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IJAM:

International Journal of Advanced Multidisciplinary

<http://greenpub.org>greenation.info@gmail.comDOI: <https://doi.org/10.38035/ijam.v5i2>
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Analysis of The Application of A Natural Ventilation System To Improve Air Quality in Laying Hen Houses (Case Study: A Laying Hen House in Banyumas)

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Abstract: Air quality is an important aspect in laying hen housing because it is closely related to thermal conditions, animal comfort, health, and productivity. Poor air circulation may cause heat and humidity accumulation and increase the concentration of pollutants such as ammonia (NH₃), carbon dioxide (CO₂), and airborne particles. The research gap addressed in this study is that most prior work on poultry-house air quality has focused on measuring environmental parameters in operating houses, while relatively little attention has been given to how air-quality principles can be integrated into the architectural design of a house before it becomes operational. This study aims to analyze the application of air-quality principles in the design of a laying hen house located in Banyumas, Stabat, Langkat Regency, North Sumatra. The study uses a qualitative descriptive approach through literature review, previous studies, comparative studies, and analysis of the proposed building design. The proposed house applies natural ventilation through openings on both sides of the building to create cross ventilation. A ridge vent is also provided at the highest part of the roof to facilitate the release of hot air from the building. In addition, the house is designed as a raised structure with a manure collection system using a movable tarpaulin placed beneath the battery cage; manure is planned to be removed periodically to reduce prolonged accumulation as one of the potential sources of ammonia. The analysis indicates that the combination of side openings, ridge ventilation, raised construction, and periodic manure removal has the potential to support better air exchange and reduce the accumulation of heat, humidity, and pollutants inside the poultry house. The **novelty** of this study lies in integrating natural-ventilation design principles with a manure-handling strategy at the design stage of a not-yet-operational commercial laying-hen house, rather than evaluating an already-operating facility. Since the building is still under construction, the effectiveness of the proposed design has not yet been verified through direct field measurements; further evaluation after the building becomes operational is therefore required to measure temperature, relative humidity, airflow velocity, NH₃, CO₂, and particulate concentrations.

Keywords: Air Quality, Ammonia, Cage Design, Cross Ventilation, Laying Hens, Natural Ventilation, Poultry House.

INTRODUCTION

Laying-hen farming is one of the important sectors in the livestock industry because it supplies eggs, a source of animal protein with high nutritional value that is consumed across a broad range of society. Along with population growth and rising food demand, the demand for eggs continues to increase, driving the development of laying-hen enterprises with more intensive rearing systems. The application of modern housing systems such as the battery cage is intended to improve production efficiency, simplify flock management, and maximize the productivity of the birds (Moula et al., 2013). However, intensive rearing systems also raise several challenges, one of which is controlling the environmental quality of the house, particularly air quality.

Air quality inside the house is an environmental factor that strongly affects the health, welfare, and productivity of laying hens. Good air conditions create a comfortable environment so that the birds can grow and produce optimally, whereas poor air quality can cause physiological disturbances, increase the risk of respiratory disease, reduce feed intake, and ultimately reduce egg production and quality (Rajashekher Reddy et al., 2007; Ruzal et al., 2011). Elevated temperature and humidity in particular induce heat stress, which has been shown to significantly reduce feed intake, egg-production rate, and egg quality in laying hens kept under hot and humid conditions (Kim et al., 2024). In addition to affecting bird performance, poor air quality can also harm the health of farm workers and cause environmental pollution around the farm (Kılıç & Yashoğlu, 2014).

Air quality in poultry houses is influenced by several key parameters, including air temperature, relative humidity, air velocity, the concentration of ammonia gas (NH_3), carbon dioxide (CO_2), and dust content (Groot Koerkamp et al., 1998; Prodanov et al., 2016). These parameters are interrelated in forming the microclimate condition inside the house. High temperature and humidity can accelerate manure decomposition, thereby increasing ammonia formation (Zhu et al., 2011; Kılıç, 2017). On the other hand, inadequate ventilation causes hot air, moisture, hazardous gases, and dust to accumulate inside the house, further worsening air quality (Lonc & Plewa, 2009). Consequently, the ventilation system becomes one of the most important aspects in creating a healthy housing environment.

Various studies show that natural ventilation is able to enhance air exchange inside the house, thereby helping to reduce the accumulation of heat, humidity, and harmful gas concentrations (Ruzal et al., 2011; Ni, 2024). The application of cross ventilation and ridge ventilation is one of the passive solutions widely used in livestock and residential buildings in tropical regions because it makes use of natural air movement and buoyancy-driven stack effects without requiring high energy consumption (Samodra & Indrawan, 2017). Besides the ventilation system, waste management also plays an important role in maintaining air quality. Prolonged accumulation of chicken manure increases the decomposition process that produces ammonia gas, so a manure-removal system capable of reducing the accumulation time inside the house is required (Zhu et al., 2011).

