20 $mL{\cdot}m^{-3}$ has been recorded in poultry farms with tunnel and conventional ventilation (NÄÄS et al., 2007).

This study aimed to evaluate *in situ* temperature, humidity, pH, and ammonia volatilization in poultry houses of two technological levels (dark house and conventional) during broiler rearing period.

MATERIAL AND METHODS

This study was conducted in poultry houses from Sonai farm, in the municipality of Rolim de Moura, Rondônia (latitude: 11°48'13"S; and longitude: 61°48'12"W, on an altitude of 277 m above sea level) from June 1 to July 31, 2015. According to the Köppen–Geiger classification (PEEL et al., 2007), the region climate is Aw, characterized as varying from equatorial to warm and humid tropical, with a well-defined dry season from March to September, minimum temperature of 24 °C and maximum of 32 °C, precipitation between high and moderately high (2,000 to 2,250 mm), and 85% relative humidity.

Sonai farm operates in a system integration composed of a conventional house (14.5 × 126 m) and a dark house (15 × 127 m), whereby the Cobb lineage is used with a mean density of 14 $birds{\cdot}m^{-2}$.

Poultry litter is made of wood shavings. After each rearing cycle, during sanitary void (5–7 days), litters are revolved with a Tobata micro tractor, and a new litter layer is added on the surface. A cypermethrin-based insecticide 6% (w/w) is also applied to the litter, at a dose of 3.8 $g{\cdot}m^{-2}$, to control lesser mealworm (*Alphitobius diaperinus* Panzer. Coleoptera: Tenebrionidae). The studied litter had already undergone six rearing cycles performed in both facilities.

For initial characterization, broiler litter density was estimated by inserting a PVC tube (9.7 Ø internal and 15 cm height) with bevel edge in 10 random points of the house. The differences among heights unfilled by the litter were evaluated with a millimeter ruler. Material collected by the tube was inserted in plastic bags to estimate masses using a semi analytic balance. The material was fractionated and referred to a stove at 105 °C for initial humidity calculation.

The other portions were placed in 750 mL beakers (n = 3) and slowly and partially wetted, so that wetting front would not reach the bottom of the container. Beakers were sealed with a parafilm needle-punched at five different points to remain in balance with the outer medium. After 24 h of stabilization, the intermediate wetted part was collected, weighed, and referred to the stove at 105 °C for estimating saturation capacity.

To evaluate temperature, an Incoterm digital thermometer was inserted in 12 equidistant and random points of the broiler litter at a 5 cm depth, concurrently with air quality estimates.

To evaluate pH, a digital pH meter was used. About 20 g of litter were hydrated and stirred with a glass stick for 1 min. After a 1-h rest, they were stirred again for a few seconds and reading was performed. The amount of water was equivalent to five times the amount of substrate (ratio 1: 5 – litter: distilled water).

To test air quality, ammonia concentration was weekly evaluated (0, 7, 14, 21, 28, 35, and 42 days of broiler rearing [0 = sanitary void]) at 14 h, in both houses. Ammonia volatilization rates within the broiler litter were monitored using the calibrated GasAlert BW-12826L3 NH_3/Datalogger-BW 128256L3 detector device, whose operational characteristics are: detecting 0 to 100 $mL \cdot m^{-3}$ of NH_3; operating temperature range of –20 to 40 °C, and relative humidity without condensation from 15 to 90%.

Volatilization was measured at 0.01, 1.00, and 1.50 m above litter level. For evaluations at 0.01 m, the NH_3 detector device was placed parallel to the ventilation blade flow, so that its sensor was not obstructed by direct contact with the litter. As for 1.0 and 1.5 m, a stick with the marked positions was used, taking the due care so that no obstruction or deviations in the normal ventilation flow would occur. All evaluations were performed in both houses (conventional and dark house) in 12 random and about 5 m equidistant points, traversed in zig-zag within the facilities. For evaluations at 0.01 m, places close to walls, range hoods, fans, and those under waterer and feeder were avoided.

Data were analyzed in a completely randomized design, in subdivided plots. The Scott–Knott test was used to contrast means, at 5% probability. All analyses were performed with the aid of the ASSISTAT free software (SILVA; AZEVEDO, 2002).

