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The Impact of Environmental Temperature-Humidity Index on Ammonia Concentration (NH_3) in Laying Hen Farms

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ABSTRACT. *Emissions of ammonia gas (NH_3) produced from the manure of laying hens can harm health and productivity. This study aims to determine the comfort level of laying hens based on the temperature humidity index (THI) which is calculated based on the temperature and humidity conditions of the cage, and its relationship with ammonia gas (NH_3) levels, as well as the factors that most influence the concentration of ammonia gas (NH_3) around the cage. Data collection was carried out in 96 units of laying hen cages in Sidenreng Rappang Regency spread across 4 sub-districts, including; Kulo, Pitu Riawa, Maritengngae, and Watang Pulu. Data collection was carried out directly by measuring the ammonia levels in the cage air using the Ammonia Gas Detector Smart Sensor AR8500 system. Temperature and humidity were measured using an Elitech DT-3 Thermo Hygrometer. Data were analyzed by correlation and multiple linear regression. The results of the research showed that as many as 53.13% of laying hens were in an "uncomfortable" condition in breeder-rearing cages in Sidenreng Rappang Regency. Air ammonia (NH_3) levels have a "strong" correlation with humidity and a "moderate" correlation with THI. The higher humidity and THI, the higher ammonia (NH_3) levels in the air. Higher humidity will increase the ammonia (NH_3) content in the cage air partially and simultaneously with the regression equation. Air NH_3 level = -11.803 + 1.328 temperature + 0.152 humidity – 1.314 THI. A total of 53.13% of laying hens are in an "uncomfortable" condition in breeder cages in Sidenreng Rappang Regency. Ammonia (NH_3) levels have a "strong" correlation with humidity and a "moderate" correlation with THI. The higher the humidity and THI, the higher the ammonia (NH_3) levels in the air.*

Keywords: ammonia gas levels (NH_3), temperature, humidity, THI, laying hens.

INTRODUCTION

The laying hen farming sector experiences a fairly rapid population increase every year due to society's increasing need for animal protein, especially eggs. Direktorat Jenderal Peternakan dan Kesehatan Hewan (2024) reported that in 2023, the consumption of animal protein by the Indonesian people, especially eggs, per capita per week, was 5.48%, one of the most widely consumed sources of animal protein. The population of laying hens in 2024 will reach 414.8 million heads. This number increased by 1.12% from the previous year. This data is in line with national egg production, which will reach 6.88 million tons in 2024, of which 92.24% of eggs come from laying hens (Direktorat Jenderal Peternakan dan Kesehatan Hewan, 2024).

One of the regions in Indonesia with the highest production of purebred chicken eggs is South Sulawesi, where the dominant population center is in Sidrenreng Rappang Regency or also known as Sidrap. Badan Pusat Statistik Sidenreng Rappang (2024) reported that in 2023, the population of laying hens in Sidenreng Rappang Regency will reach 3.79 million heads spread across 11 sub-districts. Even though the population of laying hens in Sidenreng Rappang Regency is high, most of the rearing patterns are still quite conventional, with the housing model still using an open house system. This will result in high contamination from fecal waste produced by chickens every day. Handling chicken fecal waste that is not optimal will have a negative impact on both the chickens themselves as well as on workers and the surrounding community (Gržinić et al., 2023; Rajab et al., 2022).

The odor produced by fecal waste comes from volatile organic compounds or often called volatile organic compounds (VOC). VOC is the main component of odorous substances in the livestock manure management process and causes various reactions that can have a poisoning effect on humans if the concentration exceeds a certain threshold (Orzi et al., 2018). Some of the gas emissions in manure which include VOCs include; methane gas (CH_4), nitrous oxide (N_2O), ammonia (NH_3), and hydrogen sulfide (H_2S) (Chen et al., 2020; Zhang et al., 2019).