In architecture, air quality is influenced not only by the flock-management system but also by building-design decisions. Roof form, building orientation, the size and position of openings, the ventilation system, and waste management are interrelated elements that shape the housing environment. Designing a house that takes into account local climatic conditions and airflow patterns can increase the effectiveness of natural ventilation, thereby creating a better microclimate for laying hens (Samodra & Indrawan, 2017). Design approaches are therefore an important strategy for improving air quality without relying entirely on mechanical ventilation systems.

Most of the studies reviewed above, however, share a common characteristic: they measure air-quality parameters in laying-hen houses that are already operational (e.g., Prodanov et al., 2016; Rajashekher Reddy et al., 2007; Kılıç & Yashoğlu, 2014), or they examine passive-ventilation principles in general residential or urban buildings rather than in

commercial poultry housing (Samodra & Indrawan, 2017). Relatively little attention has been given to how these air-quality and natural-ventilation principles can be deliberately integrated into the architectural design of a laying-hen house before it becomes operational, and fewer studies still connect ventilation strategy with an integrated manure-handling design as a joint pollution-control measure. This is the research gap addressed in this study.

This study takes as its case study the design of a laying-hen house located in Banyumas Village, Stabat District, Langkat Regency, North Sumatra, to analyze the application of natural ventilation and waste management in the design of a laying-hen house. The location was selected because it has a tropical climate characterized by relatively high temperature and humidity, making air-quality control an important aspect of house design. Through this case study, it is expected that insight can be gained into how theories of air quality and ventilation are applied under conditions consistent with the characteristics of the study site.

Based on the description above, this study aims to analyze the application of a natural ventilation system and a manure-management system in improving air quality in a laying-hen house through a case-study approach. The results are expected to serve as a reference for designing healthier and more efficient laying-hen houses that are suited to tropical climatic conditions, and to provide input for the development of livestock-building designs that support animal welfare and environmental sustainability. Based on this description, the research questions of this study are: (1) how is the natural ventilation system applied in the design of the laying-hen house being studied, and (2) how is the manure-management system integrated with the ventilation system to support air quality in the proposed design.

METHODS

This study uses a qualitative descriptive approach aimed at analyzing the application of natural-ventilation and manure-management principles in the design of a laying-hen house. A qualitative descriptive design was chosen because the object under study is a building that is still under construction; the phenomenon being examined is therefore the correspondence between a set of architectural design decisions and established air-quality principles, rather than a measurable, already-occurring environmental condition.

The research object is the three-dimensional design of a commercial laying-hen house located in Banyumas Village, Stabat District, Langkat Regency, North Sumatra — a site selected purposively because it represents the humid tropical climatic conditions typical of laying-hen houses built in Indonesia and because complete design documentation (floor plans, sections, and perspective drawings) was available for analysis. Because the building has not yet become operational, the unit of analysis is the building design itself, together with the underlying literature and comparative studies, rather than field measurements of an operating house. The study was carried out during 2025–2026, corresponding to the period in which the case-study building was under construction.

Data were collected through three main techniques. First, a literature review of scientific publications concerning air quality, ammonia formation, and ventilation in poultry houses was conducted, drawing on peer-reviewed journal articles, and used as the theoretical basis of the study (e.g., Groot Koerkamp et al., 1998; Prodanov et al., 2016; Rajashekher Reddy et al., 2007; Lonc & Plewa, 2009). Second, a review of previous empirical studies on air-quality measurement in laying-hen houses was carried out to identify the parameters that determine air quality and the typical ranges reported for temperature, humidity, NH₃, and CO₂ under natural ventilation (Kılıç & Yashoğlu, 2014; Zhu et al., 2011; Ni, 2024). Third, a comparative study of natural- and mechanical-ventilation systems applied in laying-hen houses in other locations (Brazil, China, and a mechanically ventilated commercial house) was conducted as a reference in evaluating the ventilation strategy adopted in the design under study. In addition, the design documents of the case-study building — including floor plans, sections, and perspective drawings, treated as the study's primary instrument of analysis — were examined to identify

the building elements related to ventilation and manure management, such as the position of side openings, the roof form and ridge vent, the height of the raised structure, and the manure-collection system.

The collected data were analyzed descriptively using a qualitative content-analysis technique, by systematically comparing the ventilation and manure-management strategies applied in the proposed design against the principles identified from the literature review and the comparative studies, element by element (side openings, roof/ridge ventilation, building elevation, and manure collection). This analysis focuses on the qualitative correspondence between the design elements and the established principles of air-quality control (temperature, humidity, airflow, NH_3 , CO_2 , and dust), rather than on quantitative measurement, since the building was not yet operational at the time of the study. The analysis is therefore predictive in nature: it evaluates the potential of the design to support air quality based on established ventilation theory and prior research findings, and identifies the environmental parameters that should be measured once the building becomes operational.

RESULTS AND DISCUSSION

Review of Related Studies

Research on air quality in laying-hen houses has been extensively conducted to determine the influence of environmental conditions on the health and productivity of the flock. Several studies show that air-quality parameters — temperature, humidity, ammonia (NH_3) concentration, carbon dioxide (CO_2) concentration, and dust content — are closely related to the ventilation system and manure management inside the house. The following review of prior studies is used as a basis for understanding the parameters that influence air quality and as a reference for analyzing the application of the ventilation system in the case-study design.