RESULTS AND DISCUSSION

At the end of its sixth rearing cycle, the litter showed a density of 0.509 ± 0.065 $g \cdot cm^{-3}$ and initial humidity of 23.05 ± 1.41%, corresponding to 31.19% of its saturation capacity (73.44 ± 16.20%). Considering that litter humidity above 45% generate problems such as paws and breasts burns (ÁVILA et al., 1992), such level arises interest. Litter humidity is also a determining factor for increased temperature and microbial proliferation, promoting fermentation and releasing gases such as nitrites, nitrates, ammonia, and hydrogen sulfide (McWARD; TAYLOR, 2000).

An association was observed between ammonia volatilization and the type of house and rearing period (Table 1). No $N–NH_3$ was detected until the 14th day at 0.01 m. Up from them, rates started increasing at all evaluated heights. The high coefficient of variation obtained in the analyses refers to the conditions inherent to the poultry houses technological level. This is particularly applicable the conventional house, in which the open system entails a varied airflow, hindering an accurate measurement.

Table 1. Ammonia volatilization at different times in two types of poultry housing between the sanitary void to the end of the 42-day cycle.

Types	Days						
	0	7	14	21	28	35	42
				0.01 m			
Dark house	0.00^a	0.00^a	0.00^a	17.25^a	26.58^a	30.83^a	55.91^a
Conventional	0.00^a	0.00^a	0.00^a	6.83^a	30.83^a	40.42^a	49.58^a
CV = 68.75%				CV = 64.91%			
				1.00 m			
Dark house	0.00^a	0.00^a	0.00^a	10.50^a	13.41^a	14.00^b	19.33^a
Conventional	0.00^a	0.00^a	0.00^a	2.50^b	14.91^a	19.16^a	20.75^a
CV = 63.17%				CV = 48.88%			
				1.50 m			
Dark house	0.00^a	0.00^a	0.00^a	9.33^a	11.17^a	11.83^b	18.17^a
Conventional	0.00^a	0.00^a	0.00^a	1.67^b	13.92^a	17.83^a	19.33^a
CV = 65.72%				CV = 49.18%			

[a,b] Different letters between columns represent a significant difference between the systems ($p < 0.05$). CV: coefficient of variation.

The Scott–Knott test, at 5% probability, showed statistically significant differences for means followed by different letters, for each height.

However, such finding cannot be generalized to the dark house system. As a closed structure, it allows a partial vacuum within the facility that generates an air velocity from 2.0 to 2.5 $m \cdot s^{-1}$, providing an adequate macroenvironment for the poultry (ROSSI, 1998; ABREU; ABREU, 2000).

The literature reports high ammonia levels, particularly during the last week of rearing, with values of up to 50 $mL{\cdot}m^{-3}$ (MIRAGLIOTTA, 2000).The higher ammonia levels was found at 0.01 m above the litter (Table 1).

Poultry houses with controlled ventilation often present $N–NH_3$ at levels of 23.2 $mL{\cdot}m^{-3}$ (TINÔCO, 2001). Considering the concentration of 20 $mL{\cdot}m^{-3}$ as reference, assumed that prolonged exposure and/or increasing concentrations of $N–NH_3$ are associated with subclinical manifestations that lead to weight loss in poultry and poses risk to rural employee's health (Table 1). A study has shown that $N–NH_3$ at 25 $mL{\cdot}m^{-3}$ causes a mean weight loss of 90 g per broilers during 7 weeks of housing (LOTT; DONALD, 2003).

The loss of nitrogen caused by ammonia volatilization is detrimental, as its presence in high concentrations promotes zootechnical performance of broilers, interferes in carcass and meat quality, deteriorates equipment and facilities, and disperses in the environment, contaminating it (DONHAM, 1999). Yet, it is a common occurrence in rearing system due to the high density of broilers (12 $birds{\cdot}m^{-2}$) and excretes, which creates favorable conditions for insects and microorganisms to develop, unfolding the nitrogen content in excretes (OLIVEIRA et al., 2003; MENDES et al., 2012).

Poultry litter temperature showed no significant difference between houses (dark house and conventional) nor between weekly evaluation periods (Table 2). Among broiler litter functions, contributing to reduce thermal oscillations in the poultry farm is an important one (ÁVILA et al., 1992; OLIVEIRA; CARVALHO, 2002). Within the studied houses, thermal oscillation was beyond the interval considered ideal to enhance ammonia volatilization (20 to 30 °C). Temperatures higher than 35 °C have no considerable influence on the volatilization process (FRANÇA, 2014).

Table 2. Temperature (°C) of the poultry litter made of wood shavings, in two types of poultry housing between the sanitary void to the end of the 42-day cycle.

