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A Comparative Study: Indoor Air Quality (PM_{10}, Ammonia, Airborne Total Bacteria) in Different Types of Broiler Chicken Farm

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Abstract Broiler chickens, one of Indonesia's promising ventures for food security, also serve as a livelihood for many people. Numerous workers engage in activities at these locations, with some dedicating up to 24 hours. This type of workplace carries various health risks, particularly concerning air quality. In Indonesia, there are three types of broiler chicken coops: Open, Semi-Enclosed, and Closed. The Closed type is claimed to be more promising and environmentally friendly. However, studies addressing these differences are still minimal. Air quality parameters such as temperature (°C), relative humidity (RH), PM_{10} (mg/m^3), Ammonia (NH_3), and total bacterial count (CFU/m^3) were examined in 30 chicken coops in Banyumas Regency, Central Java, in close proximity. There were 11 open-type broiler chicken farms, 9 semi-enclosed farms, and 10 enclosed ones. The average values for temperature, relative humidity, and airborne bacterial count exceeded the limits set by the Indonesian government. As for PM_{10} and NH_3 in all observed coops, they remained below this limit. There was a significant difference (∝=0.05) for the RH parameter (p = 0.017), PM_{10} (p = 0.023), and total airborne bacterial count (p = 0.018) among the three coop types. The Spearman Rank test indicated a significant correlation between the number of chicken and PM_{10} (p = -0.62) and Airborne Bacterial Count (p = 0.46), as well as temperature and RH (p = -0.56), temperature and NH_3 (p = -0.394), RH and NH_3 (p = 0.392). With values above the recommended limits, poultry farm managers must consider indoor disinfection and administratively regulate working hours. These efforts also aim to minimize the health risks to workers.

Keywords PM_{10}, NH_3, Airborne Total Bacteria, Chicken Farm

1. Introduction

The need for food is in line with the increasing population of Indonesia. Broiler chicken is one source of animal protein widely cultivated in Indonesia. Currently, the broiler industry is one of the most developed industries in the livestock sector, and it supports the animal protein needs of the community [1]. The productivity of broiler meat products in Indonesia in 2023 reached 3.9 million tons, an increase of 6% from the previous year [2]. Specifically, in Banyumas Regency, the livestock species' population relatively rose from 2017 to 2019 [3]. In addition to meeting food needs in Indonesia, poultry farming has positive and negative impacts. The positive effect of poultry farming is the addition of labour, while the negative impact is in the form of public health risks and worker health, such as increased pollution from microbiological sources such as air germ counts [4].

Microbes are components naturally present in the air, both indoors and outdoors. Several factors, such as geographic conditions, climate, or the population of animals and plants, influence the source of outdoor air microbes. Meanwhile, indoor air microbes usually depend on their emission sources, which can be industrial or non-industrial activities. Indoor activities that contribute to the increased airborne microbial count include silo loading and unloading, feeding poultry, fertilizer production, feed storage, and human occupancy density [5].

Air pollution from microbiological aspects adversely affects livestock production processes and increases the prevalence of airborne infectious diseases. The characteristics of microbial aerosols in farms (F) are high concentrations, diverse types, and difficulty controlling. Exposure to non-pathogenic microorganisms in high concentrations causes an excess burden and a decrease in the immune system. This makes livestock vulnerable to infections. Interaction with pathogenic microorganisms does not always result in disease under normal conditions. Nevertheless, alterations in the livestock environment can result in diseases affecting livestock, poultry, and potentially humans [6]. Airborne microbe concentrations exceeding standard limits can lead to health problems such as chronic bronchitis, respiratory tract infections, organic dust poisoning, and other respiratory diseases [7].

Regulation of the Minister of Health of the Republic of Indonesia No. 70 of 2016 concerning Standards and Requirements for Industrial Work Environment stipulates that the concentration of microbes in the air must not exceed 1000 CFU/m^3. Research data on the levels of airborne microbes in poultry farms in Indonesia are scarce. Studies conducted in Indonesian poultry farms frequently emphasize variables such as airborne dust and chemical pollutants. Conversely, research conducted in other countries has yielded contrasting results, with airborne microbial counts in farms typically exceeding 10^6CFU/ m^3 [4].

Activities on broiler chicken farms cause emissions of various gases such as ammonia (NH_3), nitrous oxide (N_2O), hydrogen sulfide (H_2S), methane (CH_4), particulates (PM), Volatile Organic Compound (VOC), and other compounds which pose a risk to animal and human health. Among all types of emissions, ammonia (NH_3) is one of the most dangerous types of gas. This gas is estimated to reach 2.67 million metric tons annually [8]. In 2017, the American Association of Poison Control Center's National Poison Data System recorded that 1846 single exposures to NH_3 gas seriously affected health. However, there were no reports that this exposure caused death directly [9].

Generally, three types of broiler chicken pens are commonly used in Indonesia: open, semi-Enclosed, and Enclosed. Open coops are made of wood or bamboo and heavily rely on environmental temperature and relative humidity (RH). In contrast, enclosed coops offer farmers the ability to regulate temperature and moisture by specific production requirements [10].

The semi-enclosed coop is a hybrid design, combining half-open and half-closed coops. This cage has an open house exterior structure, such as bamboo or wood, rather than aluminium walls, like a closed house cage. Part of the wall of this cage is covered with traditional sheets such as sacks or plastic. Air circulation in this type of coop is controlled by a fan or blower, which is smaller than in an enclosed coop. This cage also has an automatic food and drink system for chickens [11].

The enclosed coop type is also known as a tunnel system. This type of enclosed coop is described as a tunnel where air will enter from the front (inlet) and be pulled backwards to flow along the cage and expelled with the help of an exhaust fan. This coop can accommodate more chickens than the open and semi-enclosed coops. The chicken feeding system in this type of cage is regulated automatically. The use of sophisticated technology makes this cage claimed to be more environmentally friendly and has the highest production profitability [12]. Research related to livestock coop types tends to prioritize economic aspects rather than environmental conditions. Still, more comparative data on air quality must be available among open, semi-enclosed, and enclosed coops. Thus, this study aimed to compare the indoor air quality parameters of $PM_{2.5}$, ammonia, and total airborne bacteria in different boiler chicken farms.

2. Material and Methods

This descriptive-analytical research employed comparative and correlation tests statistically. Data was collected in Banyumas, a region in Central Java Province, Indonesia, situated between east longitude 108° 39'17" to 109° 27'15" and south latitude 7°15'05" to 7°37'1". Covering a land area of 1,327.60 km^2, Banyumas Regency exhibited diverse geographical features, encompassing plains, mountains, and sections of the Sungai Serayu valley. The mountainous area was located on the slopes of Mount Slamet, with an average air pressure of 1,001 mbs [13].