Prodanov, Radeski, and Ilieski (2016), in “Air Quality Measurements in Laying Hens Housing,” evaluated air quality in ten laying-hen houses with similar capacity and management systems, observing temperature, relative humidity, air velocity, oxygen content, CO_2 , NH_3 , hydrogen sulfide, and light intensity. Their results showed that the microclimate inside the house was strongly influenced by ventilation effectiveness: houses with good ventilation maintained more stable temperature and humidity than houses with poor ventilation, and ammonia and CO_2 concentrations tended to rise in houses with low air circulation, particularly as flock density increased and manure was not promptly managed. This study is comprehensive in the number of air-quality parameters measured, but focuses on measuring environmental conditions rather than on how these principles can be applied to building design; it is used in the present study as a basis for selecting the air-quality parameters to be analyzed.

Rajashekher Reddy et al. (2007), in “Assessment of Air Quality in a Poultry House,” evaluated air quality by measuring temperature, relative humidity, NH_3 and CO_2 concentrations, and ventilation conditions. Their findings showed that rising temperature and humidity contributed to increased ammonia formation from manure decomposition, lowering air quality and raising the risk of respiratory disturbance, and that ventilation unable to effectively remove hot air and gases resulted in pollutant accumulation. This study clearly links air-quality parameters to bird health but does not discuss in detail how ventilation form or building design affects air-exchange effectiveness; it therefore serves as a basis for developing the natural-ventilation concept analyzed in this study.

Lonc and Plewa (2009), in “Microbiological Air Contamination in Poultry Houses,” focused on the microbiological contamination of air inside poultry houses, examining bacteria, fungi, and dust particles as indicators of environmental quality. Their results showed that bird activity, feed, feathers, and dried manure produce dust particles that can carry microorganisms, and that higher dust content is associated with higher numbers of airborne bacteria and fungi, potentially affecting the health of both birds and farm workers. This study deepens the

biological dimension of air quality but does not relate its observations to building-design aspects.

Table 1. Summary of Previous Studies

Researcher	Research Focus	Findings	Strengths	Limitations
Prodanov, Radeski, & Ilieski (2016)	Air-quality measurement in laying-hen houses	Ventilation affects temperature, humidity, NH ₃ , and CO ₂	Comprehensive set of parameters observed	Does not discuss application in building design
Rajashekher Reddy et al. (2007)	Air-quality assessment in a poultry house	Ventilation affects NH ₃ formation and bird comfort	Explains the link between air quality and bird health	Does not discuss ventilation design strategy
Lonc & Plewa (2009)	Microbiological air contamination	Dust is a medium for bacterial and fungal dispersal	Addresses the microbiological aspect of air quality	Does not examine building-architecture aspects

Overall, these three studies show that air quality in poultry houses is influenced by several interrelated parameters — temperature, humidity, NH₃ and CO₂ concentration, and dust and microorganism content — and that the ventilation system plays a central role in maintaining microclimate balance through effective air exchange, while waste management is a determining factor because it is directly related to ammonia formation and rising humidity. However, most prior studies concentrate on measuring air-quality conditions and their effects on bird health, while discussion of how air-quality principles are applied within building design remains limited. Aspects such as building orientation, roof form, natural-ventilation systems, and the integration of waste management have not been a primary focus of these studies. This study attempts to fill that gap by analyzing how air-quality theory and prior findings can be applied to the design of the laying-hen house in Banyumas Village, Stabat District, Langkat Regency — an approach that considers not only air-quality parameters but also architectural aspects through the application of cross ventilation, ridge venting, a raised structure, and a manure-management system using a movable tarpaulin as part of the design solution.

A comparative study was also conducted to examine how ventilation and environmental control have been applied in laying-hen houses elsewhere, covering ventilation systems, the position of air openings, building form and configuration, temperature control, and the relationship between the ventilation system and the interior environment.

The first comparison concerns three commercial laying-hen houses on a single farm in Bastos, São Paulo, Brazil, which used tiered cages but different climate-control systems: tunnel ventilation with pad cooling, natural ventilation with nebulization, and simple natural ventilation. The house with simple natural ventilation used openings on the north and south sides, and one of the naturally ventilated houses also had a ventilation dome at the top of the building, allowing air to enter through the side openings and hot air to exit through the top. The results showed that thermal conditions inside the house are related to productivity and bird health, and that better-controlled ventilation systems produced more stable thermal conditions along with higher production and lower mortality. This comparison underlies the use of openings on both sides of the building and roof-level ventilation in the Banyumas design, consistent with a natural-ventilation concept that relies on air movement rather than fully on mechanical equipment.

