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Research Article

Performance of Laying Hens in Different Housing Systems Under Tropical Conditions

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Abstract | This study was conducted to determine the effect of different housing systems on the performance of laying hens under tropical conditions. A total of 120 Lohman Brown hens, aged 13 weeks were randomly divided into 2 housing system groups, each containing 6 replicates of 10. The first group was kept in cage-free hens (CF) and the second was kept in battery cage system (BC). Data were collected daily from each group and monitored from 21 weeks to 30 weeks of age. The results showed that feed consumption of cage-free and battery-cage-laying hens did not differ (P>0.05). Body weight and egg weight of laying hens reared with cage-free hens were higher than battery cage system (P<0.05). However, battery cage laying hens had higher day production and lower Feed conversion ratio (FCR) than cage-free (P<0.05). The income over feed cost for cage-free hens was higher than battery cage in weeks 27-30. In conclusion, cage-free laying hens have low performance but high income over feed costs.

Keywords | Laying hens, Housing system, Egg production, Tropical area, Economic value, Animal welfare

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INTRODUCTION

The performance of laying hens is significantly influenced by housing systems being kept, particularly in tropical climates where environmental conditions can worsen the challenges associated with poultry management (Oloyo, 2018). The tropical region is characterized by high temperature and humidity, which can be harmful to poultry birds if it is not properly managed. High temperature and humidity can lead to heat stress and even death in extreme cases (Olawumi and Ogunlade, 2007; Qureshi *et al*., 2001). Indeed, heat stress has been reported to cause a decrease in feed intake, feed efficiency, egg quality and quantity, as well as flock activity with a subsequent increase in pulse and respiratory rates, water intake and death (Ahmad *et al*., 2022; Rath *et al*., 2015; Wasti *et al*., 2020).Two predominant housing systems for laying hens namely battery cage (BC) and cage-free (CF) systems have distinct differences in terms of welfare, productivity, and egg quality (Manzoor *et al*., 2024; Volkmann *et al*., 2024). Battery cage, characterized by confined space and limited movement, has been traditionally favored for efficiency in egg production. However, the system has faced increasing scrutiny due to concerns over animal welfare, as it restricts natural behaviors and can lead to health issues including osteoporosis and feather pecking (Campbell *et al*., 2018; Ryu *et al*., 2017). Cage-free hens, which allows hens greater freedom to move and engage in natural behaviors such as foraging and nesting, has been associated with improved welfare outcomes (Rodenburg *et al*., 2022). Studies indicate that hens in cage-free environments often have better physical condition and produce eggs with higher quality attributes, such as larger size and improved shell strength (Ali *et al*., 2020; Tahamtani *et al*., 2015).

However, this system also presents challenges, including increased risks of disease transmission and variations in egg production due to factors such as stocking density and resource availability (Oliveira *et al*., 2019; Roy *et al*., 2022). A high stocking density may create various problems such as increased ammonia and heat produced from the birds, which can lead to stressful conditions (Kang *et al*., 2018). Environmental enrichment is a candidate for improving cage systems. A number of different types of modified cages have been investigated and developed. They include features such as nest boxes, perches, litter trays and pecking devices (Moroki and Tanaka, 2016). The tropical environment adds another layer of complexity to the evaluation of this housing system. High temperatures and humidity levels can impact performance, feed intake, and overall health, necessitating careful management practices to mitigate heat stress and ensure optimal production (Ketta and Tůmová, 2014; Mehlhorn and Petow, 2020). According to previous studies, the effects of housing systems on laying performance vary significantly under tropical conditions (Machebe *et al*., 2013; Sokołowicz *et al*., 2018).

MATERIALS AND METHODS

Study Location

The experiment was conducted at Argomulyo Village, Cangkringan Subdistrict, Sleman District, Special Region of Yogyakarta Province, Indonesia. The temperature, humidity, and temperature-humidity index (THI) of the research barn are presented in Figure 1.

Hens, Housing and Diet

A total of 120 Lohman Brown hens, aged 13 weeks were randomly divided into 2 housing system groups, each containing 6 replicates of 10 birds. The first group was kept in cage-free hens and the second was kept in battery cage system. Cage-free barn has a total area of 180 cm x 180 cm and equipped with a feeder, nipple drinker, as well as nest and perch area with a free area of 1.74 m^2 (5 birds / m^2) (Figure 2A and 2B). Meanwhile, the galvanic individual battery cage has an area of 35 cm x 20 cm x 55 cm with a feeder and nipple drinker installed each cage (Figure 2C and 2D). The lighting system was set up according to the Lohman strain guideline consisted of 16 hours of continuous light per day, from 06:00 to 22:00. Laying hens were fed the same diet with nutritional content according to the standard needs (Table 1).