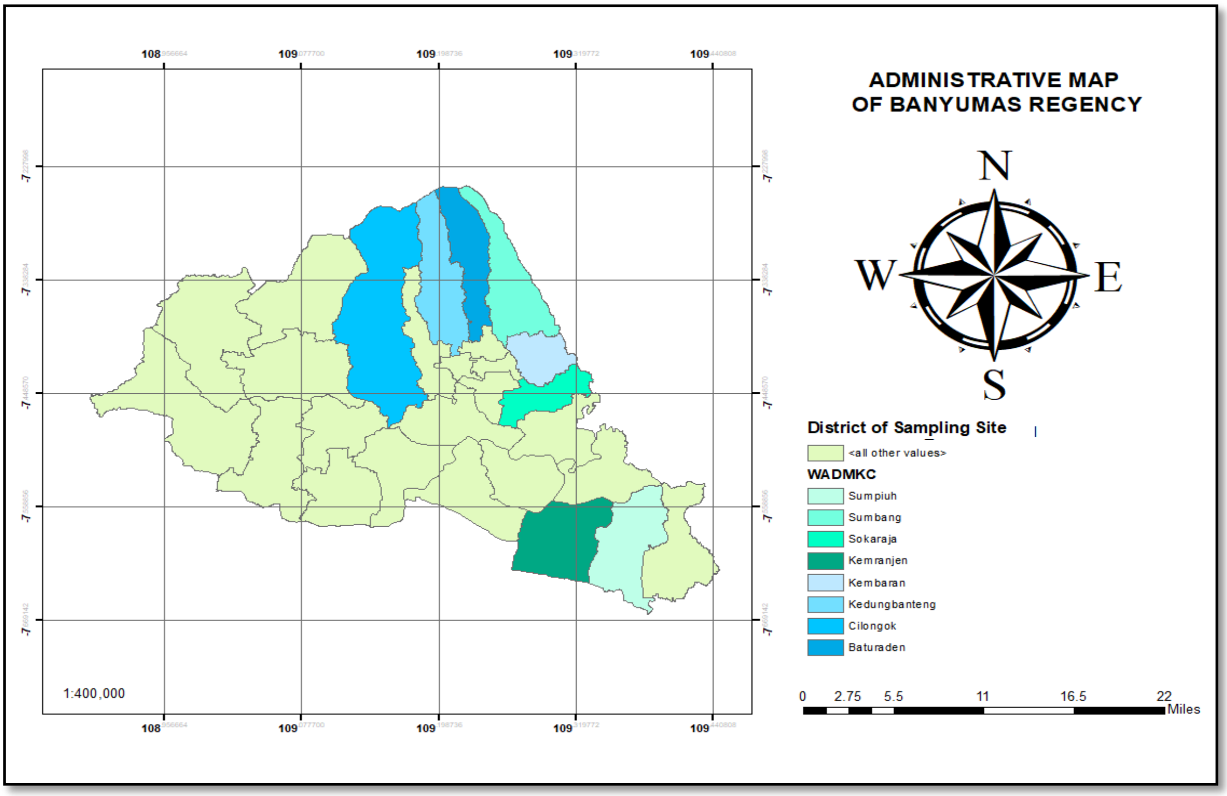

Figure 1. Location of 8 Sampling Subdistrict

There were eight subdistricts in Banyumas District used as sampling points: Kembaran (5), Sumbang (3), Sokaraja (3), Baturraden (3), Kedungbanteng (4), Kemranjen (4), Sumpiuh (2), and Cilongok (6), which can be seen in Figure 1. The sampling method employed was snowball sampling, resulting in 30 chicken farms with three types of coops: open house, semi-enclosed, and enclosed house. In addition to airborne microbial counts, this study also measured particulate matter (PM). Particles smaller than 10 micrometres are called PM_{10}, Ammonia (NH_3), temperature, and air humidity. Data was collected in February-March 2022, when the season was generally classified as rainy. However, data collection was chosen in the morning and when there was no rain. The 30 chicken farms are divided into 11 farms of open livestock farming type, nine types of semi-closed type and ten types of closed farming type. Weather, topography, and climatic conditions have uniform characteristics because they are in the same district area.

Ammonia measurements were carried out using the Ammonia Smart Gas Detector AR 8500. This tool works based on electrochemical principles. Electrochemical sensors were electrochemical measuring transducers for measuring the partial pressure of gases in atmospheric conditions. The monitored ambient air diffuses through the membrane into the electrolyte fluid in the sensor. The voltage, electrolyte, and electrode material were selected according to the NH_3 being monitored so that it is electrochemically converted at the measuring electrode, and current flows through the sensor. This current is proportional to the gas concentration [14].

Microbiological air sampling was carried out through impingement, which captured air particles forced into a binding liquid. All equipment components, particularly the impinger tube and binding solution, were sterilized using autoclaving before sampling to maintain aseptic conditions. Air was drawn into a sterile tube containing 20 ml of the binding solution, with a flow rate of 12.5 L/minute and a sampling duration of 20 minutes.

Following the sampling phase, the aerosol-containing binding solution was transported to the laboratory to analyze airborne microbial counts. Subsequently, 0.1 and 1 ml of the solution were aseptically drawn using a sterile volumetric pipette and dispensed onto sterile Petri dishes, inoculated with Plate Count Agar (PCA) using the pour plate method. The Petri dishes were incubated at 35°C for 48 hours. Following the incubation process, bacterial colonies are enumerated utilizing a colony counter. The calculation of airborne microbial counts was performed employing the formula:

$$Air\ \ Microbiology\ \left(\frac{CFU}{M3}\right) = \frac{\text{Bacterial Colony Count Result}}{\text{Air volume}}$$

Air volume = Sampling time (minutes) x 12.5 L/minute.

Airborne dust measurements were taken using a TSI Dusttrak Aerosol Monitor 8532 instrument for 20 minutes.

Before each sampling point, the instrument was calibrated by installing a zero filter and initiating the Zero Cal procedure. Temperature and humidity measurements were performed using a thermohygrometer for 10 minutes.

The data were analyzed using IBM SPSS Statistics 21. The temperature, RH, PM_{10}, NH_3 and total bacterial count values were interpreted as mean and range for each coop type. Following the assessment of normality using appropriate tests, differences in air quality among the three coop types were calculated utilizing the Kruskal-Wallis test. The relationships between each parameter were also analyzed using the Rank-Spearman correlation test.