The second comparison concerns a laying-hen house using natural ventilation in northeastern China, which has ventilation openings on both side walls and several openings along the ridge. Fresh air enters through the side openings while hot, humid air exits through the ridge openings, a flow pattern driven by pressure differences and the thermal buoyancy that occurs as hot air inside the house rises. Ridge ventilation is particularly important when the interior temperature is higher than the outside air, applying the stack effect — the tendency of

hot air to rise — so that providing an outlet at the highest point of the building allows hot, humid air to be released naturally. This comparison forms the main basis for using cross ventilation combined with ridge ventilation in the Banyumas design, in which air is planned to enter from the side of the house through open or mesh-covered areas, move past the bird-rearing area, and then be directed upward and released through roof openings.

The third comparison, used as a counterpoint to natural ventilation, concerns a commercial laying-hen house with negative-pressure mechanical ventilation — a two-story house approximately 152.4 m long and 15.24 m wide, housing about 140,000 laying hens, with fans and controlled air inlets regulating air exchange. Mechanical ventilation offers more controllable air regulation because ventilation rate can be adjusted according to interior conditions, and other studies of laying-hen houses show that ventilation configuration influences the distribution of air velocity, temperature, and humidity within the house, with well-designed systems producing more even air distribution and reducing differences in environmental conditions between areas of the house. Although mechanical ventilation offers greater environmental control, it requires more complex equipment, energy, and operational management than natural ventilation; it is therefore used here as a benchmark for determining an approach appropriate to the characteristics of the design studied. Mechanical ventilation is not adopted as the primary approach in the design, but the principle of even air distribution is retained as a reference, with the design instead relying on natural ventilation through side openings and a ridge vent so that air exchange can proceed passively by making use of wind direction and the upward movement of hot air.

Table 2. Summary of the Comparative Study

Aspect	Study 1: Brazil	Study 2: China	Study 3: Mechanical Ventilation	Case-Study Design
Ventilation system	Natural + cooling system	Natural	Negative-pressure mechanical	Natural
Side openings	Present	Present	Limited/controlled	Present
Roof ventilation	Ventilation dome	Ridge vent	Mechanical exhaust system	Ridge vent
Airflow pattern	Side → interior	Side → top	Fan-controlled	Side → middle → top
Heat outlet	Building top	Ridge vent	Exhaust fan	Ridge vent
Energy use	Low (natural system)	Low	High	Low
Manure management	Not a main focus	Not a main focus	Manure belt	Movable tarpaulin

Based on these three comparisons, side openings combined with ridge ventilation were selected as the approach most suitable for the case-study design: fresh air is planned to enter through the sides of the house, move past the bird-rearing area, and then, as it becomes hot and humid, rise and exit through the ridge vent, allowing air exchange to occur naturally while reducing dependence on mechanical systems. One aspect not extensively addressed in the comparative studies, however, is the integration of ventilation with manure management within a single design approach. In this design, manure is planned to be collected using a tarpaulin placed beneath the battery-cage area and moved periodically, shortening the residence time of manure under the house and thereby helping to control the source of ammonia formation. The

design therefore not only relies on ventilation to remove pollutants from the building but also seeks to reduce the source of pollutants through waste management.

Site Condition and Design Characteristics

The case study in this research is the design of a laying-hen house located in Banyumas, Stabat District, Langkat Regency, North Sumatra. The house is still under construction, and its three-dimensional design is used as the basis for analyzing the application of the ventilation and air-management system. The discussion in this study focuses on how the building design can support suitable air conditions for laying hens, particularly through the use of natural ventilation and the management of airflow inside the house.

The house is designed using a battery-cage system placed within a raised (stilt) structure. The cage floor is positioned higher than ground level, leaving an open space beneath the building. This condition creates a gap between the bird-rearing area and the ground and simultaneously forms part of the manure-management system, since manure falling from the battery cages does not land directly on the ground but is directed toward a collection system using a tarpaulin placed beneath the house.

In terms of air circulation, the design makes use of natural ventilation through openings on the sides of the building. The side walls use elements that allow air from the outside environment to enter the rearing area, enabling direct air exchange without relying entirely on mechanical fans. This is important because the house is situated in an open environment, allowing outside air movement to be utilized as part of the building's ventilation strategy.

The roof form is also designed to support vertical air movement. It has a gable shape with an opening at the ridge so that hot air accumulating at the top of the house can move outward. Because of the difference in air condition between the interior and exterior of the building, the hotter interior air tends to rise, and the ridge opening then serves as its outlet path.



Source: Authors' documentation, 2026.

Figure 1. Front View of the Proposed House Design

Based on the design, the airflow pattern is directed from the sides of the house toward the interior, then upward and out through the roof ridge. The ventilation system therefore does not rely solely on wall openings but also makes use of the building form to assist the release of hot air, consistent with the main objective of this study: to analyze the application of building design in supporting air quality in laying-hen houses.