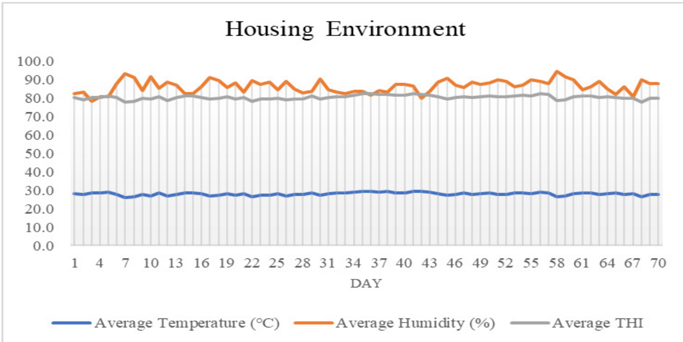

Figure 1: Variations in temperature, humidity, and temperature-humidity index (THI) in the building area during the observation period.

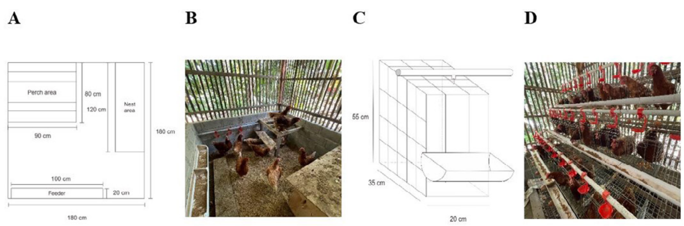

Figure 2: A: Cage-free housing design and equipment layout; **B:** Cage-free housing condition; **C:** Individual battery cage design; **D:** Battery cage housing condition.

Laying Hen Performance

All eggs were collected from each group daily and hens were monitored from 21 weeks to 30 weeks of age, while the daily egg production and weight were recorded daily. Egg production was calculated by dividing the daily count by the number of hens on the same day, while weight was recorded weekly.

$$\textit{Feed intake} = \textit{amount of feed provided} - \textit{amount of feed remaining}$$

$$\textit{Hen day egg production} = \frac{\textit{total number of egg laid}}{\textit{actual number of hen days}} \times 100\%$$

$$\textit{Feed conversion ratio} = \frac{\textit{feed intake}}{\textit{total egg weight}}$$

Table 1: Ingredients and nutrient composition of laying hen diets.

Feed ingredient	Composition (%)
Yellow corn	38.25
Heat-processed soybeans	25.00
Rice bran	11.00
Soybean meal	8.50
Corn distiller's dried grains with solubles	2.00
Crude palm oil	1.80
Limestone	9.00
Dicalcium phosphate	2.80
Mineral premix	1.00
Sodium bicarbonate	0.30
Salt	0.20
Natural betaine	0.05
Toxin binder	0.10
Calculated nutrient	Amount
Dry matter (%)	89.41
Metabolizable energy (kcal/kg)	2865
Crude protein (%)	18.20
Ether extract (%)	6.21
Crude fiber (%)	4.71
Lysine (%)	1.16
Methionine (%)	0.68
Met-Cys (%)	0.97
Threonine (%)	0.72
Tryptophan (%)	0.24
Calcium (%)	4.13
Total phosphor (%)	1.02
Available phosphor (%)	0.49
Sodium (%)	0.20
Chloride (%)	0.19
Linoleic acid (%)	3.64

Income Over Feed Cost (IOFC)

IOFC is the result of calculating the difference between weekly average income from egg sales and total expenditure on feed.

IOFC=income from egg sales- feed cost

Statistical Analysis

Data were analyzed using two-way Analysis of Variance (ANOVA) (2 housing systems × 10 laying hen ages) in a completely randomized design. Duncan Multiple Range Test (DMRT) was used to identify significant differences among treatments ($P < 0.05$). Data analysis was conducted using IBM SPSS Statistics 26 statistical program (SPSS Inc., USA).

RESULTS

Body Weight

In general, body weight cage-free hens was higher than battery cage hens, with a 2.2% greater body weight (Table 2; P<0.05). Moreover,hen body weight increased from week 21 to week 30 in all housing systems. (P<0.05). Specially, cage-free laying hens had significantly higher body weight at week 28 (Figure 3; P<0.05), whereas at other ages, the difference in body weight was not significant (P>0.05).