3. Result

Figure 2 illustrated the results of air temperature (°C) measurements in three types of broiler chicken farms. The average air temperature was 30.98°C, ranging from 25.1–33.9°C. The results of temperature measurements in all types of cages found the lowest temperature was 25.10°C in semi-closed cages located in Cilongok sub-district and the highest temperature was 33.90°C in semi-closed cages located in Kemranjen sub-district. The average temperatures for all types of open, semi-closed, and closed cages were as follows in order: 31.59°C, 30.32°C, and 30.89°C.

Data regarding the results of relative humidity (RH) measurements are presented in Figure 3. RH values ranged from 52%-95%, with an overall average of 72.97% across the 30 farms. The average RH for open-type cages was 64.64%, semi-closed cages 80.78%, and closed cages 75.1%. The lowest relative humidity was recorded in closed cages in Sokaraja District, with a value of 52%.

The results of PM_{10} measurements in broiler farms were depicted in Figure 4. The highest PM_{10} concentration was 5.40 ppm (parts per million) in a semi-enclosed cage located in Cilongok sub-district. The average measurement of PM_{10} concentration in 30 farms was 1.99 mg/m^3 with a range of 1.8-5.4 mg/m^3. The lowest PM_{10} concentration was obtained from closed cages in Kembaran Subdistrict at 1.08 mg/m^3, while the highest value was observed in semi-closed cages in Cilongok Subdistrict at 5.40 mg/m^3. The average PM_{10} for open, semi-closed, and closed cage types were as follows: 2.12 mg/m^3, 2.31 mg/m^3, and 1.58 mg/m^3.

Figure 5 shows the results of ammonia concentration measurements carried out in three types of coops in Banyumas Regency. The ammonia concentration range is between 0 – 4.3 ppm. The measurement results of ammonia concentration showed varying results in all types of cages. In open, closed and semi-closed cage types, no ammonia concentration was found (0 ppm) while the highest ammonia concentration based on the measurement results was found in the semi-closed cage type at 4.3 ppm. The average gas concentration for all types of cages was 0.9 ppm with an average by cage type of 0.57 ppm for open cage type, 0.51 for semi-closed cage type and 0.73 for closed cage type.

The results of airborne bacteria counts (CFU/m^3) for the 30 chicken farms examined are presented in Figure 6. The average airborne bacteria count was 274.37 x 10^3 CFU/m^3, with the highest value found in semi-closed cages in Cilongok subdistrict (686.22 x 10^3 CFU/m^3) and the lowest in open cages in Sumpiuh subdistrict (8.09 x 10^3 CFU/m^3). The average number of bacteria in the air for open cages was 168.85 x 10^3 CFU/m^3, semi-closed was 289.41 x 10^3 CFU/m^3, and closed was 376.91 x 10^3 CFU/m^3.

A comparison test of air quality parameters in 3 types of chicken coops is presented in Table 1. Significant differences were observed among the three coop types for the parameters RH, PM_{10}, NH_3 and total airborne bacteria count ($\propto = 0.05$).

Table 1 shows the results of the comparative test using the kruskall-wallis test, where for humidity variables, PM10 and significant germ numbers in the three types of cages with p values for the open type are 0.029 for humidity, 0.023 for PM10 levels and 0.018 for germ numbers.

Table 2 indicates a relationship between airborne PM10 levels (α=0.01) and total bacteria (α=0.05) with the number of chickens. There is also a relationship between temperature and RH (α=0.01), between temperature and NH_3 (α=0.05) and, between RH and NH_3 (α=0.05). The correlation between airborne PM10 and the number of chickens is inversely proportional, where statistically, the higher the number of chickens in the coop, the lower the dust measurement results. This correlation is classified as vital, with a value of r = -0.62. The correlation between total bacteria and the number of germs is moderate (r = 0.42) with a direct relationship. The correlation between temperature and humidity is strong (r = - 0.56). Higher temperatures are associated with a decrease in air humidity.

