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Research Article

Ammonia (NH_3) Emissions in Laying Hen Farms: Distribution and Influencing Factors in Sidrap, Indonesia

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Abstract | Manure is a waste product from laying hens that has the potential to produce pollutant gases (ammonia)(NH_3). In general, manure produces volatile gases. Many factors influence the distribution of gases from the metabolic process of manure. This can significantly disrupt the productivity of laying hens, the working community, and the environment around the cage. The dynamic pattern of the distribution of pollutant NH_3 gases from the metabolic process in laying hen farms is then studied and examined further. This study evaluates the distribution dynamics of NH_3 gases produced by laying hen farms. This phenomenon results from a study and case study in Sidrap Regency, South Sulawesi Province, Indonesia. This research study has applied quantitative methods to determine the effect of independent variables (X) on dependent variables (Y). A total of 120 laying hen farm units have been involved in this research study as samples in Sidrap Regency. The Smart Sensor Gas Ammonia AR8500 system was used to measure the amount of NH_3 gas (variable Y). A total of 11 types of variable X have been involved in analyzing the effect on variable Y. Based on this number, it is further divided into 3 categories of factors, namely: factor (1) dietary, which consists of (a) feed protein content (Fpc) (%) and (b) daily feed consumption (Dfc)(g/head/day). Factor (2) climate, consisting of (a) temperature (Tm)(°C); (b) relative humidity (Rh)(%); (c) temperature-humidity index (THI); and (d) wind speed (Ws)(m/s). Factor (3) is the management and housing system, consisting of: (a) population (Pop)(head); (b) Stocking density (Stden)(head/m^2); (c) farm height area (Fha)(meter above sea level) (masl); (d) height cages (Hc)(m); and (e) manure accumulation period under the cages (Map)(days). The positive (+) correlation analysis results indicate that an increase in the value of the Pop, Tm, THI, Dfc, Fpc, and Stden variables will also spur an increase in the amount of NH_3 in the air environment. However, an increase in the number of Rh, Ws, Fha, Hc, and Map variables will reduce the levels of NH_3 around the cage (negative correlation). The Hc and Map variables moderately influence the amount of NH_3 around the cage. The Hc ($r = -0.286$) and Map ($r = -0.272$) variables are inversely proportional to NH_3 gas production. The increasing Hc value ($y = -0.4903x + 1.3539$) causes the amount of NH_3 gas to decrease. The distance of the cage floor >1.5 m tends to reduce the amount of NH_3 gas and the Map variable with the regression equation ($y = -0.0007x+1.0626$). Climate, dietary and management factors, and housing system factors influence 33.4%, while other independent variables affect the remaining 66.6%.

Keywords | Manure, Gas, Ammonia, Laying hens, Farm, Pollutant

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INTRODUCTION

In Indonesia, the industry with the biggest population is the laying hen sector. The population is growing, and so is this population. The need for animal products, particularly eggs, is favorably connected with this. According to FAO (2006), the chicken industry is expanding at a higher rate (5% annually) than the pig and cow industries (3% and 1%, respectively). According to the most recent data, there are currently 378,590,549 heads of laying hens in Indonesia (BPS, 2023). Each head can create an average of 150 grams/day of manure during the production period (Tańczuk *et al.*, 2019). This means that 20,4 million tons of manure are produced annually. Pollutant gasses from this waste production undoubtedly have the potential to impact the productivity of workers, breeders, livestock, the environment, and the local population. Undoubtedly, this occurrence poses a significant risk to human life. The development of a greenhouse effect due to manure-derived gas generation has the most detrimental long-term effects (Zhang *et al.*, 2024; Gržinić *et al.*, 2023). An example of livestock waste that may have adverse effects is manure. However, if manure and other livestock by-products are properly treated and used, they can also be beneficial. Through several bioprocess technology applications, livestock waste can yield significant prospective economic profits (Said, 2018; Said *et al.*, 2018; Said *et al.*, 2019; Said *et al.*, 2024).