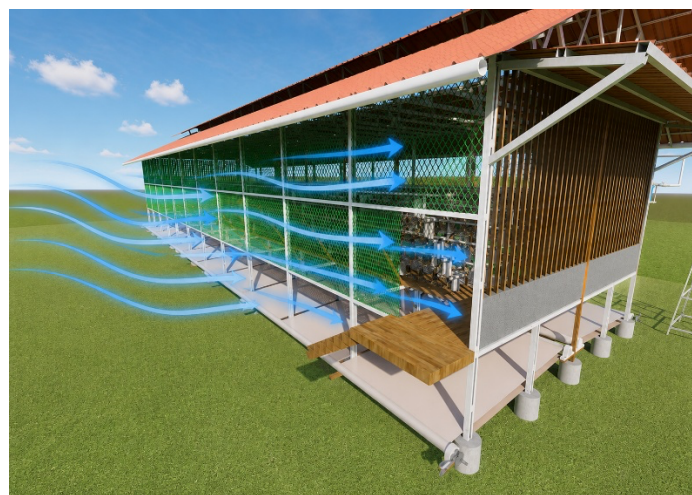
In addition to the ventilation aspect, the raised (stilt) form of the house is also related to controlling sources of air pollution. Chicken manure is one source that can affect air quality if allowed to accumulate for a long time. The design therefore provides a manure-collection system using a tarpaulin that can be moved periodically, allowing manure collected beneath the battery cage to be relocated and cleaned regularly so that it does not remain permanently under the house.

Overall, the design characteristics show an interrelationship among building form, side openings, roof ventilation, building height, and the manure-management system. These elements were further analyzed to determine their potential in supporting air quality in the laying-hen house.

Application of the Natural Ventilation System in the House Design

The ventilation system in the design of the laying-hen house in Banyumas, Stabat, adopts a natural-ventilation approach that makes use of air movement from the surrounding environment as well as the temperature difference between the interior and exterior of the building. This approach is based on the findings of prior studies, which show that ventilation plays an important role in maintaining house air conditions, particularly in controlling temperature and humidity and in helping to remove gases and polluted air generated during the rearing process. The ventilation system in the design therefore functions not merely as a building opening but as part of a strategy for maintaining the quality of the interior environment.

In the design, air openings are placed on both sides of the house. The side walls use open elements — mesh and slat arrangements — that allow air from the surrounding environment to enter the house, providing an inlet path for fresh air while enabling direct air exchange. Using openings on both sides also allows the direction of incoming air to adjust to the surrounding wind movement. With the sides of the building left open, resistance to air movement is reduced, allowing air to reach the bird-rearing area.



Source: Authors' documentation, 2026.

Figure 2. Perspective of the House Design and Airflow Pattern

As illustrated in Figure 2, airflow is planned to enter from both sides of the house and move toward the interior. This pattern forms cross ventilation — an air-exchange process that uses openings on different sides so that air can pass across the interior space. In this design, airflow is directed past the bird-rearing area before moving toward the upper part of the building. This pattern is expected to reduce stagnant-air conditions in the rearing area and to help distribute air more evenly.

Cross ventilation is important because bird activity inside the house generates heat and moisture through metabolism and respiration. If hot, humid air is not promptly replaced by

fresher air, temperature and humidity inside the house can rise. The side openings in the design therefore function as an air-exchange path that allows outside air to replace the air inside the house.

Besides making use of horizontal air movement, the design also uses vertical air movement. Air inside the house that becomes warmer tends to rise. This principle is applied through the roof form, which has a space at the ridge together with a ridge-vent opening as the air-exit path. With an opening at the highest point of the building, hot air accumulating at the top is not trapped inside the house but can be released to the outside environment.

This configuration produces a two-stage airflow pattern: air enters from the sides of the house in the first stage, and hot air exits through the roof ridge in the second stage. The combination of these two mechanisms allows natural air exchange to occur without relying entirely on mechanical ventilation. In the context of the Banyumas house design, this approach is also consistent with a building that has open sides and is situated in an environment that allows outside air movement to be utilized.

The gable roof form in the design plays a role in supporting this mechanism. The slope of the roof creates an upper space where hot air collects before being released through the ridge vent. The roof form therefore serves not only to protect the building from sun and rain but also as part of the natural-ventilation strategy, with the air outlet placed at the highest point so that rising hot air has a clear release path.



Source: Authors' documentation, 2026.

Figure 3. House Section and Direction of Air Movement

Under operating conditions, air entering through the side openings will pass through the battery-cage area, carrying the air surrounding the birds toward the upper part of the building. This movement is expected to help reduce the accumulation of heat, humidity, and pollutant-laden air around the rearing area. This becomes increasingly important because sources of air pollution in the house originate not only from bird activity but also from manure beneath the battery-cage system; ventilation effectiveness should therefore be viewed as part of a system interconnected with manure management.

Solar exposure was not used as a primary parameter in the discussion of air quality in this design. Building orientation and openings are directed more toward supporting natural air

movement and exchange. Solar radiation remains an environmental condition that affects building temperature, but it is not the focus of analysis in this study; the main focus is on how fresh air can enter, move through the rearing area, and exit again through the top of the building.

