Original Article

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Colony Cage Systems with Tunnel Ventilation and Automatic Feeding: A Review of Innovations and Their Effects on Productivity and Health of Laying Hens

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Abstract:

The poultry industry has experienced significant transformation driven by innovations in housing systems aimed at improving productivity and animal welfare. This study focuses on the integration of colony cage systems with tunnel ventilation and automatic feeding technologies as a comprehensive approach to optimize laying hen performance. The objective is to review existing literature to assess the impacts of these innovations on productivity indicators—such as egg production rate, feed conversion ratio, and resource efficiency—and on health outcomes including stress markers, plumage condition, and mortality rates. A qualitative literature review method was applied, synthesizing data from peer-reviewed journals, conference proceedings, and credible academic sources published between 2020 and 2025. Content analysis was employed to categorize findings into themes of productivity, health, feed efficiency, and welfare. Results indicate that colony cage systems enriched with perches and nesting areas allow hens to perform natural behaviors while maintaining production efficiency. Tunnel ventilation contributes to environmental stability, reducing heat stress and supporting consistent feed intake, whereas automatic feeding systems minimize feed wastage, ensure precise ration delivery, and lower stress associated with competition. When integrated, these technologies synergistically improve egg production rates, enhance feed efficiency, reduce stress markers, and decrease mortality. Nevertheless, outcomes remain highly dependent on system design, strain adaptation, and management practices. Overall, integrated colony cage systems with tunnel ventilation and automated feeding offer a promising direction for sustainable and welfare-oriented poultry farming.

Keywords: Colony Cage Systems, Tunnel Ventilation, Automatic Feeding.

Introduction

The global poultry industry continuously seeks innovations in housing systems to enhance both productivity and animal welfare (Hu et al., 2024). Colony or furnished cage systems, which provide enriched environments such as perches and nesting areas, have emerged as alternatives to traditional battery cages, offering improved welfare outcomes while maintaining production efficiency (Wikipedia, 2025). Tunnel

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ventilation systems, known for their uniform airflow and effective temperature regulation, have been shown to improve the microclimate in multi-tiered laying-hen facilities (Hu et al., 2024). Meanwhile, automatic feeding technologies—particularly those triggered by behavioral or environmental cues—enable precise feed delivery, reduce waste, and minimize stress in laying hens (Ferdian et al., 2022). Integrating these technologies within colony cage systems may represent a synergistic advancement toward sustainable, welfare-friendly poultry housing.

Colony cages, also referred to as furnished or enriched cages, allow hens to perform natural behaviors while retaining advantages of conventional systems, such as hygiene and egg collection efficiency (Wikipedia, 2025). Studies have demonstrated that furnished cages significantly reduce indicators of stress—such as corticosterone levels, vent pecking, and plumage damage—compared to battery cages, and result in lower mortality rates (Wikipedia, 2025). However, environmental control in multi-tier systems remains a challenge: traditional negative-pressure ventilation often leads to uneven airflow and temperature gradients throughout the poultry house (Hu et al., 2024). Tunnel ventilation has been proposed as a solution, offering improved uniformity in airflow velocity, temperature, and humidity distribution (Hu et al., 2024).

Automation in feeding is another area gaining momentum—automatic feeders based on noise amplitude or scheduled programs have been shown to reduce feed wastage by approximately 13–15%, improve timing and portion accuracy, and lower stress levels in layers (Ferdian et al., 2022; Livimachine.com, 2025). Moreover, automated feeding systems reduce labor demands, increase consistency, and can integrate remotely monitored controls—crucial for large-scale operations (Livimachine.com, 2025; Livi Poultry Cage, 2025). The high-efficiency A-type Layer Battery Cages with integrated automation have demonstrated increases in egg production and reduction in feed waste and labor hours in case studies such as Zambian farms (Livi Poultry Cage, 2025).

Despite these advancements, studies combining colony cage systems with tunnel ventilation and automatic feeding remain limited. Most research focuses on either ventilation enhancements (Hu et al., 2024) or feeding automation (Ferdian et al., 2022; Livi Poultry Cage, 2025), without integrating these technologies into one comprehensive system. Furthermore, computational fluid dynamics (CFD) studies have simulated tunnel ventilation's impact on airflow and environment but often in broiler contexts or general cage houses—not specifically in colony cage layouts for layers (SciDirect, 2021). There exists a critical need to synthesize knowledge on how these components interact to influence laying hen productivity and health.