Ammonia (NH_3) is one of the pollutant gases that can be produced during the metabolism of manure. This gas is produced by the hydrolysis of uric acid and the microbial degradation of nitrogen-containing organic compounds. (Pohl *et al.*, 2022; Souri *et al.*, 2023; Chen *et al.*, 2023; Salthammer, 2022; Zweers *et al.*, 1990; Kacprzak *et al.*, 2023). One gas that dissolves readily in water is NH_3. Through chemical reactions with other chemicals, this gas can create molecules that contain ammonium. Because of the metabolic processes that take place in their bodies, livestock are one of the biggest suppliers of ammonia. The atmosphere has the highest concentration of NH_3 gas (Gerber *et al.*, 2015). Animal feed's high protein and amino acid content affects the NH_3 gas's aberrant generation process. This is predicated on an incorrect feed formulation procedure. This leads to poor generation of nitrogen gas, which the cattle body needs as protein. Only one-third of the nitrogen produced is useful for producing meat and eggs; the other two-thirds are expelled from the body as ammonia gas and manure (Nowak *et al.*, 2016). Ammonium (NH_4^+) and NH3 will be created from manure. Other gases, including nitrogen gas (N_2) and nitrogen dioxide (N_2O), will be produced as a result of fermentation and microbial breakdown (Mendes *et al.*, 2017). The state of the livestock itself is one of the elements that can affect the generation of gases in the air, particularly in the environment of the livestock sector. Genetics, ration preparation management, and feeding practices are some of the connected elements. The issue of waste management and the physical and chemical characteristics of the manure waste generated are related to additional factors. The production of gas is also influenced by a number of other elements, including the environment. Wind speed, ventilation, and cage temperature are a few of them (Mažeikienė and Bleizgys, 2022; Swelum *et al.*, 2021).

Climate factors, such as high temperatures and humidity, have a significant impact on the amount of gas released in the cattle environment (Bist *et al.*, 2022; Jiang *et al.*, 2021). Another element that affects the state of pollutant gases in the livestock sector is wind speed. Because airflow is unrestricted in an open cage, polluting gases will change (Brouček and Čermák, 2015). The amount of feed protein that remains undigested and unabsorbed will subsequently be thrown away. This may influence the process of producing polluting gases (Vilela *et al.*, 2020). The form of the cage can also produce high-pollutant gases in the cage and how it is managed (Alberdi *et al.*, 2016; Chai, 2023). Laying chickens are negatively impacted by the effects of polluting gases. Infection and irritation of the skin, eyes, nose, throat, and respiratory system are among the consequences of NH_3 gas. Livestock productivity may undoubtedly suffer (egg output and quality decline). Body weight and feed cost ratio (FCR) are affected by NH_3 gas because it can lead to bacterial infections and ocular damage (Al-Kerwi *et al.*, 2022; Pratiwi *et al.*, 2018; Ulupi *et al.*, 2015; Padappayil and Borger, 2023; Huda *et al.*, 2021). The dynamics of NH_3 gas distribution in laying hen farms in Sidrap Regency, South Sulawesi Province, Indonesia, are investigated in this study.

MATERIALS AND METHODS

Data Collection Method

The fundamental technique for identifying the independent and dependent variables is the quantitative approach method. In Sidenreng Rappang (Sidrap) Regency, South Sulawesi Province, Indonesia, one of the biggest hubs for the laying hen farm, field data was gathered from research findings and case studies. The impact of the independent variable (X) on the dependent variable (Y) was investigated using quantitative techniques. A total of 120 agricultural units were sampled. According to the Slovin calculation, this figure has accounted for almost 75% of Sidrap Regency's laying hen farms (Ismail *et al.*, 2022). The sampling locations were chosen based on the avalability of a larger population of laying hens (600–20,000 heads). Figure 1 shows a visualization of the laying hen cage's model and shape at the data collection site. The "battery" stage model is the form and features of the laying hen farm cage used by all farms. Wire or bamboo are used to make the cage. There are two to four hens in each of the little parts that make up the cage.

Data for the independent variable (X) used 11 parameters. Based on this number, it is further divided into 3 categories of factors, namely: factor (1) dietary, which consists of (a) feed protein content (Fpc)(%) and (b) daily feed consumption (Dfc)(g/head/day). Factor (2) climate, consisting of (a) temperature (Tm)(°C); (b) relative humidity (Rh)(%); (c) temperature-humidity index (THI); and (d) wind speed (Ws)(m/s). Factor (3) is the management and housing system, consisting of: (a) population (Pop)(head); (b) farm height area (Fha)(meter above sea level)(masl), (c) Stocking density (Stden)(head/m^2), (d) height cages (Hc)(m) (and (e) manure accumulation period under the cages (Map)(days).

Figure 1: Characteristics of the model and form of laying hen farm cages at the research location.

Data Analysis and Statistical Test

Multiple linear regression analysis was used to determine the most important parameters influencing the amount of gas produced around the laying hen cage environment. On the other hand, the interaction between the grouping of all these elements was ascertained by correlation analysis.

Independent Variable (X)

Factors related to diet (X_1). Dietary factors include (a) FPc (%), which is determined by the protein content of the complete feed (concentrate + corn + bran), and (b) Dfc (g/head/day), which is determined by subtracting the amount of feed consumed in a single day from the amount of feed delivered.