Based on this application, the house design has a fairly clear airflow path: outside air → side openings → bird-rearing area → upper part of the house → ridge vent → outside air. This path is designed to create continuous circulation so that air inside the house does not stagnate or accumulate in a single area, consistent with prior findings that position ventilation as an important factor in controlling air quality in poultry houses.

However, because the case-study house is still under construction, the effectiveness of this ventilation system cannot yet be confirmed through direct measurement. The analysis in this study is therefore design-based and predictive, assessing the system's potential based on natural-ventilation principles and prior research findings. Accordingly, the application of side openings and a ridge vent in the design is projected to help increase air exchange, reduce the accumulation of heat and humidity, and help remove air containing gases and particles from inside the house.

The ventilation system in the design thus does not stand alone but forms an integrated unit with the building form and the environmental-management system of the house. Side openings function as the air-inlet path, the open space around the battery cage provides room for air to move, and the ridge vent functions as the hot-air release path. The relationship among these three elements is further complemented by the manure-management system, which reduces the source of air pollution inside the house.

Application of the Manure Management System in the House Design

Besides the ventilation system, manure management is another aspect that needs attention in maintaining air quality in a laying-hen house. Chicken manure is one source of air pollution inside the house because the decomposition of organic matter can produce ammonia gas. If manure is allowed to accumulate for a long period, decomposition continues and can increase ammonia concentration as well as produce odor around the house. Reducing the accumulation time of manure is therefore part of the strategy for maintaining the interior environment of the house.

In the Banyumas house design, the battery-cage system is placed on a raised structure, leaving an open space beneath the bird-rearing area. This allows manure produced by the birds to fall to the lower part of the house rather than remaining directly in the rearing area, separating the bird area from the manure-collection area so that bird activity does not come into direct contact with the waste produced.

Beneath the battery cage, a tarpaulin is planned as the medium for collecting manure. It is placed in the space below the house at a distance of about 1.5 m from the cage floor, while the overall building is raised approximately 2 m above ground level. This arrangement provides sufficient space between the bird area and the manure-collection area, while allowing manure-management and removal processes to be carried out from beneath the house.



Source: Authors' documentation, 2026.

Figure 4. Manure Collection System Using a Tarpaulin in the House Design

Manure falling from the battery cage collects on the surface of the tarpaulin. Unlike systems that allow manure to accumulate in one place for a long time, this design uses periodic removal by moving or rolling the tarpaulin so that accumulated manure can be relocated out from beneath the house. This system is intended to shorten the residence time of manure under the house and to prevent excessive accumulation in the collection area.

This system is directly related to air quality because manure is one source of ammonia formation. Ammonia is produced through the decomposition of nitrogen compounds contained in manure, a process supported by moist manure left for a long time. By carrying out periodic removal, the volume of manure beneath the house can be reduced, which is expected to control the source of ammonia formation as well.

Besides reducing the potential for ammonia formation, periodic manure removal also helps maintain the cleanliness of the space beneath the house. Manure left too long inside the building can raise local humidity and produce odor that disturbs the surrounding environment. The tarpaulin system is therefore regarded not merely as a means of relocating waste but as part of the strategy for controlling the house environment.

The raised design of the house further supports this system. The open space beneath the house allows manure to be separated from the bird-rearing area while providing working space for waste management. The building height also allows air to keep moving beneath the house, preventing the collection area from becoming a fully enclosed space — a condition expected to help reduce stagnant air around the manure source.

This manure-management system works together with the natural-ventilation system discussed previously: ventilation helps remove hot, humid, polluted air, while the manure-management system reduces the source of pollutants originating from bird waste. The two systems therefore serve different but mutually supporting functions in maintaining house air quality. The tarpaulin system also offers operational advantages because manure management can be carried out periodically without directly disturbing the bird-rearing area — collected manure can be removed from beneath the house while the birds remain in the battery cages, allowing cleaning and waste-removal processes to be carried out in a more organized manner.

However, because this system remains a design proposal for a house still under construction, its effectiveness in reducing ammonia concentration cannot yet be established through direct measurement. This study can only assess the system's potential based on waste-management principles and their relationship with air quality. The periodic use of a movable

tarpaulin is therefore projected to reduce the accumulation time of manure and, in turn, help reduce the potential formation of ammonia in the house area.

Overall, the manure-management system in the design consists of the battery cage, the space beneath the house, the collection tarpaulin, and the periodic manure-removal mechanism. This system is designed as an integrated part of the natural-ventilation strategy. By reducing the source of pollution while providing an air-outlet path from inside the building, the design is expected to create air conditions that better support the laying hens and the environment surrounding the house.

Analysis of Design Effectiveness on Air Quality

Based on the review of prior studies and the comparative study discussed above, air quality in a laying-hen house is not influenced by a single element but is the result of interaction among ventilation, thermal conditions, bird activity, and manure management. The analysis of the Banyumas house design was therefore conducted by examining the relationship between the natural-ventilation system and the manure-management system applied to the building. Because the house is still under construction, the effectiveness of the design in this study is assessed based on the design's conformity with air-quality principles and prior research findings, rather than on direct field measurement.