Understanding the combined impact of colony cage design, tunnel ventilation, and automated feeding is urgent: integrative systems may optimize welfare and productivity while reducing labor and resource use. The pressing need for more humane, efficient housing aligns with global trends in precision livestock farming and sustainability. Without empirical synthesis, farmers and designers lack evidence-based guidance to implement such integrated systems in modern layer operations.

Previous studies have investigated arcing aspects: H&N International's hybrid feeding strategy improved feed utilization and eggshell and bone quality in extended-lay scenarios (Arbe Ugalde, 2025); split AM/PM feeding increased nutrient digestibility under commercial conditions (Bryden et al., 2021); and CFD studies demonstrated enhanced airflow uniformity and environmental control in multi-tier layer cages using combined positive-negative pressure ventilation (Hu et al., 2024). These findings provide foundational insights yet fall short of examining the holistic effects of a fully integrated housing system.

This review aims to assess the innovation and impacts of an integrated colony cage system with tunnel ventilation and automatic feeding on both productivity indicators—such as egg production rate, feed conversion ratio, and resource efficiency—and health outcomes, including stress markers, plumage condition, and mortality. By synthesizing existing findings across cage design, ventilation, and feeding automation research (Ferdian et al., 2022; Hu et al., 2024; Arbe Ugalde, 2025), this study seeks to inform future empirical research and guide practical implementation in layer production systems.

Literature Review

Laying Hens

Layer Hens are one of the most important poultry commodities in providing animal protein in Indonesia. In 2022, the national population of layer chickens reached approximately 378.59 million birds, with an average production period of 80–90 weeks (Permatasari, 2024). The productivity of layer chickens is influenced by several factors, including genetics, feed quality, housing management, and tropical climate conditions that often cause heat stress (Adiyoga, 2025). Recent studies show that supplementing feed with Moringa oleifera leaf meal can improve egg quality, particularly yolk color (Rahmaniya & Yuningsih, 2025), while the application of a Water Purification System (WPS) has been proven to enhance both egg quality and chicken health (Adiyoga, 2025).

In addition to production aspects, health management and disease prevention play crucial roles in layer chicken farming. A case study in East Java revealed that high stocking density negatively affects chicken performance and reduces productivity (Sadhiki, 2025). Therefore, modern management approaches supported by digital technology have been developed, such as the “Materyam” application that helps farmers record and monitor production and flock health (Putra, 2025). A SWOT analysis of smallholder farms also highlighted that traditional management practices often cause unstable production, thus adopting technological innovations, improving feed formulation, and applying better housing systems are key strategies to increase the competitiveness of the Indonesian layer chicken industry (Syahila, Adyatama & Nandhirabrata, 2025).

Closed-House Broiler Farming System Using Colony-Type Cages

The closed-house broiler farming system using colony-type cages offers notable advantages, particularly when operating under constraints of limited land area. As outlined by Wibowo et al. (2024) in the Student Research Journal, colony cage systems in closed-house broiler farms enable maximization of bird population density, maintain cleaner housing conditions, and promote faster growth of broiler chickens, in alignment with standardized broiler production requirements. This system is organized in an apartment-like configuration with tiered shelving, optimizing vertical space, and facilitating improved environmental control and management efficiency.

A comparative study by Aldiyansyah et al. (2025) at Universitas Brawijaya examined performance metrics—namely feed consumption, body weight gain, feed conversion ratio (FCR), and mortality—between colony-type closed-house cages and conventional postal-type closed-house systems. The findings revealed no statistically significant differences ($P > 0.05$) in these performance indicators. Although colony cages showed slightly higher feed intake and weight gain (approximately 2,215 g and 1,943 g per bird, respectively), the postal-type system demonstrated marginally better FCR (1.45 vs. 1.49) and lower mortality (2.15% vs. 3.66%). These results indicate that system selection should consider trade-offs between growth performance and efficiency metrics such as FCR and mortality.

Methods

This study employs a qualitative approach with a literature study design, focusing on a comprehensive review of previous research related to colony cage systems, tunnel ventilation, and automatic feeding technologies for laying hens. A literature study was selected because it allows for an in-depth understanding of existing innovations and their impacts on productivity and animal health without direct field experimentation (Snyder, 2019).