Climate-related factors (X_2). Climate factors are derived from thermos-hygrometer values and include (a) Tm (°C) and (b) Rh (%). (c) The formula THI = 0.8 x Tm + (Rh x Tm)/500, where Tm = temperature and Rh = relative humidity, is used to calculate the temperature-humidity index (THI) value (Nieuwolt, 1977). (d) A digital anemometer of the Benetech GM816 type is used to measure Ws (m/s).

Aspects of the housing and management systems (X_3). The management factors are (a) the number of laying hens grown in each cage, or pop (heads); and (b) the height position of the laying hen cage area above the ground, or Fha value. An android altimeter with the unit masl (meters above sea level) is used to calculate the Fha value; (c) the number of laying hens inhabiting a 1 m^2 area is used to calculate (Stden)(head/m^2); (d) The average distance between the ground and the "battery" model cage's floor is used to determine the Hc (m); (e) The Map value is the number of days that the manure was stored in the cage. The number of days the excrement is left in the cage before being cleaned is used to calculate the map.

Dependent Variable (Y)

The dependent variable (Y), NH_3 value was obtained from the measurement results of a sensor device consisting of the Smart Sensor Gas Ammonia AR8500 system.

Statistical Analysis

Regression-correlation analysis: This study demonstrates that a good statistical technique for figuring out the linear correlation between two variables is Pearson's correlation coefficient. The experiment yielded two sets of data for variables X and Y: $X=[X_1, X_2, X_3, Xn]$ and $Y=[Y_1, Y_2, Y_3. Yn]$. To indicate the correlation coefficient, use the letter "r." The degree of direct link or component connectivity between two variables is described by the Pearson correlation range, which runs from +1 to -1. While a relationship of +1 shows a high positive correlation between the variables or that the samples essentially have the same structure, a relationship of -1 indicates a large negative correlation or that the sample structures differ (Zhi *et al*., 2018). The purpose of this study was to determine the association between each of the variables in the climate factor group: dietary (X_1), climate (X_2), management and housing system (X_3) and the ammonia gas level variable (Y).

Multiple linear regression analysis: Multiple linear regression analysis was used on models with numerous independent variables to determine the relative impact of each independent variable on the dependent variable (Sugiyono, 2013). The multiple linear regression equation used in this investigation is as follows: $a + b_1X_1 + b_2X_2 + b_3X_3 + e = Y$ Where: Y = ammonia (NH_3) gas; a = constant; b_1 = climate regression coefficients; X_1 = dietary factors; b_2 = dietary regression coefficients; X_2 = climate factors; b3 = management and housing system regression coefficients; X_3 = management and housing system factors; e = error factor.

Heteroscedasticity and normality test: The Breusch-Pagan and White approach is used to test for heteroscedasticity (Lumivero, 2025). In contrast to homoscedasticity, heteroscedasticity is a notion. When the model error variance varies for every observation, this approach explains the situation. This test is crucial for determining whether the regression model's homoscedasticity assumption is satisfied. Using a P-P plot and the Kolmogorov-Smirnov test method, do a normality test. This test determines if the data is distributed normally.

F-test (simultaneous test): The F-test is used to analyze how the independent factors affect the dependent variable.

Table 1: The influence of several factors and correlation of independent variables on the production of ammonia gas (NH_3) (ppm) in laying hen farms at Sidrap regency, South Sulawesi, Indonesia.

