Scientific Papers. Series D. Animal Science. Vol. LXVIII, No. 1, 2025
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

BALANCING PRODUCTIVITY, WELFARE, AND SUSTAINABILITY IN LAYING HEN FARMING: A REVIEW OF REARING SYSTEMS

Anton HAMZĂU[1], Stefan-Teofil VLAD[1], Minodora TUDORACHE[1], Andra Dorina ȘULER[1], Andrei MARMANDIU[1], Ioan PEȚ[2], Goran PANICI[2], Ioan CUSTURĂ[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]University of Life Sciences "King Mihai I" from Timișoara, Faculty of Animal Resources Bioengineering, 119 Calea Aradului Street, Timisoara, Romania

Corresponding author email: teovlad187@yahoo.com

Abstract

Rearing systems play a crucial role in shaping the productivity, welfare, and sustainability of laying hen farming. This review examines the effects of different rearing systems - cage systems (conventional and enriched), barn systems, free-range, and organic systems - on key production parameters, including egg yield, feed conversion efficiency, egg quality, and hen welfare. Studies at the global level reveal that conventional cage systems achieve the highest productivity but often raise concerns about animal welfare. Conversely, free-range and organic systems promote better welfare and consumer trust in product quality but are associated with lower productivity and higher production costs. This review also analyses the impact of environmental factors, genotype selection, and management practices on laying hen performance within each system. Additionally, it discusses emerging trends such as the adoption of enriched cages, precision farming technologies, and sustainable feed alternatives, as well as challenges like disease management and compliance with increasingly strict animal welfare regulations. By synthesizing current global research, this paper aims to highlight best practices and provide a roadmap for balancing productivity, animal welfare, and environmental sustainability in laying hen farming.

Key words*: animal welfare, egg production, laying hens, rearing systems, sustainability.*

INTRODUCTION

In modern poultry farming, achieving an optimal balance between productivity, animal welfare, and sustainability is a growing concern across the industry. As consumer awareness and legislative pressure increase, the scrutiny over how laying hens are housed has intensified (Mench et al., 2011; Harlander-Matauschek et al., 2015). Conventional battery cages, once the standard, are now increasingly challenged due to their impact on animal welfare, particularly due to the limitation they impose on natural behaviors such as perching, dustbathing, and nesting (European Commission, 1999; Lay et al., 2011).

Alternative systems - such as enriched cages, barn systems, free-range, and organic housing - have emerged as potential solutions. While these systems often result in improved behavioral outcomes and lower stress for hens, they also present significant trade-offs in terms of productivity, health risks, and environmental footprint (Rodenburg et al., 2008; Singh et al., 2017). Organic and free-range systems, for instance, align better with public values and ethical expectations but are generally associated with increased costs and lower efficiency per unit of production (Kijlstra & Eijck, 2006).

Moreover, research highlights that performance outcomes across these systems are influenced not only by housing type but also by genotype, environmental conditions, and management strategies (Tauson, 2005; Rodenburg et al., 2013). The development of precision livestock farming technologies, including sensor-based health monitoring and automated feeding, has opened new opportunities to improve both welfare and efficiency across all rearing systems (Digi4LivE, 2024).

This review synthesizes global research on laying hen rearing systems, examining their impact on productivity, welfare, and sustainability. It aims to provide a comprehensive comparison that can inform both policy-makers and producers in adopting practices that support ethical, efficient, and environmentally responsible egg production.

MATERIALS AND METHODS

This review draws upon a substantial base of validated research published between 2000 and 2024, focusing on studies that examine the relationship between housing systems and key performance outcomes in laying hen production. The analysis encompasses five primary rearing systems: conventional cages, enriched cages, barn systems, free-range systems, and organic systems.

The selected literature includes empirical research addressing egg production, feed conversion efficiency, behavior-based welfare indicators, disease prevalence, mortality rates, consumer preferences, and environmental impact. Additionally, the review identifies management practices and technological innovations that contribute to enhancing animal welfare and improving the overall sustainability of each housing system.