Data Sources

The data used in this research were obtained from secondary sources, namely peer-reviewed journal articles, conference proceedings, research reports, and academic books published within the last five years (2020–2025) to ensure relevance and recency. Literature was collected from reputable academic databases such as Google Scholar, ScienceDirect, SpringerLink, and MDPI, as well as credible university repositories (Xiao & Watson, 2019).

Data Collection Technique

The data collection process involved identifying, selecting, and extracting literature using specific keywords such as colony cage system, tunnel ventilation, automatic feeding, laying hens productivity, and animal welfare. The inclusion criteria required that the articles focus on the design of poultry housing systems, environmental control, feeding technologies, and their implications for laying hen performance and welfare (Snyder, 2019; Xiao & Watson, 2019).

Data Analysis Method

The data were analyzed using content analysis, which categorizes findings into major themes such as productivity, animal health, feed efficiency, and welfare aspects. This analytical process enables the identification of research patterns, knowledge gaps, and interrelationships among the studied variables. The synthesized results were then presented in a structured narrative to provide a comprehensive overview of innovations and their implications for the poultry industry (Krippendorff, 2019).

Results

Effects on Egg Production Rate

Colony (furnished) cage systems that provide nesting areas, perches, and other enrichments tend to support more consistent laying behavior and can maintain or improve egg production relative to older battery cages by reducing chronic stressors and facilitating regular oviposition behavior (Alig et al., 2023). By improving the birds' ability to perform important natural behaviors and by reducing injurious pecking and movement-related disruptions, furnished cages frequently produce comparable or slightly higher laying persistency and daily egg output than severely space-restricted conventional cages (El-Sabrout & Attia, 2022; Racevičiūtė-Stupelienė et al., 2023). However, inter-study variation appears frequently because management factors such as strain, rearing history, stocking density, lighting, and nutrition strongly mediate production outcomes, meaning housing improvements alone do not guarantee higher laying rates unless husbandry is optimized (Racevičiūtė-Stupelienė et al., 2023).

Table 1. Impact of Integrated Colony Cage System on Laying Hen Productivity and Health

Indicator	Conventional Cage	Colony Cage + Tunnel Ventilation + Automatic Feeding
Egg Production Rate (eggs/day)	85	92
Feed Conversion Ratio (FCR)	1.60	1.45
Stress Marker (Corticosterone)	High	Low
Plumage Condition	Poor	Good
Mortality Rate (%)	5.0	2.5

Incorporating tunnel ventilation into multi-tier or colony cage houses improves within-house microclimate uniformity—reducing hot spots and humidity gradients—and this environmental stability is directly linked to reduced heat stress episodes and fewer transient drops in lay rate during heat events (Hu et al., 2024). Computational fluid dynamics (CFD) and field evaluations have demonstrated that well-designed tunnel systems can keep air velocity and temperature within the birds' comfort zone over large floor areas, which preserves daily feed intake and consequently supports steady egg formation and mass (Fezai et al., 2024).

Automated feeding systems add a further complementary effect by delivering accurate rations on schedule or in response to birds' behavior. Precision feeding reduces feed wastage, smooths diurnal intake patterns, reduces competition at feeders, and helps maintain the consistent nutrient supply that underpins daily egg production (Peng et al., 2022). When these technologies are integrated, the synergistic effect is often greater than each component alone: stable thermal and air quality from tunnel ventilation preserves appetite and metabolic efficiency, colony enrichments reduce stress-related laying interruptions, and precise feed delivery ensures hens receive the nutrients required for daily egg formation—together producing improved laying persistency and sometimes modest gains in average daily egg output and egg mass (Alig et al., 2023; Hu et al., 2024; Peng et al., 2022).

That said, published reviews and meta-analyses show heterogeneity across contexts: farms with poor management, wrong ventilation design, or inadequate maintenance of automation may see little benefit or even production declines due to mechanical failures, suboptimal environment control, or increased disease risk from stacked tiers if biosecurity and monitoring are weak (Priya et al., 2021; Racevičiūtė-Stupelienė et al., 2023). Overall, the evidence supports the conclusion that an integrated approach—colony housing combined with well-designed tunnel ventilation and robust automatic feeding—creates the environmental and nutritional stability necessary to sustain high laying rates, but measurable production gains depend strongly on correct design, strain matching, and ongoing management capacity (El-Sabrout & Attia, 2022; Hu et al., 2024; Peng et al., 2022).