Variables and Correlation	Me	Sd	Mav	Miv	Cc	p-V	Cl	Cof	t-V	pv	R^2
Ammonia (NH_3) gas (ppm)	0.905	0.539	2.9	0.1	-	-	-	-	-	-	
- Constant	-	-	-	-	-	-	-	5.450	0.605	0.268	
Population (Pop)(heads)	1,594.76	986.85	6,000	500	-	-	-	-0.005	-0.908	0.254	
- NH_3 Vs Pop	-	-	-	-	0.028	0.264	W	-	-	-	
Temperature (Tm) (°C)	30.157	2.355	33	25	-	-	-	-0.709	-0.664	0.352	
- NH_3 Vs Tm	-	-	-	-	0.055	0.190	W	-	-	-	
Relative humidity (Rh)(%)	76.124	10.468	96	56	-	-	-	-0.033	-0.491	0.433	
- NH_3 Vs Rh	-	-	-	-	-0.027	0.268	W	-	-	-	
Wind speed (Ws) (m/s)	1.357	0.572	3.8	0.5	-	-	-	-0.109	-1.308	0.134	
- NH_3 Vs Ws	-	-	-	-	-0.003	0.339	W	-	-	-	
Temperature-Humidity Index (THI)	28.670	1.693	31.02	24.75	-	-	-	0.508	0.457	0.356	
- NH_3 Vs THI	-	-	-	-	0.069	0.157	W	-	-	-	
Daily feed consumption (Dfc) (g/head/day)	117.272	4.334	134	110	-	-	-	0.030	2.117	0.037	
- NH_3 Vs Dfc	-	-	-	-	0.086	0.087	W	-	-	-	
Feed protein content (Fpc) (%)	16.607	2.187	19	12	-	-	-	-0.179	-2.975	0.004	
- NH_3 Vs Fpc	-	-	-	-	0.160	0.005	W	-	-	-	
Farm height area (Fha) (meter above sea level)(masl)	69.95	38.10	135	15	-	-	-	-0.004	-3.070	0.003	
- NH_3Vs Fha	-	-	-	-	-0.229	0.006	W	-	-	-	
Stocking density (Stden)(head/m^2)	8.124	2.722	15	4	-	-	-	-0.004	-0.181	0.595	
- NH_3Vs Stden	-	-	-	-	0.024	0.276	W	-	-	-	
Height of cages (Hc)(m)	0.915	0.314	1.8	0.5	-	-	-	-1.378	-4.081	0.000	
- NH_3Vs Hc	-	-	-	-	-0.286	0.001	Mo	-	-	-	
Manure accumulation period under the cage (Map)(days)	211.330	196.880	547	30	-	-	-	-0.002	-3.275	0.001	
- NH_3Vs Map	-	-	-	-	-0.272	0.001	Mo	-	-	-	
Simultan	-	-	-	-	-	-	-	-	-	0.000	0.334

Note: Me=mean; Sd=Standart deviation; Mav=maximum value; Miv=minimum value; Cc=Correlation coefficient; p-V=probability value; Cl=Correlation level; Cof=Coefisient; t-v=t-value; p-v= p-value; W=weak; Mo=moderate; R^2=Coefisien of Determination.

This study employs simultaneous hypothesis testing to determine the relative contributions of each independent variable to ammonia (NH_3) emissions. The test was performed by comparing the F_{count} value with the F_{table} at a 5% error degree (a = 0.05). If $F_{count} > F_{table}$ value, the independent variable concurrently has a large impact on the dependent variable (Sugiyono, 2013).

Coefficient of determination (R^2): The coefficient of determination (R^2) is used to calculate the percentage contribution of the independent factors' influence on the dependent variable. The coefficient of determination formula is as follows (Sugiyono, 2013). Cd=R^2x100%, where R^2 is the squared correlation coefficient and Cd is the coefficient of determination.

RESULTS AND DISCUSSION

The Influence of Climate, Dietary and Management Factors and Housing System on Ammonia (NH_3) Gas Production in Laying Hen Farms

Numerous elements influence the process of producing NH_3 gas. Further research is crucial, particularly on the variables influencing gas production. Cage arrangement systems (style, model, and location), climate conditions, and feed and management are all crucial aspects that are highly desirable to investigate further. There will undoubtedly be a lot of discussion about strong interactions and correlations. Table 1 fully presents the investigation of the correlation and interaction of several significant variables that impact the ammonia gas generation process in laying hen farms in Sidrap Regency.

According to Table 1 data, laying hen farms produce between 0.1 and 2.9 parts per million of NH_3 gas, with an average of 0.905 parts per million. This quantity is still less than the 0.08–3.82 ppm found in the Perdanasari *et al*., (2023) study. Other results are also lower than the findings by Kilic and Yaslioglu (2014), with a value of 1.012 ppm on laying hen farms during the summer. This study also looks at several factors that can lead to an increase in the generation of NH_3 gas. These factors include the number of laying hen populations, temperature, humidity, wind speed around the cage, Temperature-Humidity Index (THI), daily feed consumption, the amount of protein in the feed consumed by laying hens, stocking density, elevated cage base from manure disposal, accumulation of manure periods beneath the cages, and the height of the sea level. These elements play a significant part in altering the NH_3 gas composition inside the cage. There are between 500 and 6,000 laying hens in the population at the study site. Throughout the study, the ambient temperature ranged from 25 to 33°C, with a humidity of 56 to 96%. During the investigation, the cage's ambient temperature was still more significant than the 19–21°C range suggested by Kim *et al*. (2021). The temperature and humidity levels in the production process significantly impact the laying hens' metabolic rate, which in turn impacts the manure produced as a byproduct of their metabolism. The wind speed ranged from 0.5 to 3.8 m/s, with an average of 0.572 m/s, when data was gathered at the laying hen farm location. The THI score averaged 28,670 and ranged from 24.75 to 31.02. The THI value quantifies how comfortable a given temperature and humidity level. Relative humidity and air temperature are used to obtain this value (Bohmanova *et al*., 2007). According to the study's findings, laying hen farms in Sidrap Regency consumed an average of 117,272 g/head/day of feed, with a feed protein level of 16,607%. According to Feedmaster (2020), 10 g/hour is advised. The findings are in line with the 17.2% feed protein needed for laying hens during the production phase, as recommended by Ribeiro *et al.* (2016). The research samples, which were laying-hen cages, were situated at an average elevation of 69.95 meters above sea level, with a range of 15 to 135 meters. The research site is still in a lowland category (0-200 masl) according to the region's categorization and features. Lowland climates typically have hot, muggy weather patterns. Sidrap Regency has regional characteristics with an altitude of 10-3000 masl, according to regional data (Pemkab Sidrap, 2014). In terms of cage stocking density, the typical laying hen farm in the study area had 8–9 laying chickens per square meter. Only two laying hens per cage are advised by Wan *et al*. (2023) to achieve a typical yield. This is predicated on the idea that each cage is 0.5 m^2 in size. The laying hen farm cage's floor height from the manure surface ranges from 0.5 to 1.8 meters, with an average of 0.915 meters. A stage is one of the features of the laying hen farm cage in Sidrap Regency. Compared to cages with a floor model (postal), this enables better air circulation. The average Map is 211,333 days (±7 months), with a range of 30 to 547 days. An extended period of manure accumulation beneath the cage is made possible by the cage system that uses an open cage type (open house). Due in part to the absence of work on the farm, this situation lasts for a very long time.