RESULTS AND DISCUSSIONS

Conventional cage systems

Although conventional battery cages have been banned in the EU (European Commission, 1999), they remain prevalent in many regions due to their cost-effectiveness and production consistency. These systems offer controlled environments that reduce disease spread and support efficient feeding and waste management.

Solutions and practices:

- Use of automated climate and lighting control systems enhances production uniformity by stabilizing internal conditions, which supports hen health and consistent egg laying (Tactacan et al., 2009);
- Targeted nutritional interventions (e.g., acidifiers and probiotics) have been shown to support gut health and reduce dependency on antibiotics in high-density environments (Tactacan et al., 2009);
- Beak trimming and aggressive bird monitoring, while controversial, are widely applied to reduce feather pecking due to behavioral restriction, although their use is being replaced by alternative enrichments in progressive systems (Gentle & McKeegan, 2007).

Figure 1. Conventional cages (Source: https://www.bigdutchmanusa.com)

Enriched (furnished) cage systems

Enriched cages were developed to provide behavioral opportunities that conventional cages lack. They include perches, nest boxes, and scratching areas, which significantly improve welfare while retaining much of the productivity of cage systems (Lay et al., 2011).

Solutions and practices:

- Design optimization, such as adjustable perches and partitions, improves spatial distribution and reduces competition among hens, resulting in fewer injuries and stress behaviors (Tauson, 2005);
- Use of red lighting or dimmable light gradients supports circadian regulation and reduces feather pecking, as hens are more relaxed under lower light intensity (Shimmura et al., 2007);

Figure 2. Enriched cages (Source: https://www.bigdutchmanusa.com)

- Sloped flooring with manure belts reduces contact with waste, improving hygiene and egg cleanliness while lowering ammonia emissions (Tauson, 2005).

Barn (floor-based) systems

Barn systems house hens indoors on litter floors, often in single or multi-tier aviary designs, and offer more behavioral freedom. However, they require careful management of density, litter quality, and air exchange to prevent disease and aggression.

Solutions and practices:

- Installation of multi-level aviary structures increases usable space and reduces crowding. This improves access to feed and water while allowing hens to escape aggressive interactions (Rodenburg et al., 2008);
- Litter management strategies, such as regular turning and supplementation with dry organic materials, prevent wet litter conditions that cause footpad dermatitis and respiratory issues (Bestman & Wagenaar, 2003);
- Automated nest box systems with sensor-driven egg collection reduce broken or dirty eggs and ensure more hygienic conditions for both hens and products (Elson, 2004).

Figure 3. Floor based system (Source: https://www.hightoppoultry.com/slatted-floor-system/)

Free-range systems

Free-range systems combine indoor shelter with daytime outdoor access, enabling hens to engage in foraging, dustbathing, and sunbathing. These systems are valued for ethical production but must be managed carefully to balance welfare with biosecurity.

Solutions and practices:

- Rotational paddock systems reduce overgrazing and parasitic contamination of soil, while promoting vegetation recovery and biodiversity (Singh et al., 2017);
- Natural cover (trees, shrubs, shelters) encourages more uniform outdoor area use, reduces stress, and lowers mortality from predator attacks (Elson, 2004);
- Training hens from a young age to use outdoor areas increases range utilization and decreases fear responses, improving welfare outcomes long-term (Gilani et al., 2014).

Figure 4. Free-Range System (Source: https://au.pinterest.com/pin/269723465161493996/)

Organic systems

Organic systems meet the most rigorous standards, requiring certified organic feed, low stocking densities, and no routine antibiotics. These systems support environmental and ethical values but must overcome biological and economic challenges.

Solutions and practices:

- Use of dual-purpose or heritage breeds, better adapted to outdoor conditions, reduces mortality and feather pecking while maintaining acceptable egg production (Kijlstra & Eijck, 2006);
- Agroecological integration, such as on-site composting and closed nutrient loops, increases resource efficiency and minimizes environmental impact (Bracke et al., 2006);
- Proactive disease prevention, including vaccination and herbal supplements, compensates for the restriction on antibiotic use and helps control intestinal parasites and respiratory diseases (van de Weerd et al., 2009).