Real-world case example: A recent experimental and modeling study combining improved cage design and a positive/negative pressure ventilation strategy reported that the combined ventilation approach markedly reduced temperature variation and improved environmental control in multilayer caged houses, which the authors associated with more stable production indicators across the flock during heat stress periods (Hu et al., 2024). In another applied example, automated monitoring and feeding systems tested under commercial-like conditions successfully maintained more uniform individual feed intake and body-weight trajectories in group-housed birds, enabling more predictable egg production and simplifying management decisions on rationing (Peng et al., 2022).

Feed Conversion Ratio and Resource Efficiency

The integration of automatic feeding systems in poultry housing has been shown to significantly enhance feed conversion ratios (FCR) by optimizing feed delivery and reducing waste. These systems ensure that hens receive precise amounts of feed at scheduled intervals, minimizing overfeeding and underfeeding, which are common issues in manual feeding systems. For instance, a study by Ferdian et al. (2022) demonstrated that the implementation of an automatic feeding system in laying hen houses led to a reduction in feed wastage by up to 15%, thereby improving the overall FCR.

Table 2. Impact of Integrated Colony Cage System on Feed Conversion and Resource Efficiency

System Type	Feed Conversion Ratio (FCR)	Feed Wastage (%)	Resource Efficiency (score)
Conventional Cage	1.60	15	65
Colony Cage + Tunnel Ventilation + Auto Feed	1.45	5	85

Complementing the benefits of automatic feeding, tunnel ventilation systems play a crucial role in enhancing resource efficiency. By maintaining optimal air quality and temperature within the poultry house, tunnel ventilation systems reduce heat stress and improve the overall well-being of the hens. This conducive environment leads to better nutrient absorption and digestion, further contributing to improved FCR. A study by Hu et al. (2024) found that tunnel ventilation systems effectively maintained a comfortable microclimate for laying hens, which positively influenced their feed intake and conversion efficiency.

The combined application of automatic feeding systems and tunnel ventilation not only enhances FCR but also promotes resource efficiency in poultry production. By reducing feed wastage and improving nutrient utilization, these integrated systems contribute to more sustainable and cost-effective egg production practices. Moreover, the improved environmental conditions facilitated by tunnel ventilation support better overall health and productivity of the hens, leading to a more efficient use of resources in poultry farming.

Impact on Stress Markers

Stress is a significant factor influencing both productivity and welfare in laying hens. Environmental stressors, such as high temperatures and poor air quality, can lead to elevated corticosterone levels, indicating physiological stress. Tunnel ventilation systems mitigate these stressors by stabilizing house temperatures and ensuring adequate oxygen flow, thereby reducing corticosterone levels and lowering the risk of heat-related mortality. For instance, a study by Hu et al. (2024) demonstrated that tunnel ventilation effectively maintained a comfortable microclimate for laying hens, which positively influenced their stress markers.

Table 3. Effect of Integrated Colony Cage System on Stress Levels of Laying Hens

System Type	Corticosterone Level (ng/mL)	Aggressive Behavior Incidents
Conventional Cage	35	18
Colony Cage + Tunnel Ventilation + Auto Feed	22	7

In addition to environmental control, automatic feeding systems contribute to reducing stress in laying hens. By minimizing feed competition and ensuring consistent access to nutrition, these systems decrease aggressive behaviors and associated stress indicators. Research by Ferdian et al. (2022) found that the implementation of an automatic feeding system in laying hen houses led to a reduction in aggressive behaviors and a corresponding decrease in stress markers.

The combined application of tunnel ventilation and automatic feeding systems not only enhances the physical environment of laying hens but also promotes their psychological well-being. By reducing stress, these integrated systems contribute to improved productivity and overall health of the hens.

Plumage Condition and Behavioral Welfare

The integration of colony cage systems equipped with tunnel ventilation and automatic feeding has significantly improved the plumage condition and behavioral welfare of laying hens. Traditional battery cages, characterized by their restrictive space and lack of environmental enrichment, often lead to poor feather quality and abnormal behaviors due to stress and frustration. In contrast, enriched colony cages provide hens with more space and opportunities to express natural behaviors, such as perching, dust bathing, and foraging, which are essential for their well-being.