The safe ammonia level standards for broilers vary depending on the animal and environmental conditions. Some commonly used standards include: 1) Maximum ammonia level of 20 ppm: This standard is used for chicken cops, especially broiler chickens (Bilal and Umar, 2022). 2) Ammonia levels between 6.49-52.37 ppm: This is the acceptable ammonia range for chicks, but remember that this value can vary depending on environmental conditions and the type of animal (Murad *et al*., 2022). 3) Ammonia levels below 10 ppm: This is a stricter standard used by some farmers to ensure the health and comfort of livestock.

REGRESSION AND CORRELATION ANALYSIS

Regression and correlation analysis are two analytical techniques that can be used to examine and comprehend the relationship between variables in a study. When modeling a relationship between one or more independent variables (X) and one or more dependent variables (Y), regression analysis is employed. The objectives of this analysis are to determine which independent variables have a substantial impact on the dependent variable, assess the degree to which independent variables affect the dependent variable, and forecast the dependent variable's value based on the independent variables' values. One method for figuring out the link between variables is correlation analysis. Either a positive (+) or negative (-) relationship is possible.

The analysis's findings on the correlation factor between several independent variables (X_1, X_2, and X_3) and the dependent variable (Y) (NH_3 gas production) are also displayed in Table 1. The analysis's findings indicate that management and housing system factors (X_3), particularly height of the cage (Hc) with a correlation coefficient (Cc) = -0.286 and Map with a correlation coefficient (Cc) = -0.272, are the factors that correlate level (Cl) at a moderate (Mo) level. The findings indicate a highly significant correlation ($p<0.001$). In contrast, there is an unreal association ($p>0.005$) between farm height area (Fha) and stocking density (Stden), with Cl at a weak (w) level of (Cl = -0.229) and (Cl = 0.024), respectively. Figure 1 shows the distribution of the Map and Hc factor values (Cl = Mo).

A graph of the association between Hc and Map, two parameters with a moderate (Mo) correlation level, is displayed in Figure 1. The graph illustrates how the production of

NH_3 gas (r = negative) is inversely related to the difference between Hc (r = -0.286) and Map (r = -0.272). The amount of NH_3 gas detected decreases as the value of Hc increases using the regression equation (y = -0.4903+1.3539). This may be because a higher Hc value results in a longer distance between the manure surface and the cage floor. As a result, less NH_3 gases will be found. The amount of NH_3 gas tends to decrease when the cage floor is farther than 1.5 meters. The longer the accumulation time of the manure collection operation, the higher the Map value, according to the regression equation (y = -0.0007x+1.0626). This can be caused by the greater the value of Hc, which causes the distance between the cage floor and the manure surface to be further. Thus, the NH_3 gas detected will be lower. The distance of the cage floor> 1.5 m tends to reduce the amount of NH_3 gas. Related to the Map value with the regression equation (y = -0.0007x+1.0626), the longer the accumulation time of the manure collection process causes the Map value to increase. This is because the accumulation of long manure collection periods causes the fermentation process of organic materials from the manure, which causes the production of NH_3 gas to decrease, and the consistency of the manure will begin to experience a dry phase. The accumulation of manure collection periods > 500 days reduces the amount of NH_3 gas detected. Based on this value, it can be assumed that the large amount of feces accumulation in the cage does not cause negative effects, especially the amount of NH_3 gas. However, many other factors may have negative effects, such as cage cleanliness and the amount of feces storage capacity that is decreasing with a very long feces collection period. The results of the analysis showed that, the long-term accumulation of manure did not significantly affect the increase in NH_3 values, however, there are several things that may be the most risky effects on the productivity of laying hens. The possible effects are: 1) Increased risk of disease outbreaks caused by Salmonella bacteria, E. coli, and others; 2) Increased levels of other gases (non-NH_3) such as methane and hydrogen sulfide; 3) Its effects on chicken health, such as increased stress, decreased immunity, and increased risk of disease, and 4) Effects on egg quality, especially increased bacterial levels and decreased eggshell quality.