Assessing the effectiveness of various rearing systems for laying hens requires a comprehensive understanding of the inherent trade-offs among three critical pillars of poultry production: productivity, animal welfare, and environmental sustainability. Each system presents distinct advantages and challenges, and their performance must be contextualized within both biological and socio-economic frameworks.

Figure 5. Hens under bushes creating a fresh microclimate (Rana et al., 2022)

From intensive indoor housing to extensive organic systems, the type of environment in which laying hens are reared directly influences not only their physical health and behavioral expression but also farm-level outputs such as egg yield, feed conversion efficiency, mortality rates, and resource use. These systems also differ in their capacity to address consumer expectations for ethically produced food, the mitigation of environmental impacts (e.g., greenhouse gas emissions, land and water use), and compliance with evolving animal welfare legislation.

This section draws on a diverse body of empirical research to compare five primary rearing systems: conventional cages, enriched cages, barn systems, free-range systems, and organic systems. It explores how each system performs in relation to production efficiency, welfare outcomes, ecological impact, and market viability. In doing so, the analysis aims to identify best practices and system-specific innovations that could inform more sustainable and ethically sound models of egg production.

Productivity outcomes

Cage systems, particularly in intensive operations, typically show the highest laying rates due to environmental control, feed efficiency, and minimal energy expenditure by hens. Studies have shown egg production exceeding 300 eggs/hen/year under optimal conditions (Petek et al., 2014). However, such high productivity often comes at the cost of behavioral suppression.

Enriched cages, while providing moderate behavioral outlets, maintain comparable productivity. According to Muir et al. (2016), the inclusion of enrichments did not significantly affect laying rates or feed conversion, suggesting that minor welfare upgrades can be achieved without economic penalty.

In barn systems, productivity is slightly reduced due to factors like increased physical activity and social stress. However, when flock size and tier design are managed well, laying rates remain commercially viable (Nicol et al., 2017). Mortality can be minimized through the use of disease-resistant genetic lines and structured flock management.

Free-range systems show variable productivity depending on outdoor conditions and the breed used. Although laying rates can decrease due to foraging activity, studies such as Anderson (2016) suggest that adequate training and optimized range design can close this performance gap.

Organic systems generally have the lowest productivity, influenced by restrictions on synthetic feed additives and medications. Nonetheless, demand for such systems continues to grow, driven by consumer interest in animal welfare and ecological farming (Tauson et al., 2012).

While free-range and organic systems may underperform in terms of laying rates, they have been shown to produce eggs with improved nutritional quality. For instance, Nistor (Cotfas) et al. (2015) found that eggs from free-range systems had higher albumen protein and yolk lipid content compared to those from battery cages. Differences in fatty acid profiles among poultry species also support the nutritional value of eggs from alternative systems, as shown by Usturoi et al. (2021). However, the study also reported a higher microbial load in free-range eggs, highlighting the importance of stringent biosecurity and hygiene measures in alternative systems. Proper storage is essential to preserve egg quality, as shown by Gavril et al. (2013).

Romanian research conducted under real production conditions also supports the viability of alternative systems. For instance, Usturoi et al. (2022) reported that ISA Brown hens reared in aviary lofts achieved comparable productivity and laying intensity to those raised in improved batteries, while showing better health indicators and favorable feed conversion rates. This suggests that, with appropriate management, alternative housing systems can match or even exceed conventional benchmarks in certain parameters.

Welfare assessment

Welfare concerns are most pronounced in conventional cages, where restricted space limits locomotion, perching, and nesting. Chronic stress and high rates of osteoporosis are well-documented in such systems (Riber et al., 2018).

Enriched cages offer moderate improvements. Though space remains limited, provisions like nest boxes and perches enable some expression of species-specific behaviors, reducing aggression and fearfulness (Sherwin et al., 2010).