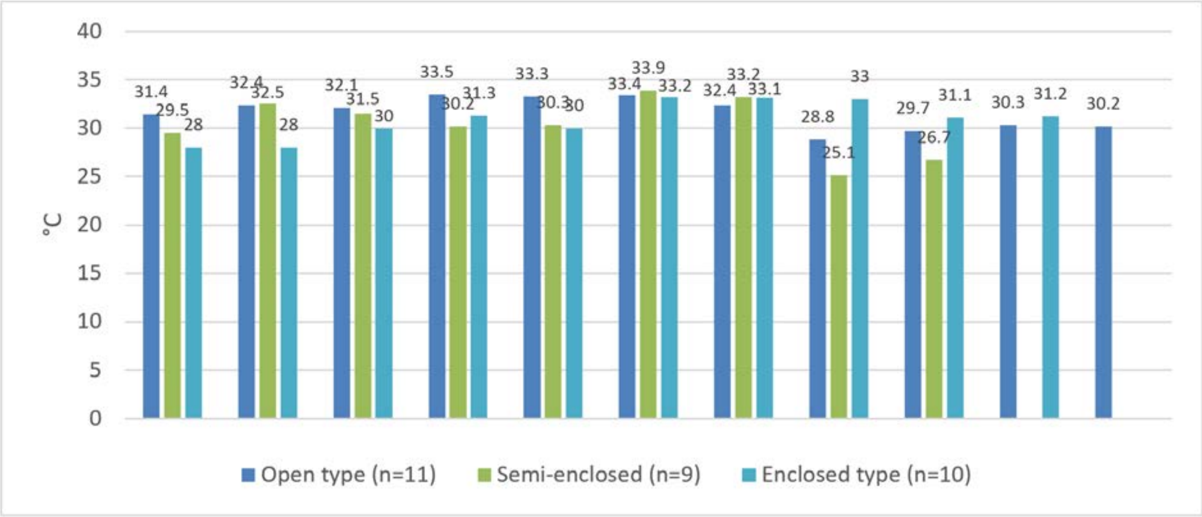

Figure 2. Result of Air Temperature (°C) Measurement

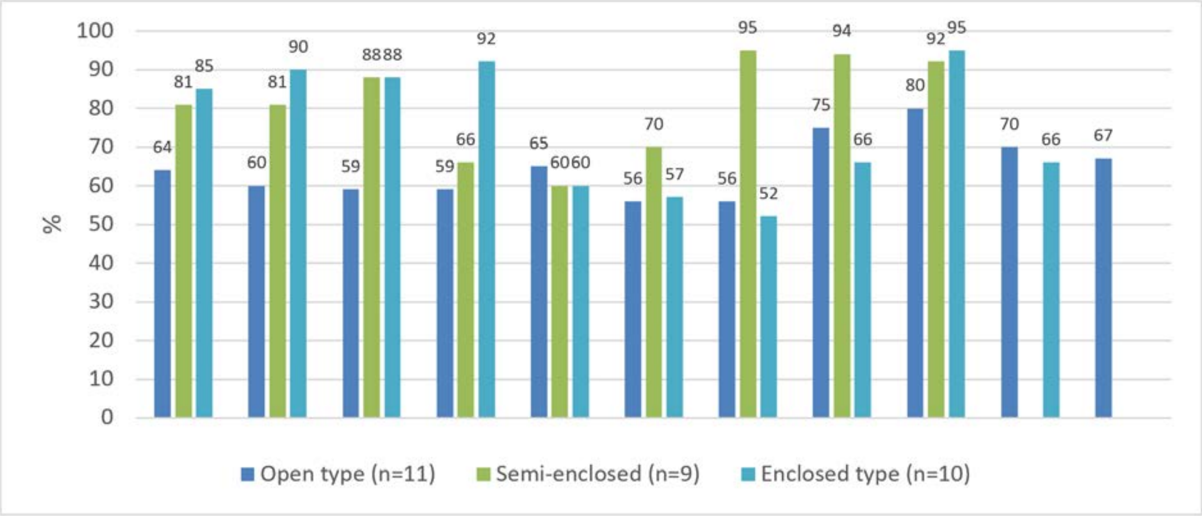

Figure 3. Result of Relative Humidity / RH (%) Measurement

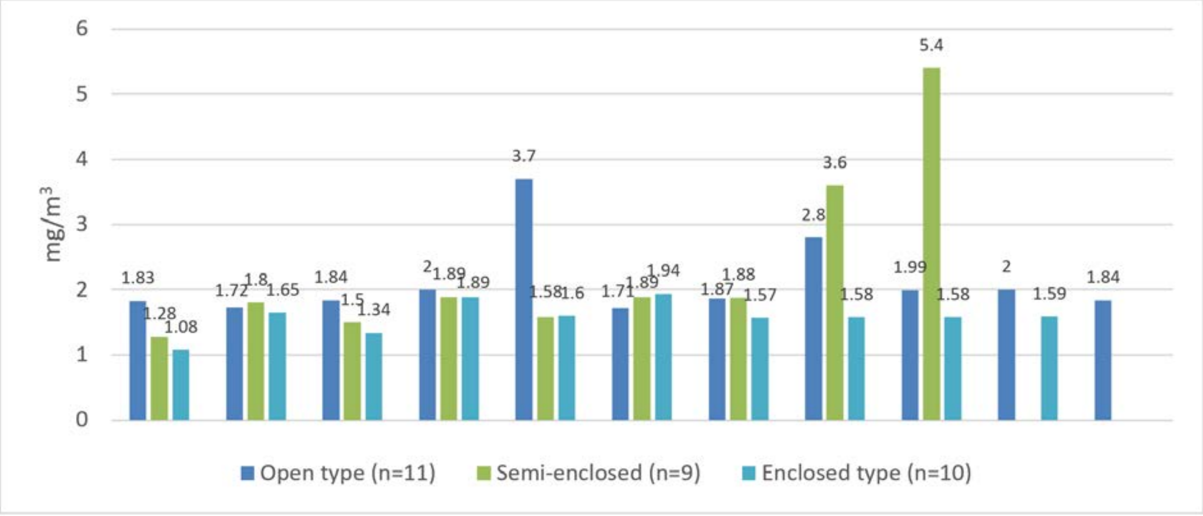

Figure 4. Result of Particulate Matter / PM_{10} (mg/m^3) Measurement

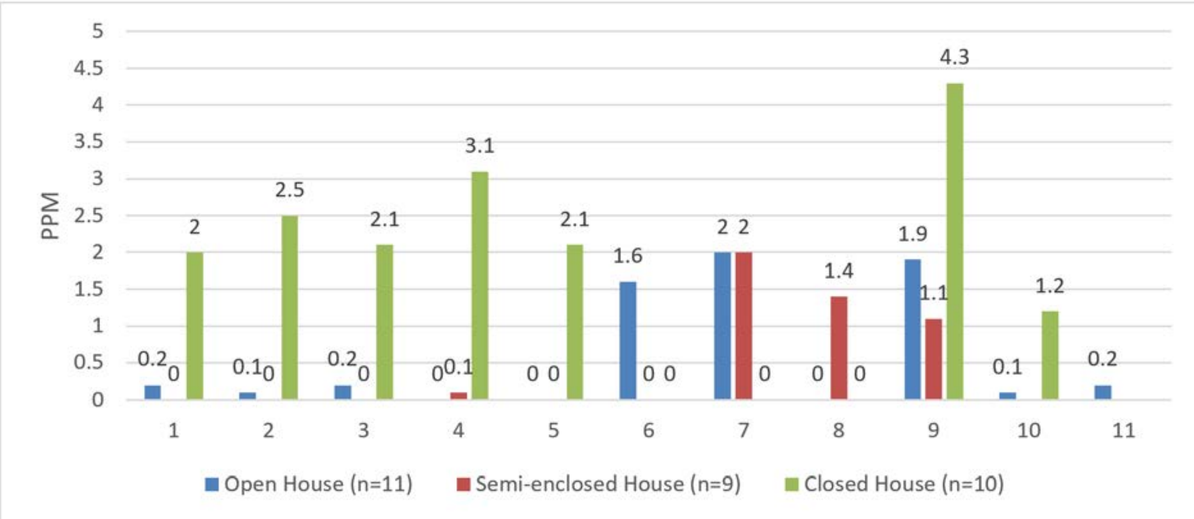

Figure 5. Result of Ammonia /NH_3 (ppm) Measurement

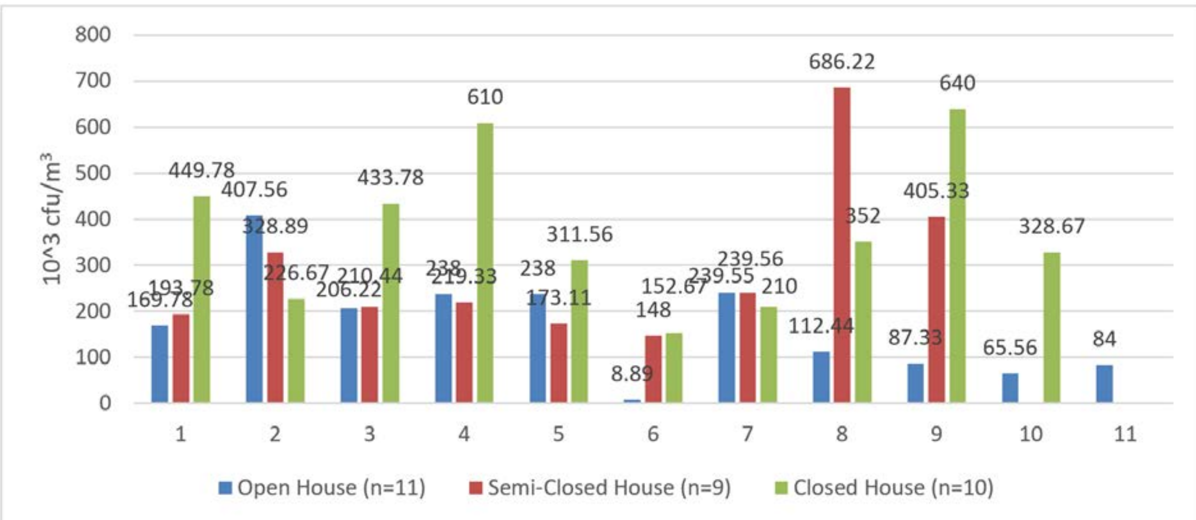

Figure 6. Result of Airborne Total Bacteria (CFU/m^3) Measurement

Table 1. Results of Kruskal-Wallis Test

Indoor Air Quality	*p*	Mean Rank			SD
		Open Coops	Semi-enclosed Coops	Enclosed Coops	
Temperature (°C)	0.547	17.82	14.17	14.15	2.165
RH (%)	0.029*	10.32	20.67	16.55	11.875
PM_{10} (mg/m^3)	0.023*	20.18	16.22	9.70	0.855
NH_3 (ppm)	0.089	14.45	11.67	20.17	1.168
Airborne Total Bacteria (CFU/m^3)	0.018*	10.05	16.17	20.90	168.397x10^3

Table 2. Result of Rank Spearman Test

	Number of Chicken	Chicken's Age	Temperature (°C)	RH (%)	PM10 (mg/m^3)
Temperature (°C)	-0.12	-0.18			
RH (%)	0.05	-0.05	-0.514**		
PM_{10} (mg/m^3)	-0.62**	-0.05	0.06	-0.01	
Ammonia (ppm)	0.147	0.34	-0.394*	0.392*	
Total Airborne Bacteria (CFU/m^3)	0.46*	-0.11	-0,20	0.27	-0.18

Many studies have indicated that the air quality in chicken farms triggers respiratory problems such as nasal irritation, dry cough, asthma, and asthma-like symptoms [15]. This issue is linked to air pollution commonly occurring in the form of respirable and inhalable dust, chemical hazards (H_2S, NH_3, CO), as well as biological hazards present in the air [16]. The level of air pollution in chicken coops can be influenced by different coop types in terms of ventilation conditions, floor arrangement, and waste management [17].

Currently, Indonesia lacks dedicated regulations specifying the threshold values for air parameters in chicken farms. However, considering that chicken farms can be categorized as workplaces, environmental regulations related to workplaces can be applied. Minister of Manpower Regulation Number 5 of 2018 serves as a relevant reference for this study. This regulation sets limits for temperature (23°-26°C), relative humidity (40-60%), respirable dust (PM_{10}) at 10 mg/m^3, and total airborne bacteria at 7000 CFU/m^3 [18].

4. Discussion

4.1. Air Temperature (°C)

The average temperature showed equivalent values to some previous studies by Chen [19]. The high temperature in the chicken farm is due to the presence of heaters to regulate the temperature. These heaters are placed with the aim of regulating the temperature in the chickens according to the age range of the chickens. The highest average temperature of 31.59°C was observed in open cages and the highest temperature was recorded in semi-enclosed cages at 33.90°C. The highest temperature for the Enclosed type cage was 33°C and the lowest was 28°C. These results show that the average temperature for all types of cages is in the temperature range >30°C. This temperature difference is due to the absence of technology to lower the temperature in these two types of cages. High temperatures beyond the recommended limits can negatively affect worker productivity [20]. Statistical test results indicate no significant temperature differences among the three coop types (p=0.547) [18]. The statistical results confirmed that there was no significant difference between the temperatures of the different cage types.