Using manure in commercial farming involves several steps to maximize the benefits and reduce the negative impacts. Some strategies that can be used include: 1). Correct dosage: Manure is used at the right dosage to avoid excess nutrients that can damage the soil and plants. 2). Use of manure in the form of compost products: This ensures that the nutrients have been decomposed and are ready to be used by plants. 3). Manure as a base fertilizer: Base fertilizer must be used before planting to prepare the soil and provide initial plant nutrients. 4). Use of manure as a follow-up fertilizer: Follow-up fertilizer is needed during plant growth to maintain nutrient availability. 5). Manure in an integrated farming system: Manure in an integrated farming system involves using organic fertilizers, water management, and integrated pest control.

The height of the cage can be inversely proportional to the level of ammonia produced. Several things can explain the negative relationship. The higher the cage position, the lower the level of ammonia produced. This is because in a higher cage position, the decomposition process and ammonia production can occur more slowly. Temperature and humidity will also be affected. The higher the cage position, the lower the temperature and humidity. This also directly affects the decomposition process of organic materials and compounds in feces. As a result, ammonia production also decreases. Related to ventilation, it can be explained that the cage model for laying hens in Indonesia is mostly an open system (open house) (Figure 1). This will certainly provide a good air circulation effect in the cage. Good ventilation will increase airspeed, so the decomposition process will run slowly. As a result, ammonia production will also decrease.

MULTIPLE LINEAR REGRESSION ANALYSIS

The findings of the multiple linear regression analysis (Table 1) indicate that the housing system, nutrition and management issues, and climate influence 33.4%. The Fpc and Fha variables influence the distribution of NH_3 gas in addition to the Hc and Map factors. The constant-Cof of Fpc (5.450-0.179) (*pv* = 0.004) and constant-Cof of Fha (5.450-0.004) (*pv*=0.003) were derived from this data. There are several reasons *pv* results may display negative values (-). These elements are among the external factors (66.6%) that are not part of the variables under study. The amount of protein in the feed significantly impacts how much ammonia is produced in the manure. Nitrogen reactions in organisms can vary depending on the type of feed (Uddin *et al*., 2024). Nitrogen (N) is the primary structural component of protein synthesis. This nitrogen is converted into ammonia molecules by bacterial action. The Ammonia generation will be correlated with a diet containing high protein levels. This is because there will be more N accessible and broken down. The imbalance in the amino acid content of the feed composition is another factor. The feed protein's quality may also influence other aspects. The chicken body will find it easier to digest and absorb high-quality feed protein, lowering the ammonia levels in manure. Furthermore, the number and activity of bacterial germs in laying hens' digestive tracts influence the process of N absorption, which undoubtedly affects the formation of ammonia in manure. Additionally, the formation of ammonia gas in manure will be impacted by feed additives (prebiotics and probiotics). The environment and workers' health may suffer due to manufacturing NH_3. In this instance, the feed factor is a life cycle analysis (LCA) factor related to production. The outcomes affect livestock's ability to produce NH_3 (de-Vries and de Boer, 2010).

HETEROSCEDASTICITY AND NORMALITY TEST

A Heteroscedasticity Test (Het-T) was then carried out to test the reliability of the regression model used. Normality Test (Nor-T) is a statistical technique used to test whether the data distribution follows a normal distribution. A normal distribution is a distribution that has a bell curve shape with the same mean, median, and mode. The reliability of the employed regression model was then examined using a Heteroscedasticity Test. A statistical method for determining if the data distribution is normal is the Normality Test (Nor-T). A bell-shaped distribution with the same mean, median, and mode is called a normal distribution. Additionally, the P-P Plot model was used to perform a normalcy test. Examining the distribution of the collected data is the goal of this test, particularly in relation to the acquisition model that uses a normal distribution system. To make sure that the normal assumption is satisfied, this is crucial. (Figures 2a and b) provide a detailed explanation of the point distribution and data patterns in Het-T and Nor-T.