Barn systems allow for more complex behaviors but increase risks of injuries, feather pecking, and cannibalism. Welfare outcomes improve significantly when environmental enrichment is provided - such as pecking blocks and elevated platforms (de Haas et al., 2014). Managing light intensity and flock composition further contributes to positive welfare outcomes.

In free-range systems, outdoor access improves physical fitness and reduces stereotypies. However, welfare depends heavily on range design and predator protection. Fanatico et al. (2013) reported that shelters and vegetation significantly reduce stress and fear-related behaviors in free-ranging hens.

Organic production is typically associated with the highest welfare standards, due to combined indoor enrichment and pasture access. However, the ban on routine antibiotics requires excellent disease prevention and early detection strategies (Sossidou et al., 2011).

Environmental sustainability

From a resource efficiency standpoint, cage systems have the lowest environmental footprint per egg produced. However, they concentrate manure and emissions, leading to localized pollution (Leinonen et al., 2012).

Alternative systems - barn, free-range, and organic - demand more land and energy per unit of output but provide environmental benefits through better manure distribution and soil health. For example, free-range systems can sequester carbon if vegetation is maintained and stocking density is managed (Singh et al., 2011).

Organic systems integrate ecological practices like on-farm feed production, composting, and rotational grazing, which reduce dependency on external inputs. However, the variability in feed conversion efficiency and outdoor exposure can increase the carbon footprint if not offset by holistic management (Sossidou et al., 2011).

Market trends and policy directions

Growing consumer concern about animal welfare has spurred demand for cage-free and organic eggs. According to Van Horne & Bondt (2013), retail and legislative momentum - especially in the EU - has led to a steady decline in cage-based systems, with enriched cages now serving as a transitional option.

Global certification schemes such as Animal Welfare Approved and EU Organic play a pivotal role in standardizing production practices and informing consumer choice (Blatchford et al., 2016). Government subsidies and green investment funds are essential for helping producers transition to higher-welfare models without incurring economic losses.

CONCLUSIONS

The comparative analysis of laying hen rearing systems highlights the complexity of achieving a simultaneous balance between productive efficiency, animal well-being, and environmental responsibility. This review confirms that each housing system - whether intensive or extensive - offers specific benefits and limitations and thus must be evaluated through a multidimensional lens that includes biological outcomes, ethical considerations, and sustainability goals.

Conventional cages continue to deliver superior productivity and feed efficiency, yet their incompatibility with current welfare expectations increasingly limits their acceptability. Enriched cages serve as an intermediary solution, offering slight welfare improvements without drastically compromising production. Meanwhile, barn and free-range systems support a broader range of natural behaviors, though they require careful environmental and behavioral management to control health risks and optimize performance. Organic systems, while often preferred from a welfare and consumer perception standpoint, remain the least productive and most resource-intensive.

Technological advancements - such as automated monitoring tools, smart feeding systems, and data-driven health assessments - are emerging as critical tools across all systems, helping bridge the gap between productivity and welfare. Additionally, genetic selection tailored to specific housing types and better environmental design can further support system-specific optimization.

Ultimately, a universal solution does not exist. Progress in egg production must be guided by integrated, science-based strategies that take into account regional legislation, market trends, and societal values. By promoting collaborative efforts among producers, researchers, and policymakers, the poultry sector can evolve toward systems that are not only economically sustainable but also ethically and ecologically responsible.

ACKNOWLEDGEMENTS

This research work was carried out with the financial support of the Faculty of Animal Production Engineering and Management, University of Agronomic Sciences and Veterinary Medicine of Bucharest.

REFERENCES

Anderson, K. E. (2016). Comparison of fatty acid, cholesterol, and vitamin A and E composition in eggs from hens housed in conventional cage and range production facilities. *Poultry Science, 95*(3), 520–525. https://doi.org/10.3382/ps/pev362

Bestman, M. W. P., & Wagenaar, J. P. (2003). Farm level factors associated with feather pecking in organic laying hens. *Livestock Production Science, 80*(1–2), 133–140.