The relative humidity (RH) has an average of 70.13%, interpreted similarly to previous studies, categorizing it as exceeding the threshold [16][19]. The lowest average RH is observed in open coops (54%), while the highest RH is recorded in semi-enclosed coops (94%). The elevated RH in semi-enclosed coops aligns with findings from earlier studies [21]. The highest RH for the Enclosed type cage was 95% and the lowest was 52%.These results show that the average temperature for all types of cages is in the temperature range >90%. RH values have a significant difference among the three coop types (p=0.017). The RH in chicken farms is influenced by climatological conditions, as the sampling occurred during the transition from the dry to the rainy season. Some coops experienced rainfall before the sampling, impacting the moisture content in the air [22]. The statistical results confirmed that there was significant difference between the RH of the different cage types.

A negative correlation exists between temperature and air humidity in chicken farms in general (r = -0.56). This is attributed to the type of humidity measurement, which is RH, where RH represents the actual amount of water vapor in the air compared to the current temperature. Warm air contains more water vapor than cold air. Therefore, as the air temperature increases, its relative humidity (RH) decreases [23]. An increase in RH in farms can enhance ammonia evaporation [24] and support the proliferation of fungi in the air [21].

4.2. Particulate Matter / PM_{10} (mg/m^3)

The lowest dust concentration is 1.08 mg/m^3 in enclosed coops, while the highest dust concentration is 5.40 mg/m^3 in semi-enclosed coops. The presence of PM_{10} dust in chicken farms originates from chicken excrement, fine feathers, and other waste materials on the farm. Semi-enclosed coops with the highest values use wood-burning stoves for heating, contributing to the increased PM_{10} levels in the farm air [25].

As previously mentioned, the measured PM_{10} in chicken farms has an average of 1.99 mg/m^3. This value does not exceed the regulatory limit (10 mg/m^3); similarly, the highest dust measurement result is 5.40 mg/m^3. These findings align with previous studies conducted in Korea [26] and Indonesia. The interpretation of the results is comparable as none surpass the established limits.

However, the results from a study conducted in South Sumatra are significantly lower than the findings of this research, with the unit used being µg/m^3 [27].

There is a strong and inverse relationship between dust and the number of chicken in the examined farms. This finding contradicts previous research that focused on Enclosed coop types [6]. PM_{10} levels in chicken farms are influenced by various factors, including wind speed, air pressure, and the intensity of coop cleaning [28]. In this study, the highest chicken population is observed in enclosed coops. Enclosed coops feature more modern technology, including fans, compared to the other two coop types. Due to the technological differences among the three coops, enclosed coops with a higher chicken population exhibit lower dust levels, consistent with the Mean Rank Kruskal-Wallis results in Table 1.