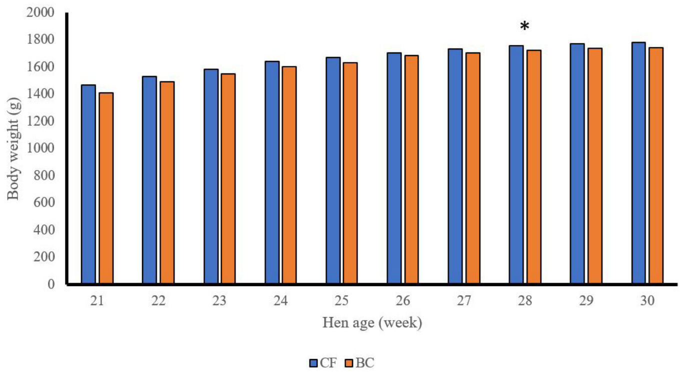

Figure 3: Comparison of body weight of laying hens reared in cage-free vs battery cage housing systems between 21 and 30 weeks of age. Note: * indicates significant difference P<0.05.

Feed Intake

Feed consumption of cage-free and battery cage laying hens did not differ (Table 2; P>0.05). Feed intake rose progressively with age (P<0.05) and at week 21, hens kept in battery cage had higher feed consumption than cage-free (P<0.05). However, feed consumption of cage-free layers was higher than battery cage in weeks 28-30 (Figure 4; P<0.05).

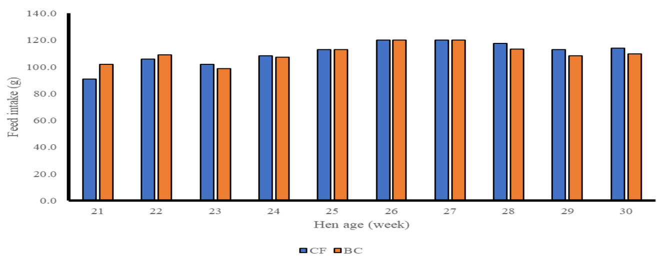

Figure 4: Comparison of feed intake of laying hens reared in cage-free vs battery cage housing systems between 21 and 30 weeks of age.

Hen Day Production

Battery cage laying hens had higher day production than cage-free (Figure 5; P<0.05). Egg production improved as the age increased in all production systems (P<0.05). Battery cages outperformed cage-free henss in weeks 22–26 (P<0.05), but differences narrowed thereafter.

Links Researchers

Table 2: Effects of housing system and hen age on laying hen productivity.

Item	BW (g)	FI (g)	HDP (%)	FCR	EW (g)
Housing type					
Cage-free	1661^{a}	110.5	67.4^{b}	3.6^{a}	53.7^{a}
Battery cage	1626^{b}	110.1	76.7^{a}	2.9^{b}	53.1^{b}
Hens age (week)					
21	1436^{g}	96.6^{f}	40.5^{e}	6.4^{a}	46.5^{f}
22	1509^{f}	107.4^{d}	58.6^{d}	4.1^{b}	50.6^{e}
23	1565^{e}	100.2^{e}	67.9^{c}	3.1^{c}	51.7^{de}
24	1619^{d}	107.7^{d}	72.0^{bc}	3.0^{c}	52.4^{d}
25	1649^{d}	112.9^{c}	75.2^{bc}	2.9^{c}	53.8^{c}
26	1691^{c}	119.0^{a}	73.0^{bc}	3.1^{c}	54.6^{bc}
27	1715^{bc}	119.0^{a}	78.5^{ab}	2.8^{c}	55.4^{ab}
28	1739^{ab}	115.6^{b}	84.6^{a}	2.5^{c}	56.7^{a}
29	1754^{ab}	110.6^{c}	85.2^{a}	2.4^{c}	56.1^{a}
30	1759^{a}	112.0^{c}	84.9^{a}	2.4^{c}	56.6^{a}
SEM	10.5	0.73	0.02	0.14	0.31
ANOVA					
Housing type	0	0.55	0	0	0.04
Hens age	0	0	0	0.00	0
Housing type x Hen age	0.99	0	0	0.01	0.66

BW, body weight; FI, feed intake; HDP, hen day production; FCR, feed conversion ratio; EW; egg weight; SEM, standard error of the mean. Note: $^{a, b, c}$ Different notations in the same column indicate significant differences P<0.05.