Types*	Days**						
	0	7	14	21	28	35	42
Dark house	35.0^a	35.0^a	36.9^a	35.4^a	35.7^a	38.3^a	39.0^a
Conventional	33.2^a	35.0^a	36.3^a	36.1^a	37.4^a	37.2^a	38.8^a

*CV = 3.24%; **CV = 3.60%. ^{a,b} Different letters between columns represent a significant difference between the systems ($p < 0.05$).
CV: coefficient of variation.

Excreta amount increases along with poultry development, which contributes to raise litter humidity level. Despite the association between adopted technology and evaluation period (Table 3), we found no statistic significant difference between the technological level within the houses—"dark house" (28.08% U) and conventional (27.53% U). At the end of rearing cycle, the conventional system presented humidity between 40 and 60%—ideal levels for potentiating ammonia volatilization (FRANÇA, 2014). Litter humidity may be variedly associated with particulate size, material used, and litter thickness. According to the literature, the litter requires a humidity level between 20 and 25% not to accumulate dust and to inhibit the proliferation of microorganisms (TEIXEIRA, 2013).

Table 3. Mean humidity of the poultry litter made of wood shavings, in two types of poultry housing between the sanitary void to the end of the 42-day cycle.

Types*	Days**							Mean
	0	7	14	21	28	35	42	
Dark house	20.61^a	26.88^a	18.64^b	37.22^a	30.11^a	29.15^b	33.99^b	28.08^a
Conventional	16.22^b	24.37^b	22.85^a	24.19^b	30.35^a	32.88^a	41.84^a	27.53^a

*CV = 5.41%; **CV = 6.79%. a,b Different letters between columns represent a significant difference between the systems ($p < 0.05$).
CV: coefficient of variation.

An association between housing type and evaluation period for the variable pH was also found (Table 4). For MIRAGLIOTTA (2000), litter pH is more associated with the microbial activity within this medium than the house environmental conditions, which is explained by the amount of deposited raw material (manure) and the physicochemical conditions, favoring such reactions. For example, the *Bacillus pasteurii*, a major ureolytic bacteria, cannot grow at neutral pH, but thrives in litters with a pH above 8.5 (LIMA, 2014).

Table 4. Hydrogen potential (pH) of the poultry litter made of wood shavings, in two types of poultry housing between the sanitary void to the end of the 42-day cycle.

Types*	Days**						
	0	7	14	21	28	35	42
Dark House	8.86[a]	8.48[a]	8.62[a]	9.44[a]	8.74[a]	8.44[b]	8.66[b]
Conventional	8.78[a]	8.40[a]	8.38[b]	9.16[b]	8.72[a]	8.98[a]	9.30[a]

*CV = 2.45%; **CV = 1.89%. [a,b] Different letters between columns represent a significant difference between the systems ($p < 0.05$). CV: coefficient of variation.

Excreta accumulation results in increased pH levels and, consequently, a greater conversion of NH_4^+ (nonvolatile) to NH_3 (volatile) and a higher ammonia volatilization (OWADA et al., 2007; SANTOS et al., 2012). Levels of pH at 9 or even 10.5 potentiate ammonia volatilization and those losses. Besides being a source of environmental pollution, it also represents an impoverishment of the nitrogen quality in broilers litter aimed to fertilize agricultural areas by reducing the use of industrial fertilizers, generating economic gains (FRANÇA, 2014).

No ammonia ($N–NH_3$) was found in poultry houses air during initial periods of rearing. Despite the complex interactions among several factors resulting in ammonia volatilization, neither temperature nor pH limited the studied variables, since volatilization has been observed at lower pH than those observed for example, pH 7.66 in a litter that has not been treated with $N–NH_3$ reducing additives (OLIVEIRA et al., 2003). Strong correlation levels have been established between ammonia volatilization and humidity (0.8142), as well as between ammonia volatilization and temperature (0.8041) (Table 5). This is explained by the dynamics between initial humidity and temperature of the material used as litter (wood shavings), due to rearing management.

Table 5. Correlation values* between pH, humidity (U%), temperature (T°C) and ammonia volatilization at 0.01 m in broiler litter.

	pH	U%	T°C	$N–NH_3$
pH	-	0.37	−0.08	0.18
U%	0.37	-	0.62	0.81
T°C	−0.08	0.62	-	0.80
$N–NH_3$	0.18	0.81	0.80	-

*0.00 to 0.19: very weak; 0.20 to 0.39: weak; 0.40 to 0.69: moderate; 0.70 to 0.89: strong and 0.90 to 1.00: very strong (GIULIATTI et al., 2015).