4.3. Ammonia / NH_3 (ppm)

The concentration of ammonia gas (NH_3) in 30 cages in Banyumas Regency has an average of 0.94 ppm. The average concentration of ammonia gas in the open house, semi-closed house, and closed house types is 0.57 ppm, 0.51 ppm, and 1.73 ppm respectively. All of these results are still below the Threshold Limit Value (NAB) determined by Minister of Health Regulation No. 5 of 2018 (25 ppm).

The low concentration of ammonia gas (NH_3) is caused by several factors including the provision of rice husks for the cage floor [29], the intensity of chicken manure disposal [15], and the air circulation in the cage [30]. Apart from that, data collection was carried out when there was not much activity in the cage so that no droppings were flying around and increasing the concentration of NH_3 in the air [24].

The results of the Kruskal-Wallis test showed that the concentration of NH_3 gas in the three types of cages did not have a significant difference ($p > 0.05$). The third cage that was measured used rice husks as litter material. This material can absorb NH_3 and NH_{4+} so that emissions into the chicken coop are lower [29]. There has been no previous research that specifically differentiates NH_3 concentrations in the 3 types of chicken coops. The open and semi-closed house-type cages have relatively similar manure control by removing the manure when the chicken reaches 20 days of age, while the Enclosed house type only cleans the manure after the harvest period is over. There is a significant difference between manure control and NH_3 gas concentration [31]. If compared, the results of this study are in a different direction from these results.

Several things were explained that caused there to be no significant differences, including measuring the concentration of ammonia gas (NH_3) in the third cage was carried out at the closest time, where the age of the chicken in each cage varied greatly. 3 Enclosed-house type cages have low ammonia concentrations so they are not detected by equipment (< 0.1 ppm). This affects the lifespan of chicken in the third cage which is <10 days [32]. Statistically, this value of 0 lowers the mean rank of close-house cages and causes the results to have no differences between the three types of cages.

The open and semi-Enclosed house types have almost the same average. These two types of cages have a lower chicken capacity compared to Enclosed houses. However, both have a hollow floor type. This allows chicken manure as the main source of ammonia gas (NH_3) to be exposed to the air so that the concentration becomes lower [33]. Closed-house cages that have the most advanced technology had the highest average NH_3 concentration in this study, although statistically, the difference was not significant compared to the other two types. The performance of Enclosed-house enclosures is greatly influenced by fan conditions. If conditions are bad, a tunnel effect can form so that ammonia gas (NH_3) that should be released circulates inside the cage [34].

The results of the Spearman Rank test show that there is a positive influence of RH on NH_3 levels in the air. This is in line with previous research which found that increasing RH can increase NH_3 volatilization [35]. The higher the RH value, the damper and softer the chicken droppings will be [36]. This condition supports N mineralization due to microbial activity and various enzymatic reactions [37].

On the other hand, the Spearman Rank test shows a negative relationship between temperature and NH_3 with a correlation coefficient of -0.394. This is different from the interpretation of previous studies where temperature has a positive correlation with NH_3 levels. Theoretically, the relationship between temperature and NH_3 is described by Henry's law and constant equilibrium [38]. However, other studies state that high temperatures (>32°C) result in NH_3 volatilization [39]. Meanwhile, the average temperature in this study was 30.98°C and there was no statistical difference in temperature between the three types of cages. Apart from temperature, other factors influence the existence of NH_3, including humidity, wind speed, rain, and the presence of sunlight [40].

4.4. Total Airborne Bacteria (CFU/m^3)

This study's airborne bacteria count measurements shown in Figure 6 fall within a range similar to several previous studies [41] However, when compared to workplace airborne bacteria count standards, all results in this study are considered to exceed the threshold. The bacterial count in chicken farms is influenced by meteorological conditions such as temperature and humidity [19]. Meanwhile, statistical tests in this study indicate divergent interpretations, as shown in Table 2.

There is also a study that yielded consistent results with this research, where RH does not play a significant role in relation to the airborne bacteria count in chicken farms [42]. In addition to meteorological conditions, the type of flooring and coop type can impact the variation in the total bacterial count [33]. This is further illustrated in Table 2, where Spearman's correlation indicates significant differences in airborne bacterial counts among the three coop types.

Several studies have stated that the primary source of microbial contamination in the air of chicken farms is their excrement [43]. The amount of chicken excrement increases with the number of chicken being raised. Therefore, it is reasonable for this study's results to show a significant relationship between the number of chicken and the airborne bacteria count, as presented in Table 2. On average, Open-type chicken coops have fewer chicken than the other types (n = 3545). This coop type also allows sunlight to enter with ample ventilation, leading to natural disinfection of the air within it [44]. Furthermore, almost all observed open coops practice removing the coop floor when the chicken are over 20 days old, allowing their excrement to fall outside the coop. Conversely, the presence of fans in enclosed coops can contribute to the spread of bioaerosols up to a distance of approximately 20 meters [45].

An environmentally friendly solution that can be used to control airborne germs is nanosilver technology. Silver has historically been known to function as an antimicrobial agent with its ability to inhibit bacterial growth. Silver innovation in the form of nanosilver has a size that is much smaller than the size of microbes. Physically, biologically and chemically, the characteristics of different substances can cause various unexpected reactions [46].

5. Conclusions

The research results indicate that the average temperature, RH, and airborne bacterial count surpass the established limits set by the Indonesian government. However, PM_{10} and NH_3 levels in all observed coops remain below this limit. Significant differences are observed for RH, PM_{10}, NH_3, and airborne bacterial count parameters among the open, semi-enclosed, and Enclosed broiler chicken coop types.

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REFERENCES

[1] D. Maryani, E. Herawati, T. Kusmayadi, T. Rohayati, and T. Nurhayatin, “Analysis of Driving Factors of Public Interest in Broiler Chicken Livestock Business in Karangpawitan Garut,” *JANHUS J. Ilmu Peternak. J. Anim. Husb. Sci.*, vol. 5, no. 1, p. 98, 2020, doi: 10.52434/janhus.v5i1.1117.

[2] Badan Pusat Statistik RI, “Populasi Ayam Ras Pedaging menurut Provinsi,” *Badan Pusat Statistik RI*. p. https://www.bps.go.id/indicator/24/478/1/populasi-, 2021.

[3] S. Mastuti, E. Yuwono, R. Widiyanti, N. N. Hidayat, and L. Setiana, “Analysis of Population Trends and Zooning Development of Commercial Broiler Chicken in Banyumas Regency,” in *Journal Animal Production*, 2020, pp. 204–211.

[4] B. Wu, L. Qin, M. Wang, T. Zhou, Y. Dong, and T. Chai, “The composition of microbial aerosols, PM2.5, and PM10 in a duck house in Shandong province, China,” *Poult. Sci.*, vol. 98, no. 11, pp. 5913–5924, 2019, doi: 10.3382/ps/pez365.