One of the main aspects applied in the design is the use of natural ventilation through side openings. Openings on both sides allow air from the surrounding environment to enter the building and move past the bird-rearing area, creating an opportunity for natural air exchange so that the air inside the house is not entirely trapped. This application is consistent with prior findings showing that ventilation plays an important role in controlling house air conditions, particularly in reducing the accumulation of heat and gases generated during the rearing process.

The airflow pattern in the design is directed to form cross ventilation: air enters through the side of the building, moves past the battery-cage area, and is then directed toward the top of the house. This system provides a clearer airflow path than a building with only one-sided openings; with two open sides, air has the opportunity to move across the interior space, helping to reduce areas of low air movement.

In addition to horizontal movement, the design makes use of vertical air movement through the ridge vent at the top of the roof. Hot air forming inside the house tends to rise and collect at the highest point of the building; the ridge opening provides an outlet path so that heat and humidity at the top can be released to the outside environment. The combination of side openings and ridge vent forms a ventilation system that works in two directions of movement, horizontal and vertical.

This roof application distinguishes the design from approaches that rely solely on wall openings. The roof functions not only as a protective element but also to support the release of hot air, making the roof form and configuration part of the natural-ventilation strategy. This is also consistent with the comparative studies, which show the use of side openings and roof-level ventilation as an approach to house air circulation.

In terms of temperature, the applied ventilation system is projected to help reduce heat accumulation inside the house. Birds generate heat through metabolism, and interior temperature can rise if this heat is not effectively removed; prior work has shown that maintaining adequate ventilation at high ambient temperature is directly linked to sustaining egg production, since heat stress reduces feed intake, egg-production rate, and egg quality once the temperature–humidity index rises above a comfortable threshold (Ruzal et al., 2011; Kim et al., 2024). Air entering from the sides of the house can replace the hotter air inside, while hot air moves toward the top and exits through the ridge vent — a buoyancy-driven mechanism consistent with the stack-effect principle applied in passive building design in tropical urban

settings (Samodra & Indrawan, 2017). This mechanism is expected to help maintain a thermal condition more suitable for laying hens.

From the humidity aspect, ventilation also plays a role in removing moisture from inside the building, which originates from bird respiration, manure, and the surrounding environment. If humid air cannot escape, relative humidity inside the house can rise. Through continuous air exchange, more humid air can be replaced with air from outside, giving the design potential to help control humidity through natural ventilation.

Control of ammonia gas (NH_3) is achieved through two complementary approaches: ventilation, which helps remove ammonia-containing air from inside the house, and the manure-management system, which reduces the source of ammonia formation. This dual approach is consistent with field measurements showing that NH_3 concentration in naturally ventilated layer houses rises together with indoor temperature and humidity as manure decomposition accelerates (Kılıç & Yashioğlu, 2014; Kılıç, 2017; Zhu et al., 2011). Combining the two is important because removing polluted air alone, without controlling the source of pollution, does not fully resolve the problem.

In this design, manure is collected using a tarpaulin placed beneath the battery cage and then moved periodically. This system is projected to reduce the time manure remains beneath the house. With a shorter accumulation time, the potential for decomposition that produces ammonia is also expected to be reduced, since collected manure is not left continuously in the same location but is removed through the tarpaulin-moving mechanism.

The relationship between ventilation and the manure-management system can be described as a single chain: manure is one source of pollutants, the tarpaulin system helps reduce that source, while ventilation helps remove air already containing heat, humidity, and pollutants from inside the building. With this approach, the design not only seeks to address the impact of poor air quality but also to reduce one of its sources.

In terms of carbon dioxide (CO_2), natural ventilation also has a role in supporting air exchange. Carbon dioxide is produced mainly through bird respiration and can increase if air exchange inside the building is low. Side openings allow outside air to enter and replace the air inside the house, while the ridge vent provides an additional path for air release. The design therefore has potential to prevent the accumulation of less-fresh air within the rearing area.

Dust and airborne particles are also related to the ventilation system and house management. Bird activity, feed, feathers, and dried manure can become sources of particles inside the building. Insufficient air movement can allow particles to persist longer in the rearing area, whereas good air exchange can help carry particle-laden air out of the building. However, the effectiveness of the design regarding dust cannot be confirmed by design alone, since particulate concentration is also influenced by bird activity, feed condition, humidity, and operational activities within the house.

Table 3. Application of the Design to Air-Quality Aspects

Air-Quality Aspect	Findings from the Literature	Application in the Design	Expected Potential
Temperature	Heat must be removed from the house	Side openings and ridge vent	Reduces heat accumulation
Humidity	Ventilation helps exchange humid air	Cross ventilation	Helps control humidity
Airflow velocity	Air movement supports bird comfort	Openings on both sides + tarpaulin with periodic removal + ventilation	Increases air exchange

NH ₃	Originates from manure decomposition	Tarpaulin + periodic removal + ventilation	Reduces the source and accumulation of NH ₃
CO ₂	Produced by bird respiration	Natural air exchange	Reduces potential accumulation
Dust	Originates from bird activity and building materials	Ventilation and manure management	Helps remove particles from the house

Based on this analysis, the house design can be considered to have good potential to support air quality, particularly because the ventilation system and the manure-management system are designed as an integrated whole. The side openings provide an air-inlet path, the open space allows air to move past the bird-rearing area, the ridge vent provides a hot-air release path, and the tarpaulin system helps control manure accumulation as a source of pollution.