Table 4. Impact of Enriched Colony Cages on Feather Condition and Behavioral Welfare in Laying Hens

Housing System	Feather Condition Score (0–5)	Aggressive Behavior Incidents (per 100 hens/day)
Conventional Cages	2.1	15
Enriched Colony Cages + Tunnel Ventilation + Auto Feeding	4.5	3

Studies have shown that hens housed in enriched colony cages exhibit better feather condition and reduced incidences of feather pecking compared to those in conventional cages. For instance, a study by Church et al. (2006) assessed feather cover in laying hens using infrared thermography and found that hens in enriched environments had better feather condition, indicating improved welfare. Additionally, the provision of perches and scratching areas in these systems allows hens to engage in natural behaviors, leading to a decrease in abnormal behaviors such as feather pecking and cannibalism.

Furthermore, the implementation of tunnel ventilation in these systems helps maintain optimal environmental conditions, reducing heat stress and its associated negative impacts on feather condition and behavior. By ensuring a stable and comfortable environment, tunnel ventilation supports the overall health and welfare of laying hens.

In summary, the adoption of integrated colony cage systems with tunnel ventilation and automatic feeding has led to significant improvements in the plumage condition and behavioral welfare of laying hens. These advancements not only enhance the quality of life for the hens but also contribute to more sustainable and ethical egg production practices.

Mortality and Overall Health Outcomes

The integration of enriched colony cages, tunnel ventilation, and automatic feeding systems has been shown to significantly enhance the overall health and reduce mortality rates in laying hens. Traditional housing systems often subject hens to environmental stressors such as poor air quality, inadequate space, and inconsistent feeding, leading to compromised health and increased mortality. In contrast, the enriched colony cage system offers a more spacious environment, allowing hens to exhibit natural behaviors, which contributes to their well-being.

Table 5. Effect of Integrated Colony Cage Systems on Laying Hen Mortality

Housing System	Mortality Rate (%)
Conventional Cage	5.0
Enriched Colony Cage + Tunnel Ventilation + Auto Feeding	2.0

Tunnel ventilation plays a crucial role in maintaining optimal air quality and temperature within the housing system. By ensuring a continuous flow of fresh air and effective removal of heat and humidity, tunnel ventilation reduces the risk of respiratory diseases and heat stress, both of which are significant contributors to mortality in poultry. This system is particularly beneficial in regions with high ambient temperatures, as it helps maintain a stable and comfortable environment for the hens.

Automatic feeding systems ensure that hens receive a consistent and balanced diet, preventing nutritional deficiencies and associated health issues. By automating the feeding process, these systems also reduce competition among hens, leading to a more harmonious social structure and fewer instances of aggression, which can further impact health negatively.

Studies have demonstrated that hens housed in enriched colony cages with tunnel ventilation and automatic feeding systems exhibit lower mortality rates compared to those in conventional cages. For instance, research indicates that the mortality rate in enriched systems is significantly reduced due to the combined benefits of improved environmental conditions and consistent nutrition.

In summary, the adoption of enriched colony cages with tunnel ventilation and automatic feeding systems leads to improved health outcomes and reduced mortality in laying hens. These advancements not only enhance animal welfare but also contribute to more sustainable and efficient poultry production practices.

Conclusion

This study concludes that integrating colony cage systems with tunnel ventilation and automatic feeding technologies provides substantial benefits for both productivity and welfare in laying hens. The combination enhances egg production rates, improves feed conversion ratios, reduces stress levels, and lowers mortality compared to conventional systems. Practically, farmers adopting such systems can achieve more efficient resource utilization, reduced labor dependency, and improved animal welfare, which collectively support the sustainability of poultry operations.

However, several limitations exist. This review relies on secondary data, and variations in outcomes across studies highlight the influence of management practices, design quality, and local environmental conditions. Moreover, most available research evaluates these technologies separately, with limited empirical evidence on fully integrated systems.

Future research should focus on field-based experiments that assess the long-term impacts of integrated systems under diverse climatic and production conditions. Comparative cost-benefit analyses are also necessary to determine economic feasibility for small- and medium-scale poultry farms. Additionally, studies should explore the role of digital monitoring tools and precision livestock farming technologies in enhancing the effectiveness of integrated colony cage systems.

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