One of the dominant volatile compounds found in poultry manure, especially laying hens, is ammonia gas (NH_3). Ammonia (NH_3) can produce nitrous oxide (N_2O) which can decompose after deposition in the soil or oxidize in the air, thus indirectly affecting the production and emissions of greenhouse gases. Ammonia (NH_3) is also one of the main sources of $PM_{2.5}$ formation. Particulate Matter ($PM_{2.5}$) is air particles measuring ~2.5 µm (Kim et al., 2021). High $PM_{2.5}$ concentrations can cause regional smog. Ksheem & Antille (2016) explained that 75% of the total nitrogen in livestock manure can be released into the air in the form of emissions due to the volatilization process, most of which is released in the form of ammonia gas (NH_3). High concentrations of ammonia gas (NH_3) around the cage will affect the chicken's comfort level, causing stress which results in reduced immunity and production (Arianto et al., 2019; Mohammed, 2022; Sheikh et al., 2018).

Many factors cause the high release of ammonia gas (NH_3) into the air, including; waste handling, feed composition, and the environment Intergovernmental Panel on Climate Change (2019). The environment is a factor that directly influences the release of ammonia gas (NH_3). Some environmental factors include; housing management, density, and climate factors (wind speed, temperature, and air humidity) (Eglin & Hassouna, 2016).

Data collected by EDGAR (2015) from 1970 to 2015 reports that several islands in Indonesia have been exposed to ammonia gas (NH_3) in quite high concentrations, including the islands of Java and Sulawesi, especially South Sulawesi. Sidenreng Rappang Regency is one of the areas with quite high ammonia gas (NH_3) contamination, due to the high population of laying hens with conventional housing management. However, studies regarding the factors causing high levels of ammonia gas (NH_3) pollution, especially in Sidenreng Rappang, are still limited. This is the basis on which this research was conducted. This study aims to determine the comfort level of laying hens based on the temperature humidity index which is calculated based on the temperature and humidity conditions of the cage, and its relationship with ammonia gas (NH_3) levels, as well as the factors that most influence the concentration of ammonia gas (NH_3) around the Farms. This study provides information regarding the factors that most contribute to ammonia gas levels in the laying hen farming industry.

MATERIALS AND METHODS

This research was conducted in May 2024. The research location was in laying hen cages in 4 (four) sub-districts in Sidenreng Rappang Regency, South Sulawesi, namely Kulo, Pitu Riawa, Maritengngae, and Watang Pulu Districts, which are the concentration of farms with the largest laying hen populations. The population of this study was 127 farms. The number of samples taken was calculated using the Slovin formula (Ismail et al., 2022), therefore, the sample of this study was 96 units or 75.59% of the number of farms in Sidenreng Rappang Regency, with a population of 127 units.

Data Collection

Data collection in this research used a survey method with observational collection. Data was collected directly by measuring the concentration of ammonia gas (NH_3) in the air in the cage using the Ammonia Gas Detector Smart Sensor AR8500 system. Temperature and humidity were measured using an Elitech DT-3 Thermo Hygrometer. The data obtained is the average of measurements at 3 (three) cage points: the front, middle, and back of the cage. The Temperature Humidity Index (THI) is calculated using the Nieuwolt (1977) formula:

$$THI = 0,8T + \frac{RH\ x\ T}{500} \boxed{0,8T + \{\frac{RH\ x\ T}{500}\}} \boxed{0,8T + \{\frac{RH\ x\ T}{500}\}}$$

Data analysis

The data obtained were tabulated using Excel software and analyzed for correlation and multiple linear regression using IBM SPSS version 20 software to get the average value, standard deviation, correlation coefficient, and regression equation. The analysis results are used to determine the relationship and closeness of the relationship between air ammonia (NH_3) levels and the factors temperature, humidity, and THI.

RESULT AND DISCUSSION

Comfort Level of Laying Hens Based on Temperature Humidity Index (THI)

The temperature humidity index (THI) is a standard used to measure the level of potential heat stress in livestock. Zaky et al. (2024) divide THI into 3 categories: <29 is considered “comfortable”, 29-30.5 is “Partially comfortable”, and >30.5 is “uncomfortable”. Figure 1 below showed the percentage of comfort level for laying hens based on THI. The total number of cages observed was 96 units, where 53.13% of chickens were in the "uncomfortable" zone. This showed that most of the temperature and humidity in the cage in Sidenreng Rappang Regency cause stress in laying hens. Cage conditions with high temperature and humidity would trigger a significant spread of ammonia gas (NH_3) (Adler et al., 2021). This will continue to reduce feed consumption, which ultimately results in chicken growth.