Nonetheless, the actual effectiveness of the design still needs to be verified once the house is completed and operational. Measurement of temperature, humidity, airflow velocity, NH₃, CO₂, and particulates can be carried out in a subsequent research stage to determine whether the conditions projected through the design are actually achieved in the field. The present findings should therefore be more accurately understood as an analysis of the application of air-quality principles at the design stage, rather than as a performance measurement of an operating house.

As the final finding (novelty) of this study, the integration of a side-opening and ridge-vent ventilation system with a periodically-moved tarpaulin manure system, applied together at the design stage of a laying-hen house before it becomes operational, represents a design approach not extensively documented in previous studies, which mostly examine ventilation and manure management separately in already-operating houses. Overall, the design demonstrates that air quality can be considered from the earliest stage of design through the relationship among building form, the ventilation system, and manure management, an approach expected to produce laying-hen houses that not only meet space requirements for rearing but also provide environmental conditions that better support the health and comfort of the birds.

CONCLUSION

Conclusion

Based on the review of the literature and the analysis of the design, air quality is an important aspect in the design of a laying-hen house because it is related to thermal conditions, comfort, health, and the rearing environment of the birds. Prior studies show that temperature, humidity, air velocity, ammonia concentration (NH₃), carbon dioxide concentration (CO₂), and particulates are among the parameters associated with air quality inside a house, and that good ventilation is required to support air exchange and reduce the potential accumulation of heat, humidity, and gases generated by rearing activity. Research on laying-hen houses also shows that air-quality conditions can differ across different parts of a house, making the ventilation system and the position of measurement important aspects to consider.

In the design of the laying-hen house in Banyumas, Stabat, the application of air-quality principles was carried out through a combination of natural ventilation and a manure-management system. Openings on both sides of the house are designed to enable cross ventilation, while an opening at the roof ridge (ridge vent) is used as the outlet path for hot air. In addition, the house is made in the form of a raised structure with a manure-collection system using a tarpaulin that can be moved periodically. This system is designed to reduce the

accumulation of manure, one of the sources of ammonia formation; prior studies also show that prolonged manure accumulation can increase gas concentrations such as NH_3 , making waste management an important part of maintaining house air quality.

The house design therefore has potential to support air quality through the integration of side openings, air movement, the ridge vent, the raised building form, and periodic manure management. However, because the house is still under construction, the effectiveness of the design cannot yet be proven through field measurement. Further research after the house becomes operational is needed to measure temperature, humidity, air velocity, NH_3 , CO_2 , and particulates so that the correspondence between the design and actual field conditions can be determined, thereby answering the research questions posed at the outset of this study.

Limitations

This study has several limitations. First, the analysis is based on a single case-study design that is still under construction, so its findings cannot yet be generalized to other laying-hen houses or regions with different climatic and site characteristics. Second, because the building has not yet operated, the study relies on a qualitative, design-based, and predictive analysis rather than on direct field measurement of temperature, humidity, airflow velocity, NH_3 , CO_2 , and particulates. Third, the analysis does not account for operational factors that may influence air quality once the house is in use, such as flock density, feeding practices, and worker management routines. The findings should therefore be interpreted within the scope of a design-stage analysis rather than as verified performance results.

Recommendations

Future research should measure temperature, relative humidity, airflow velocity, NH_3 , CO_2 , and particulate concentrations directly once the house becomes operational, in order to verify the effectiveness projected through this design analysis. Subsequent studies could also broaden the scope of the research object to houses with different sizes, orientations, and climatic locations, and could employ computational tools such as computational fluid dynamics (CFD) simulation to model airflow patterns more precisely. In addition, further studies could examine the relationship between the manure-management system and ammonia-reduction performance over a longer operational period, and evaluate the economic and labor implications of the periodic manure-removal mechanism.

Author Contributions

All authors made significant contributions to this study. These contributions included research conceptualization, development of the design-analysis framework, data collection through literature review and design documentation, analysis and interpretation of the results, manuscript preparation, scholarly revision, and final approval of the manuscript for publication. All authors confirm that they have read and approved the final version of the article.

AI Disclosure Statement

The authors declare that artificial intelligence (AI) tools were used during the preparation of this manuscript solely for the purposes of English-language translation and editorial refinement of the text originally drafted by the authors. The authors have thoroughly reviewed and revised the content and take full responsibility for the entire publication.

Acknowledgment

The authors would like to express their gratitude to the Faculty of Engineering, Universitas Batam, and to all parties who provided support, data access, and input during the preparation of this study.

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