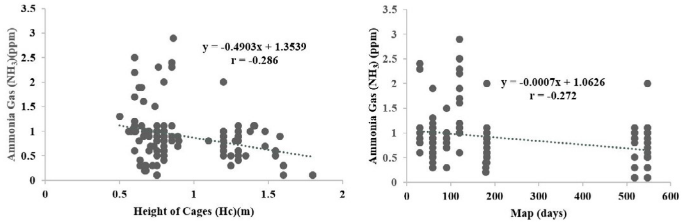

Figure 2: Graph of correlation between manure accumulation period under the cage (Map)(days) and Height of cages (m) on the production of ammonia gas (NH_3) (ppm) as pollutant gas in laying hen farms.

Table 2: Results of the F-test analysis (simultaneous hypothesis testing) for Ammonia (NH_3) gas in laying hen farms at Sidrap regency, South Sulawesi, Indonesia.

ANOVA^a						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Variable: Ammonia Gas (NH_3)						
1	Regression	11.645	11	1.059	4.958	0.000^b
	Residual	23.272	109	0.214		
	Total	34.917	120			

a: Dependent Variable: Air Ammonia Levels; **b:** Predictors: (Constant), dietary, climate and management, and housing system factors.

This Het-T test aims to assess a regression model's residual variance. The value of the independent variables generated determines this. This testing procedure aims to determine whether the regression model's homoscedasticity assumption is satisfied. The regression model is undoubtedly unreliable if this supposition is not fulfilled. The Scatterplot graph's representation in Figure 2a indicates that there is no discernible pattern or flow to the point distribution. This assumption demonstrates that homoscedasticity occurs or that heteroscedasticity does not exist. Homoscedasticity indicates that the residual (data) distribution stays constant, increasing the validity and accuracy of the regression predictions. The residual data presentation has a symmetrical distribution between the left and right sides of the diagonal line, as seen by the data visualization in Figure 2b. The data has demonstrated a normal distribution, according to this graphic. Since the distribution of points is comparatively near a straight line, it may be said that the assumption of normality has been satisfied, and the residual (data) has been regularly distributed.

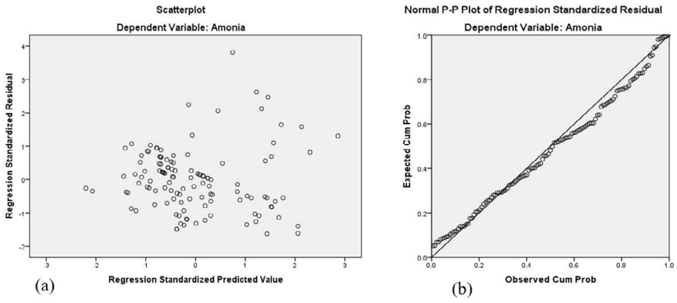

Figure 3: Graph of a scatterplot of Heteroscedasticity Test (a) and P-P plot Normality Test (b) on the production of ammonia gas (NH_3) (ppm) as pollutant gas in laying hen farms.

SIMULTANEOUS TEST (F TEST)

To test a hypothesis incorporating multiple independent variables at once, a simultaneous test is required. This is necessary to ensure that variations in the independent variables may concurrently account for variations in the dependent variable. Table 2 presents the full test results of how climate, housing system variables, and food and management factors affect the amount of NH_3 gas in laying hen farms.

Table 2's data indicates that the significance value (sig) found is 0.000 ($p<0.05$), indicating the rejection of H_0. The test's findings show that housing systems, food and management elements, and climate greatly and concurrently influence the process of lowering the amount of ammonia gas. Ammonia generation in livestock is influenced by feed types and nutrient digestibility, according to Lee *et al.* (2021), particularly for the anions and cations (Na + K-Cl-S) kinds. The sorts of these ions directly impact urine pH. Naturally, this will also directly impact livestock's ammonia production. According to Ndegwa *et al.* (2008), NH_3 is theoretically also required by plants as a source of nutrients for growth; however, an excess of N in NH_3 can potentially be detrimental to the ecosystem. Increased nitrogen oxide (N_2O) and N saturation in forest soils, nitrate contamination in drinking water, eutrophication of surface water leading to toxic algal blooms and reduced water quality, changes in vegetation or ecosystems, and climate change linked to soil acidification processes through the nitrification process are some of the effects that take place.

Coefficient of Determination

An indicator is required to assess the dependability of the regression model that is used to quantify and explain the percentage of data variability. The coefficient of determination (Cd) (R^2) is one of them. Table 3 displays all the findings from the computation of the Cd value generated by this investigation.

Table 3: Results of the Coefisien Determination (R^2) for Ammonia (NH_3) gas in laying hen farms at Sidrap regency, South Sulawesi, Indonesia.