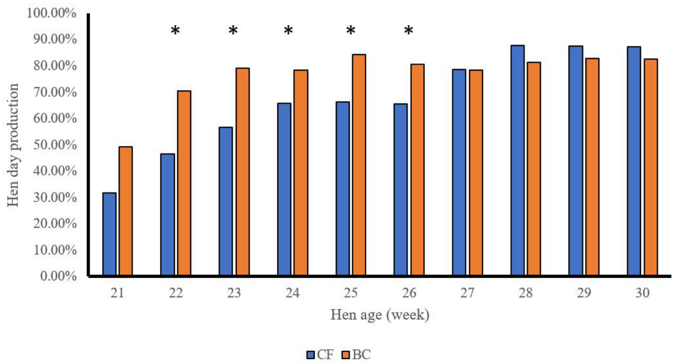

Figure 5: Comparison of average hen day production of laying hens reared in cage-free vs battery cage housing systems between 21 and 30 weeks of age. Note: * indicates significant difference P<0.05.

Feed Conversion Ratio (FCR)

FCR of battery cage laying hens was lower than cage-free (Table 2; P<0.05). Moreover FCR declined as egg production rose (P<0.05). In addition, battery cage laying hens had a lower FCR in week 21 - 26 (Figure 6; P<0.05).

Egg Weight

Egg weight of cage-free laying hens was generally greater than battery cage (Table 2; P<0.05). Furthermore, egg weight increased with age across all housing systems (P<0.05). In addition, cage-free hens produced heavier eggs in weeks 26, 27, and 29 (Figure 7; P<0.05).

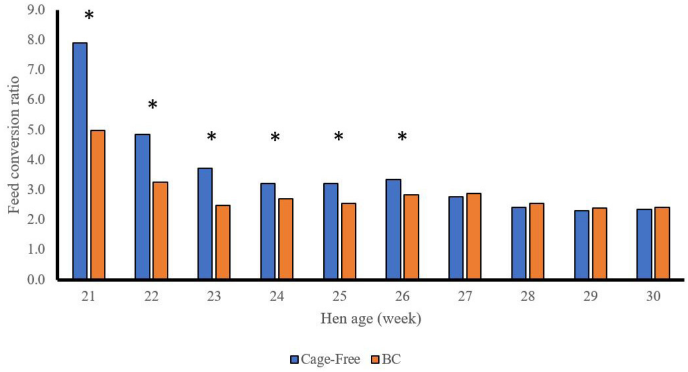

Figure 6: Comparison of average feed conversion ratio of laying hens reared in cage-free vs battery cage housing systems between 21 and 30 weeks of age. Note: * indicates significant difference P<0.05.

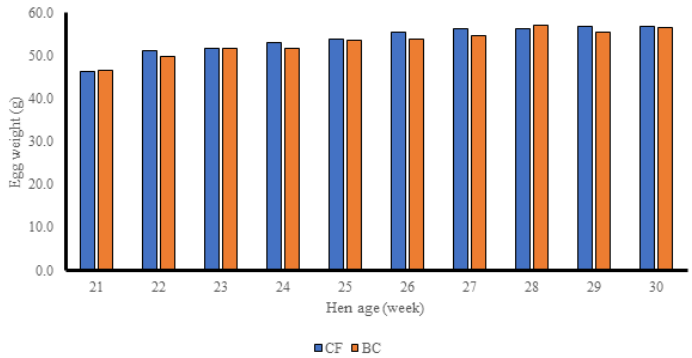

Figure 7: Comparison of average egg weight produced by laying hens reared in cage-free vs battery cage housing systems between 21 and 30 weeks of age. Note: * indicates significant difference P<0.05.

Income Over Feed Cost (IOFC)

Battery cage showed higher income over feed cost than cage-free in weeks 23, 24, 25, and 26 when egg price in both groups was considered equal to the current market egg price at IDR 25000 per kg (Figure 8; P<0.05). However, the price of cage-free laying eggs was higher than battery cage (IDR 32000 per kg). As a result, cage-free income over feed cost was higher than battery cage in weeks 27-30 (Figure 9; P<0.05).

DISCUSSION

In this study, housing system didn't affect feed intake of laying hens. However, feed consumption of laying hens in battery cage was significantly high at the start of rearing but decreased over time. Petek *et al.* (2009) housing system (battery cage vs cage-free) did not affect feed intake of laying hens. In other research, Sekeroglu *et al.* (2010) showed that laying hens housed in cage-free or litter-based systems tend to have higher feed consumption compared to those in conventional battery cages In addition, Dikmen *et al*. (2016) found that chickens reared in a free-range system had higher feed intake than chickens reared in battery cages. Moreover, Ahammed *et al*. (2014) observed that Lohmann Brown hens in a barn system had a higher feed intake and feed conversion ratio than conventional cage and aviary system. It is caused due to the cage-free hens, hens have more activities and movements that require more energy (Dikmen *et al*., 2016).