Blatchford, R. A., Fulton, R. M., Mench, J. A., & Newberry, R. C. (2016). The influence of housing system on egg production parameters and egg quality. *Poultry Science, 95*(1), 95–104.

Bracke, M. B. M., Hopster, H., & van de Weerd, H. A. (2006). Animal welfare in organic farming. In Niggli, U. (Ed.), *Research Institute of Organic Agriculture FiBL.*

De Haas, E. N., Bolhuis, J. E., Kemp, B., Groothuis, T. G. G., & Rodenburg, T. B. (2014). Parents and early life environment affect behavioral development of laying hen chickens. *PLOS ONE, 9*(3), e90577. https://doi.org/10.1371/journal.pone.0090577

Digi4LivE. (2024). IoT Sensors for Livestock Farming: Enhancing Efficiency and Animal Welfare. https://www.digi4live.eu/articles/iot-sensors-livestock

Elson, H. A. (2004). Poultry welfare in intensive and extensive production systems. *World's Poultry Science Journal, 60*(3), 341–346.

European Commission. (1999). Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. *Official Journal of the European Communities*. https://eur-lex.europa.eu

Fanatico, A. C., Owens, C. M., & Emmert, J. L. (2013). Organic poultry production: Consumer perceptions, opportunities, and regulatory issues. *Journal of Applied Poultry Research*, *22*(4), 1043–1049.

Gavril, R.N., Usturoi, M.G., & Usturoi, A. (2013). Table eggs quality, according to the storage period. *Current Opinion in Biotechnology, 24*(1).

Gentle, M. J., & McKeegan, D. E. (2007). Physiological and behavioural responses of hens to beak trimming. *Animal Welfare, 16*(3), 295–298.

Gilani, A. M., Knowles, T. G., & Nicol, C. J. (2014). Factors affecting ranging behaviour in young and adult laying hens. *British Poultry Science*, *55*(2), 127–135.

Harlander-Matauschek, A., Toscano, M. J., Sandilands, C. A., Rodenburg, T. B., Turner, J. A., & Janssen, P. H. M. (2015). The ethics of laying hen housing systems. *Journal of Agricultural and Environmental Ethics, 28*(3), 491–510.

Kijlstra, A., & Eijck, I. A. J. M. (2006). Animal health in organic livestock systems. *Journal of the Science of Food and Agriculture, 86*(14), 1871–1878.

Lay, D. C., Jr., Fulton, R. M., Hester, P. Y., Karcher, D. M., Kjaer, J. B., Mench, J. A., Mullens, B. A., Newberry, R. C., Nicol, C. J., O'Sullivan, N. P., & Porter, R. E. (2011). Hen welfare in different housing systems. *Poultry Science, 90*(1), 278–294.

Leinonen, I., Williams, A. G., Waller, A. H., & Kyriazakis, I. (2012). The environmental impacts of egg production systems in the UK. *Poultry Science*, *91*(1), 238–249. https://doi.org/10.3382/ps.2011-01666

Mench, J. A., Sumner, D. A., & Rosen-Molina, J. T. (2011). Sustainability of egg production in the United States: The policy and market context. *Poultry Science, 90*(1), 229–240.

Muir, W. M., Cheng, H. W., Croney, C., & Garner, J. P. (2016). The ethics of housing systems for laying