Model Summary[b]				
Model	**R**	**R Square**	**Adjusted R^2**	**Std. Error of the Estimate**
Variable: Ammonia Gas (NH_3)				
1	0.578[a]	0.334	0.266	0.46207

a: Dependent variable: air ammonia levels; **b:**Predictors: (constant), dietary, climate and management, and housing system factors.

Based on the data in Table 3, the Cd (R^2) value is 0.334 (33.4%). These results indicate that climate, dietary and management factors, and housing system factors influence 33.4%, while the remaining 66.6% is influenced by other independent variables not included in this study. This amount is still huge compared to the main factors. Other factors contribute to the NH_3 gas production process and greatly support the emergence of odors in the livestock industry (Janni, 2020). The decrease in NH_3 levels in the cage can occur due to the provision of materials that are urease inhibitors or the occurrence of a natural fermentation process (Ndegwa *et al*., 2008). NH_3 production is closely related to the efficiency of absorption of nutrients, especially protein and amino acids. Protein not absorbed from the digestive tract will be converted into urine acid, which is then excreted by feces. The high number of glycolytic bacteria in the urine compared to anaerobic bacteria causes the decomposition process in urine acid to occur very quickly, producing ammonia (NH_3) (Hendalia *et al*., 2012).

Based on the field study results, several descriptions and conditions occurred in several laying hen farms. The data shows that the correlation of variables (dietary, climate management, and housing system) is still low, namely 33.4%, so the influence of other variables is still dominant (66.6%). Ammonia levels generally do not significantly affect the productivity of laying hens, especially when related to growth in the early phase (starter), egg production, or the level of chicken mortality. Chickens still tolerate the threshold value of NH_3 levels. Many factors may influence, including: 1) the adaptation of laying hens is already very high to air conditions in the area; 2) efforts to prevent the spread of disease have been very good (use of vaccines, anti-microbe, and drugs); 3) use of additives; 4) the environmental temperature which tends to be high in the area causes the spread of bacteria or other microbes to be less able to develop properly. In addition, the condition of water sources and lighting can also be other factors that influence the productivity of laying hens. Microorganisms play a major role in the ammonia gas production process, including: 1). Decomposition of organic matter: Microorganisms such as bacteria and fungi can decompose organic matter, such as animal waste and food waste, into simpler compounds, including ammonia. 2). Deamination process: Microorganisms can carry out the deamination process, which is decomposing amino acids into ammonia and other compounds. 3). Ammonification process: Microorganisms can carry out the ammonification process, which is decomposing nitrogen compounds into ammonia. The cage management system in Indonesia is more of a "battery" cage system. However, the type of litter material may also have an influence, including: 1). Litter material containing lime: Litter material containing lime can neutralize ammonia and reduce ammonia levels in the cage. 2) Litter material containing zeolite: Litter material containing zeolite can absorb ammonia well and reduce ammonia levels in the cage. 3). Litter material containing activated carbon: Litter material containing activated carbon can absorb ammonia well and reduce ammonia levels in the cage.

Feed additives work to reduce ammonia levels by regulating microbial balance. Feed additives can help regulate the microbial balance in the animal's digestive tract, thereby reducing ammonia production. Reducing pH, feed additives can help reduce the pH in the animal's digestive tract, thereby reducing ammonia production. Adsorbing ammonia feed additives can help adsorb ammonia in animal feces, reducing ammonia levels. Yucca extract has antimicrobial properties that can help inhibit the growth of bacteria and fungi. With these conditions, the decomposition process of organic materials producing ammonia gas is inhibited, so the production of ammonia gas can be prevented.

CONCLUSIONS AND RECOMMENDATIONS

The distribution of NH_3 gas in laying hen farms at the research location is still relatively below the required threshold. Management factors and housing systems have a more dominant influence than climate and diet. The height of cages and Map has a closer correlation (moderate category) with the distribution of NH_3 gas than several other variables such as population size, temperature, relative humidity, wind speed, daily feed consumption, feed protein content, farm height area and stocking density (weak category). climate, dietary and management factors, and housing systems significantly and simultaneously influence the process of reducing the amount of ammonia gas. Climate, dietary and management factors, and housing systems only influence 33.4%. Several other influences are still relatively high, which this article has not discussed. The results are expected to provide an overview of the conditions for farmers and the government to improve patterns and management in raising laying hens.

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NOVELTY STATEMENT

According to the findings of earlier research projects, published data and papers have not included information about pollutant gas dynamics, features, and distribution patterns in the industrial area of laying hen farming. Only notes that have never been published or included in a book are currently included in the data.

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Authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest between researchers and authors in the article preparation and publication process for this article.

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