In the first week, small chicks are restricted to a small portion of the house. Thereafter, occupied area is gradually expanded until the entire space is been used, at the second week of rearing. Consequently, the proportion area/excreta amount in the house changes, influencing humidity and pH levels.

For volatilization behavior, we observed that ammonia emissions at 0.01 m above litter exceeded 20 $mL{\cdot}m^{-3}$ up from the 4th week, reaching 52.75 in the 6th week of housing. Such change is associated with the increase in excretes resulting from chickens growth. Up from the 20th rearing day, concentrations above 20 $mL{\cdot}m^{-3}$ are recorded both in poultry farms with tunnel and conventional ventilation (NÄÄS et al., 2007), which, in closed intensive rearing systems, may present values of up to 50 $mL{\cdot}m^{-3}$ in the last week of the cycle (JONES et al., 2005). Concentrations greater than 60 $mL{\cdot}m^{-3}$ predispose birds to respiratory diseases, increasing the risks of secondary infections and reducing broilers performance by about 15% (HARDOIM et al., 1997; SIMIONI JR. et al., 2009). Other related problems are: plantar cushions burn (calluses), itchy eyes, skin irritations and forefoot calluses, weight loss, low uniformity, disease susceptibility, and blindness due to high levels of NH_3 in the rearing environment (COBB-VANTRESS BRASIL, 2008).

Overall, ammonia concentrations at 1.00 and 1.50 m above litter reached minimum requirement for acceptable air quality (20 $mL{\cdot}m^{-3}$ $N–NH_3$) in both types of poultry houses during the final weeks of rearing. In Brazil, as well as in other countries, this is considered the tolerable concentration for a working environment of up to 8 $h{\cdot}day^{-1}$ (BRAZIL, 2008).

Regarding poultry farms conditions, with emphasis on ammonia control, it was verified that producers in Southern Santa Catarina with a journey of 6 to 8 h perceive the smell of ammonia, yet 86% do not use personal protective equipment, and 35% reported having health problems, as allergies and skin irritation (ZANATTA, 2007). High concentrations of ammonia in the air may also cause vertigo, intoxication, low blood-oxygen, and worsen respiratory diseases (FERNANDES; FURLANETO, 2004). $N–NH_3$ at levels of 5 $mL{\cdot}m^{-3}$ is detectable only to some people, but between 5 to 15 $mL{\cdot}m^{-3}$ it is easily detectable by odor (FRANÇA, 2014).

The highest levels of ammonia volatilization were found at 0.01 m. It was lower at 1.00 and 1.50 m because, at these heights, ammonia is removed by the ventilation system, which has 60 fans in the conventional system and eight range hoods in the dark house system.

Studied additives, reported in the literature, that showed higher efficiency in inhibiting ammonia volatilization proved that it is possible to improve rearing environments as for gases presence (such as ammonia) and substantially reduce their harmful effects on the health of poultry, workers, nearby communities, and even in the environment. However, the dynamics of gas emission may vary according to management circumstances and the apportioned application of inhibitors (SAMPAIO et al., 1999). If interesting and economically viable, additives could be used in broiler litter from half of the rearing cycle onwards as a strategy to reduce volatilization levels.

CONCLUSIONS

In both studied rearing systems (dark house and conventional), ammonia levels in the facilities become critical after the final half of the rearing period.

Temperature and pH were not limiting, and litter humidity acted as a control variable for ammonia volatilization within the houses.

Despite the contrasting technological levels in the conventional and dark house, the dynamics of ammonia production had no significant difference at 0.01 m above broiler litter.

AUTHORS' CONTRIBUTIONS

Conceptualization: Ferreira, E.; Saturnino, K.C. **Data curation:** Fogaça, I. **Formal analysis:** Fogaça, I. **Investigation:** Fogaça, I.; Ferreira, E.; Mehanna, M.N. **Methodology:** Doni, T.R.S.; Ferreira, E. **Supervision:** Saturnino, K.C. **Validation:** Fogaça, I.

AVAILABILITY OF DATA AND MATERIAL

The datasets generated and/or analyzed during the study are available in the Repositório Institucional da Universidade Federal de Rondônia: https://www.ri.unir.br/jspui/handle/123456789/2144.

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CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

Not applicable.

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