[5] R. L. Górny, “Microbial aerosols: Sources, properties, health effects, exposure assessment—A review,” *KONA Powder Part. J.*, vol. 37, no. 37, pp. 64–84, 2020, doi: 10.14356/kona.2020005.

[6] Y. Zhang *et al.*, “Association between organic dust exposure and adult-asthma: A systematic review and meta-analysis of case-control studies,” *Allergy, Asthma Immunol. Res.*, vol. 11, no. 6, pp. 818–829, 2019, doi: 10.4168/aair.2019.11.6.818.

[7] W. Yang *et al.*, “Detection and analysis of fine particulate matter and microbial aerosol in chicken houses in Shandong Province, China,” *Poult. Sci.*, vol. 97, no. 3, pp. 995–1005, 2017, doi: 10.3382/ps/pex388.

[8] R. B. Bist, S. Subedi, L. Chai, and X. Yang, “Ammonia emissions, impacts, and mitigation strategies for poultry production: A critical review,” *J. Environ. Manage.*, vol. 328, no. November 2022, p. 116919, 2023, doi: 10.1016/j.jenvman.2022.116919.

[9] R. P. Padappayil and J. Borger, “Ammonia Toxicity,” 11 Maret. Accessed: Nov. 22, 2023. [Online]. Available: https://www.cdc.gov/niosh/topics/ammonia/default.html

[10] N. A. Setianto, I. Ismoyowati, H. Aunurrohman, and V. Armelia, “Productivity of Broiler Chicken Farming Business Using Semi Closed House Cage Type Company Partnership Pattern in Kebumen District,” in *Prosiding Seminar Teknologi dan Agribisnis Peternakan VIII–Webinar: “Peluang dan Tantangan Pengembangan Peternakan Terkini untuk Mewujudkan Kedaulatan Pangan,”* 2021, pp. 24–25. [Online]. Available: http://jnp.fapet.unsoed.ac.id/index.php/psv/article/view/1214%0Ahttp://jnp.fapet.unsoed.ac.id/index.php/psv/article/download/1214/545

[11] F. N. Falah, “Kandang Ayam Closed House: Pengertian dan Keunggulannya,” Chickin Blog. Accessed: Feb. 25, 2024. [Online]. Available: https://chickin.id/blog/kandang-ayam-closed-house-pengertian-dan-keunggulannya/

[12] R. Prihandanu, A. Trisanto, and Y. Yuniati, “Model Sistem Kandang Ayam Closed House Otomatis Menggunakan Omron Sysmac CPM1A 20-CDR-A-V1,” *Electrician*, vol. 9, no. 1, pp. 54–62, 2015.

[13] Banyumas District Government, “Letak Geografis.” Accessed: Jan. 11, 2024. [Online]. Available: https://www.banyumaskab.go.id/page/307/letak-geografis

[14] D. Kwak, Y. Lei, and R. Maric, “Ammonia gas sensors: A comprehensive review,” *Talanta*, vol. 204, pp. 713–730, 2019, doi: 10.1016/j.talanta.2019.06.034.

[15] T. J. Ogunleye, A. M. Taiwo, T. F. Akinhanmi, L. O. Oyediran, and T. A. Arowolo, “Assessment of air quality, health status and lung function of workers from selected poultry management systems in Ogun State, Nigeria,” *Clin. Epidemiol. Glob. Heal.*, vol. 18, no. October, p. 101159, 2022, doi: 10.1016/j.cegh.2022.101159.

[16] Hamid, A. S. Ahmad, and N. Khan, “Respiratory and Other Health Risks among Poultry- Farm Workers and Evaluation of Management Practices in Poultry Farms,” *Rev. Bras. Cienc. Avic. / Brazilian J. Poult. Sci.*, vol. 20, no. 1, pp. 111–118, 2018, doi: 10.1590/1806-9061-2017-0513.

[17] H. E. Polat, “Effects of Poultry Building Design on Indoor Air Quality in Humid Climates,” *J. Anim. Plant Sci.*, vol. 25, no. 5, pp. 1264–1272, 2015.

[18] Minister of Manpower, “Peraturan Menteri Tenaga Kerja No 5/2018 K3 Lingkungan Kerja,” *Permenakertrans*, vol. 5, pp. 1–258, 2018, [Online]. Available: https://jdih.kemnaker.go.id/keselamatan-kerja.html

[19] G. Chen *et al.*, “Aerosol Concentrations and Fungal Communities Within Broiler Houses in Different Broiler Growth Stages in Summer,” *Front. Vet. Sci.*, vol. 8, no. December, pp. 1–9, 2021, doi: 10.3389/fvets.2021.775502.

[20] J. E. Wardana, O. C. Dewi, and J. S. Sari, “Comfortable Room Condition for Working and Resting,” *J. Archit. Des. Urban.*, vol. 3, no. 2, pp. 59–71, 2021, doi: 10.14710/jadu.v3i2.10501.

[21] R. Adams, B. I. Idemudia, E. E. Imarhiagbe, B. Ikhajiagbe, Emmanuel Ukpebor, and F. O. Ekhaise, “Comparative Assessment of Indoor and Outdoor Air Environment of Poultry Farms in Edo State, Nigeria,” *Studia Universitatis Babes-Bolyai Biologia,* vol. 67, no. 1, 2022, doi: 10.24193/subbbiol.2022.1.06.

[22] J. P. Harrouz, D. Al Assaad, M. Orabi, K. Ghali, D. Ouahrani, and N. Ghaddar, “Modeling and Optimization of Poultry House Passive Cooling Strategies in Semiarid Climates,” *Int. J. Energy Res.*, vol. 45, no. 15, pp. 20795–20811, 2021, doi: 10.1002/er.7139.

[23] S. Valsson and A. Bharat, “Impact of Air Temperature on Relative Humidity - A study,” *Architecture*, no. February, pp. 38–41, 2011.

[24] E. S. Soliman and R. A. Hassan, “Influence of Housing Floor on Air Quality, Growth Traits, and Immunity in Broiler Chicken Farms,” *Adv. Anim. Vet. Sci.*, vol. 8, no. 9, pp. 997–1008, 2020, doi: 10.17582/JOURNAL.AAVS/2020/8.9.997.1008.

[25] G. W. Fuller, A. H. Tremper, T. D. Baker, K. E. Yttri, and D. Butterfield, “Contribution of Wood Burning to PM10 in London,” *Atmos. Environ.*, vol. 87, pp. 87–94, 2014, doi: 10.1016/j.atmosenv.2013.12.037.