hens: The virtue of necessity. *Poultry Science, 95*(10), 2196–2206. https://doi.org/10.3382/ps/pew134
Nicol, C. J., Bestman, M., Gilani, A.-M., De Haas, E. N., De Jong, I. C., Lambton, S., Wagenaar, J. P., Weeks, C. A., & Rodenburg, T. B. (2013). The prevention and control of feather pecking: Application to commercial systems. *World's Poultry Science Journal, 69*(4), 775–788.
Nistor (Cotfas), L.I., Albu, A., Nistor, A.C., & Usturoi, M.G. (2015). Aspects of eggs quality provided from free range and conventional systems. Journal of Microbiology, *Biotechnology and Food Sciences, 5*(2), 186–189.
Petek, M., Alpay, F., & Orman, A. (2014). Production traits of laying hens kept in different housing systems. *Brazilian Journal of Poultry Science, 16*(4), 289–294.
Rana MS, Lee C, Lea JM, Campbell DLM. Relationship between sunlight and range use of commercial free-range hens in Australia. PLoS ONE. (2022) 17:1–27. doi: 10.1371/journal.pone.0268854.
Riber, A. B., van de Weerd, H. A., de Jong, I. C., & Steenfeldt, S. (2018). Review of environmental enrichment for broiler chickens. *Poultry Science, 97*(2), 378–396.
Rodenburg, T. B., Uitdehaag, K. A., Ellen, E. D., Komen, J., & van Arendonk, J. A. M. (2008). Feather pecking and cannibalism in non-beak-trimmed laying hens in aviary systems. *Applied Animal Behaviour Science, 110*(3–4), 133–148.
Sherwin, C. M., Richards, G. J., & Nicol, C. J. (2010). Comparison of the welfare of layer hens in 4 housing systems. *British Poultry Science, 51*(4), 488–499. https://doi.org/10.1080/00071668.2010.502518
Shimmura, T., Hirahara, S., Azuma, T., Eguchi, Y., Uetake, K., & Tanaka, T. (2007). Effect of perch design on perching behavior of laying hens in enriched cages. *Applied Animal Behaviour Science, 103*(1–2), 1–16.
Singh, M., Cowieson, A. J., & Hartcher, K. M. (2017). Outdoor stocking density and its impact on welfare of hens in free-range systems. *Animal Production Science, 57*(6), 1234–1240.
Singh, R., Cheng, K. M., & Silversides, F. G. (2011). Production performance and egg quality of four strains of laying hens housed in conventional and free-range systems. *Poultry Science, 90*(1), 1–13.
Sossidou, E. N., Elson, H. A., & Tserveni-Gousi, A. S. (2011). Enrichment and stocking density effects on welfare of laying hens in organic systems. *Journal of the Hellenic Veterinary Medical Society, 62*(1), 42–49.
Tactacan, G. B., Cho, S. Y., Cho, J. H., Kim, I. H., & Han, Y. K. (2009). Effects of dietary acidifiers on performance and gut health of laying hens. *Poultry Science, 88*(5), 1077–1082.
Tauson, R. (2005). Management and housing systems for laying hens. *World's Poultry Science Journal, 61*(4), 477–490.
Tauson, R., Kjaer, J., Maria, L., Cepero, R., & Holm, K. E. (2012). Evaluation of production, egg quality, health and welfare in laying hens housed in furnished cages and alternative systems. *World's Poultry Science Journal, 68*(4), 707–718.
Usturoi, M.G., Ratu, R.N., Radu-Rusu, R.M., Ivancia, M., & Usturoi, A. (2021). Fatty acid profile in eggs and eggs products. *Scientific Papers. Series D. Animal Science, 64*(2), 399–403.
Usturoi, Al., Usturoi, M.G., Avarvarei, B.V., Pânzaru, Claudia, Simeanu, Cristina, Usturoi, Mădălina-Iuliana, Spătaru, Mihaela, Radu-Rusu, R.M., Doliş M.G., & Simeanu, D. (2022) Research Regarding Correlation between the Assured Health State for Laying Hens and Their Productivity. *Agriculture-Basel, 3*(1), Article Number 86, DOI 10.3390/agriculture13010086.
Van de Weerd, H. A., Keatinge, R., & Roderick, S. (2009). A review of key health-related welfare issues in organic poultry production. *World's Poultry Science Journal, 65*(4), 649–684.
Van Horne, P. L. M., & Bondt, N. (2013). Competitiveness of the EU egg sector. *LEI Wageningen UR Report.*
***https://www.bigdutchmanusa.com. Retrieved April 20, 2025.
***https://www.hightoppoultry.com/slatted-floor-system/. Retrieved April 20, 2025.
***https://au.pinterest.com/pin/269723465161493996/. Retrieved April 20, 2025.