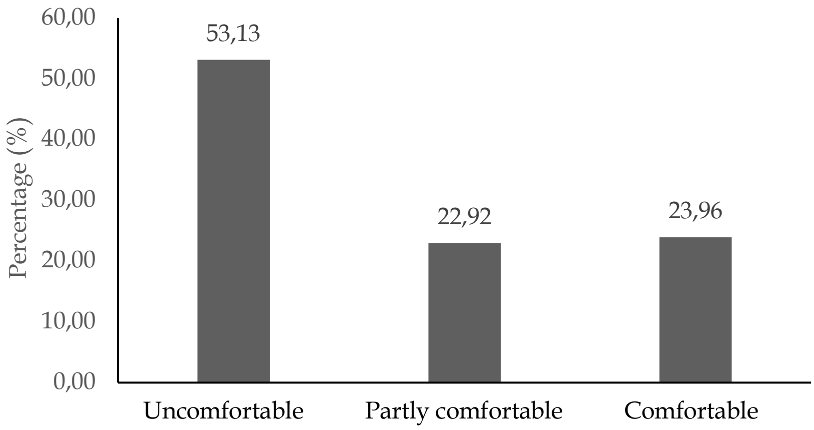

Figure 1. Percentage of comfort level of laying hens based on environmental THI value

Li et al. (2020) explained that excessive concentrations of ammonia gas (NH_3) are known to be one of the causes of environmental stress for chickens because they can reduce feed intake and inhibit growth. Furthermore, Sitorus et al. (2019) explained that in cage model cages, high temperatures and concentrations of ammonia gas (NH_3) will cause respiratory irritation which causes inefficient heat release and reduces the level of appetite in chickens.

Air Ammonia (NH_3) Levels and Climatic Factors in the Laying Hen Cage Environment

The results of research that has been carried out on variables include temperature, humidity, THI, and air ammonia (NH_3) levels. The data obtained consists of the average, standard deviation, and total sample (N) which are presented in Table 1. The average air ammonia (NH_3) content in this study was lower than the results obtained by Kilic & Yaslioglu (2014) in laying hens cages for 3 months. Fabbri et al. (2007) reported that emissions and concentrations of ammonia gas (NH_3) were around 2 ppm in summer.

The results of temperature measurements in this study showed a higher value than Ulupi & Afnan (2016) who reported that the normal temperature in the cage for laying hens is in the range of 20-24°C. Temperatures above this range indicate heat stress in laying hens. Furthermore, Andrade et al. (2017) found that heat stress in laying hens occurred at cage temperatures ranging from 20.2-32.8°C. The cage humidity in this study was lower than the results of the study by Diaz et al. (2018). Diaz et al. (2018) who reported that comfortable humidity standards for laying hens are in the range of 60-70%. THI in laying hen cages in this study was higher than Kumar et al. (2016) who reported that during the summer the average THI of cages was 29.19. Higher values indicate uncomfortable conditions in laying hens.

Table 1. Mean and standard deviation of environmental variables for laying hens

Variables	Mean	Std. Deviation	N
Temperature (°C)	33.47	2.20	96
Humidity (%)	54.81	14.92	96
THI	30.44	2.11	96
Ammonia Level (NH_3) (ppm)	0.99	1.09	96

Correlation of Air Ammonia (NH_3) Levels with Climate Factors

The observation results in Table 2 show the correlation value, p-value, and significance between air ammonia levels and temperature, humidity, and THI. Sugiyono (2013) explains that a correlation coefficient of 0.60-0.80 is included in a strong correlation, a value of 0.40-0.59 is in the medium category, while a value below 0.40 indicates a weak correlation. Based on this grouping, it can be seen that air ammonia (NH_3) levels and humidity have a strong correlation (r = 0.115) with a significant relationship ($P<0.05$). Ammonia (NH_3) levels with THI showed a moderate correlation (r = 0.530) with a significant relationship ($P<0.05$). Ammonia (NH_3) levels with temperature showed a weak correlation (r = 0.115) with no significant relationship ($P>0.05$).