[26] K. Y. Kim and H. J. Ko, “Field Survey on Concentration and Emission of Dust in Different Types of Poultry Houses of South Korea,” *Atmosphere (Basel).*, vol. 11, no. 5, pp. 1–10, 2020, doi: 10.3390/atmos11050530.

[27] A. F. Nurhidayah and U. Niken, “Improvement of Hydrogen Sulfide, Particulate Matter 10 um and Differential Leukocytes on Different Rearing Temperatures of Broilers,” *J. Peternak. Sriwij.*, vol. 12, no. 1, pp. 41–49, 2022.

[28] S. Zhang, L. Zhou, L. Jia, J. Li, B. Liu, and Y. Yuan, “Numerical Simulation on Particulate Matter Emissions from a Layer House during Summer in Northeast China,” *Atmosphere (Basel).*, vol. 13, no. 3, 2022, doi: 10.3390/atmos13030435.

[29] H. A. Alarefee, C. F. Ishak, R. Othman, and D. S. Karam, “Effectiveness of mixing poultry litter compost with rice husk biochar in mitigating ammonia volatilization and carbon dioxide emission,” *J. Environ. Manage.*, vol. 329, no. May 2022, p. 117051, 2023, doi: 10.1016/j.jenvman.2022.117051.

[30] M. D. Oliveira, F. C. Sousa, J. O. Saraz, A. A. Calderano, I. F. F. Tinôco, and A. P. S. Carneiro, “Ammonia emission in poultry facilities: A review for tropical climate areas,” *Atmosphere (Basel).*, vol. 12, no. 9, pp. 1–12, 2021, doi: 10.3390/atmos12091091.

[31] J. L. Oliveira, H. Xin, L. Chai, and S. T. Millman, “Management and production: Effects of litter floor access and inclusion of experienced hens in aviary housing on floor eggs, litter condition, air quality, and hen welfare,” *Poult. Sci.*, vol. 98, no. 4, pp. 1664–1677, 2019, doi: 10.3382/ps/pey525.

[32] H. Li, X. Wen, R. Alphin, Z. Zhu, and Z. Zhou, “Effects of two different broiler flooring systems on production performances, welfare, and environment under commercial production conditions,” *Poult. Sci.*, vol. 96, no. 5, pp. 1108–1119, 2017, doi: 10.3382/ps/pew440.

[33] S. Heitmann *et al.*, “Effects of a slatted floor on bacteria and physical parameters in litter in broiler houses,” *Vet. Anim. Sci.*, vol. 9, no. April, 2020, doi: 10.1016/j.vas.2020.100115.

[34] V. I. Trokhaniak, N. A. Spodyniuk, O. M. Trokhaniak, O. V. Shelimanova, P. H. Luzan, and O. R. Luzan, “Investigation of the Influence of Exhaust Fan’S Location on the Upper Line on Poultry House Aerodynamics With the Use of Cfd,” *INMATEH - Agric. Eng.*, vol. 67, no. 2, pp. 425–432, 2022, doi: 10.35633/INMATEH-67-43.

[35] R. K. Tabase, G. Næss, and Y. Larring, “Ammonia and Methane Emissions from Small Herd Cattle Buildings in a Cold Climate,” *Sci. Total Environ.*, vol. 903, no. August, p. 166046, 2023, doi: 10.1016/j.scitotenv.2023.166046.

[36] C. Delon, C. Galy-lacaux, D. Serça, E. Personne, E. Mougin, and M. Adon, “Modelling Land – Atmosphere Daily Exchanges of NO, NH_3, and CO_2 in a Semi-arid Grazed Ecosystem in Senegal,” *Biogeosciences*, vol. 16, no. 2, pp. 2049–2077, 2019.

[37] K. Cassity-Duffey, M. Cabrera, and J. Rema, “Ammonia Volatilization from Broiler Litter: Effect of Soil Water Content and Humidity,” *Soil Sci. Soc. Am. J. B*, pp. 543–550, 2015, doi: 10.2136/sssaj2014.07.0294.

[38] R. K. Tabase, G. Næss, and Y. Larring, “Ammonia and Methane Emissions from Small Herd Cattle Buildings in a Cold Climate,” *Sci. Total Environ.*, vol. 903, no. August, p. 166046, 2023, doi: 10.1016/j.scitotenv.2023.166046.

[39] D. E. Jiménez-de-Santiago, J. Ovejero, M. Antúnez, and A. D. Bosch-Serra, “Ammonia Volatilization from Pig Slurries in a Semiarid Agricultural Rainfed Area,” *Sustainability*, vol. 16, pp. 1–11, 2024.

[40] J. Pedersen, T. Nyord, A. Feilberg, and R. Labouriau,

"Analysis of The Effect of Air Temperature on Ammonia Emission from Band Application of Slurry," *Environ. Pollut.*, vol. 282, p. 117055, 2021, doi: 10.1016/j.envpol.2021.117055.

[41] P. Douglas, S. Robertson, R. Gay, A. L. Hansell, and T. W. Gant, "A systematic review of the public health risks of bioaerosols from intensive farming," *Int. J. Hyg. Environ. Health*, vol. 221, no. 2, pp. 134–173, 2018, doi: 10.1016/j.ijheh.2017.10.019.

[42] X. Xu *et al.*, "Airborne Bacterial Communities in The Poultry Farm and Their Relevance with Environmental Factors and Antibiotic Resistance Genes," *Sci. Total Environ.*, vol. 846, no. July, p. 157420, 2022, doi: 10.1016/j.scitotenv.2022.157420.

[43] Q. A. Almatawah, H. S. Al-khalaifah, A. S. Aldameer, A. K. Ali, A. H. Benhaji, and J. S. Varghese, "Microbiological Indoor and Outdoor Air Quality in Chicken Fattening Houses," *J. Environ. Public Health*, pp. 1–10, 2023.

[44] W. Hiwar, M. F. King, H. Kharrufa, E. Tidswell, L. A. Fletcher, and C. J. Noakes, "The impact of ventilation rate on reducing the microorganisms load in the air and on surfaces in a room-sized chamber," *Indoor Air*, vol. 32, no. 11, pp. 1–11, 2022, doi: 10.1111/ina.13161.

[45] B. L. Smith and M. D. King, "Sampling and Characterization of Bioaerosols in Poultry Houses," *Microorganisms*, vol. 11, no. 8, 2023, doi: 10.3390/microorganisms11082068.

[46] M. Raharjo, A. Subagio, Sulistyani, and Y. Aryanti, "Synthesis of Nanosilver Nitrate for Vector Control (aedes aegypti) in Banjarnegara, Central Java (Case of Endemic Area DHF Banjarnegara)," *J. Commun. Dis.*, vol. 53, no. 1, pp. 62–66, 2021, doi: 10.24321/0019.5138.202110.