Ammonia (NH_3) levels and humidity have a strong correlation in line with studies conducted by Wei et al. (2015), who found that high levels of ammonia (NH_3) in the air in inappropriate humidity conditions will reduce the productivity and immunity of chickens. Naseem & King (2018) further explained that the release of ammonia in the form of gas or emissions which is often called volatilization is greatly influenced by the humidity around the chicken cages. Inappropriate humidity conditions will cause bacterial oxidation of uric acid which causes a reaction to form ammonia gas (Swelum et al., 2021).

Ammonia (NH_3) levels with THI showed a moderate correlation in line with the study of Zhao et al. (2021) on broiler chickens which found a correlation value of 0.507. THI refers to the chicken's comfort level which is based on temperature and humidity conditions. THI emphasizes the stress conditions experienced by chickens. This stress condition will increase if the concentration of ammonia gas (NH_3) in the cage is also higher. Conditions with a high THI will force the chicken to panting (breathing through the throat at a fast tempo) (Kang et al., 2020). High levels of ammonia (NH_3) in the air in the cage will disrupt the chicken's respiratory system (Zhou et al., 2021). If heat stress occurs with high concentrations of ammonia (NH_3) it will cause acute respiratory problems which can lead to decreased productivity or death.

Table 2. Correlation of temperature, humidity, and THI with ammonia (NH_3) levels in laying hen farming

Correlation between Variables	Correlation coefficient	p-Value	Correlation Levels
Temperature x Ammonia Level (NH_3)	0.115	0.06	Weak
Humidity x Ammonia Level (NH_3)	0.817	0.00	Strong
THI x Ammonia Level (NH_3)	0.530	0.00	Medium

Regression of Climate Factors with Air Ammonia (NH_3) Levels

The results of multiple linear regression analysis (Table 3) show the influence of climate factors on air ammonia (NH_3) levels in chicken cages resulting in the equation air ammonia (NH_3) levels = -11.803 + 1.328 temperature + 0.152 humidity – 1.314 THI. The coefficient of determination (R2) is 0.747, which means that 74.4% simultaneously. The humidity factor significantly ($P<0.05$) influences the ammonia (NH_3) content of the air in the laying hen cage. This equation explains that humidity greatly influences air ammonia levels compared to other variables.

Table 3. Effect of temperature, humidity, and THI on ammonia levels in the air of laying hen farming

Variable	Coefficient	t-Value	Sig.	R^2
Constant	-11.803	-3.354	0.001	
Temperature (°C)	1.328	1.577	0.118	
Humidity (%)	0.152	2.404	0.018	
THI	-1.314	-1.416	0.160	
Simultaneous			0.000	0.747

These results are in line with the correlation between ammonia (NH_3) levels and humidity. In this study, humidity is a climatic factor that greatly influences the concentration of ammonia gas (NH_3) in the cage. High humidity will result in wet manure for a longer duration of time, because of the high-water vapor in the air. This will trigger the formation of higher levels of ammonia gas (NH_3) due to water vapor and ureolytic bacteria which are more active in humid conditions, to produce the urease enzyme. Lohmann Management Guide (2020) explains that the recommended humidity for laying hens ranges from 60-70%, especially in tropical areas.

Babadi et al. (2022) explain that sources of humidity in poultry cages can come from air entering the cage, moisture from manure, and steam resulting from chicken breathing. Therefore, low humidity rarely occurs in chicken cages, so the main problem is high humidity conditions. This will reduce the performance and welfare level of the chickens. Humidity lower than 60% will cause chickens to become dehydrated more quickly, while higher than 70% will result in heat stress and difficulty in releasing heat in chickens. In addition, high humidity will trigger an increase in air ammonia (NH_3) concentrations (Apalowo et al., 2024; Mwesigwa et al., 2016). The humidity condition of the Sidenrendeng Rappang location in this study was below 60%, which was 54.81%. This causes discomfort in laying hens. In line with the chicken comfort index (THI), which shows that >50% of chickens are in uncomfortable conditions.

CONCLUSION

As many as 53.13% of laying hens are in an "uncomfortable" condition in breeder cages in Sidenreng Rappang Regency. Ammonia (NH_3) levels have a "strong" correlation with humidity and a "moderate" correlation with THI. The higher the humidity and THI, the higher the ammonia (NH_3) levels in the air. Conditions of high ammonia (NH_3) levels can be suppressed by maintaining stable humidity in the cage in the range of 60-70%.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in this manuscript.

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