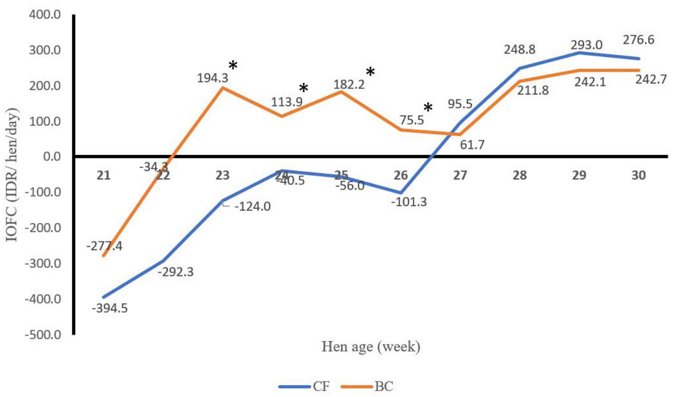

Figure 8: Income over feed cost (IOFC) of laying hens raised in cage-free vs battery cage systems (21–30 weeks of age); assumed egg price: both systems = IDR 25,000 (Indonesian Rupiah). Note: * indicates significant difference P<0.05.

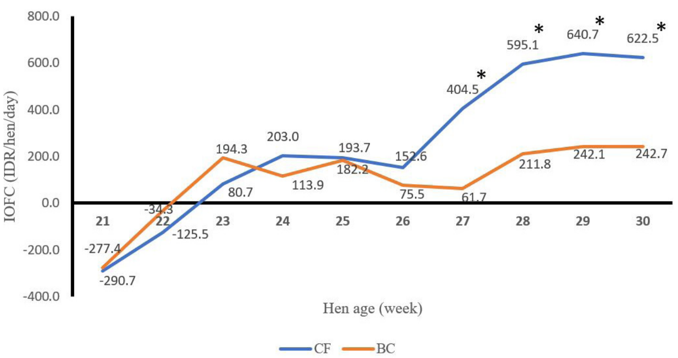

Figure 9: Income Over Feed Cost (IOFC) of laying hens in cage-free vs. battery cage systems (age 21–30 weeks); assumed egg prices: cage-free = IDR 32,000; battery cage = IDR 25,000 (Indonesian Rupiah). Note: * indicates significant difference P<0.05.

Huneau-Salaün *et al*. (2011) observed that feed intake could be affected by the initial adaptation period in battery cage, where laying hens may initially consume more feed due to stress or adjustment to the environment. Over time, as hens adapt, feed intake may stabilize or decrease. Feed intake patterns can vary significantly during the rearing phase, with initial high consumption levels that may decline as hens reach maturity and energy requirements stabilize (Regmi *et al*., 2016). The differences in feed intake between laying hens kept in cage-free and battery cage systems are influenced by several factors, including housing environment, activity levels, and available behavioral opportunities. Hens housed in cage-free hens tend to have higher feed intake compared to those in battery cage. This phenomenon can be attributed to the increased movement and activity levels associated with cage-free environment, which allows hens to engage in natural behaviors such as foraging, perching, and dust bathing (Araujo Netto *et al*., 2017; Kalkan and Yalçın, 2021).

The study also showed that cage-free laying hens have a higher body weight compared to battery hens. Several studies have found that laying hens housed in cage-free henss tend to have higher body weight compared to those in conventional battery cages (Kang *et al*., 2013; Keßler *et al*., 2021). The larger group size and more space allowance in cage-free henss can also contribute to the higher body weight. Cage-free hens typically provides hens with more space to move around, which promotes natural behaviors. This increased activity can lead to better muscle development and overall body condition. In contrast, hens in battery cage are confined to a limited space, which restricts movement, potentially resulting in lower muscle mass and body weight over time (Skrbic *et al*., 2022). Studies have shown that hens in environments with greater space allowance tend to have higher body weights, due to engagement in more physical activity capable of promoting growth (Moe *et al*., 2010).

Battery cage system typically provides a controlled environment with optimized space, which can lead to more efficient feed utilization and higher egg production rates. The confined space allows for easier management of resources such as feed and water, ensuring that hens have consistent access to necessary nutrients (Duy *et al*., 2020). Cage-free hens, while promoting natural behaviors, may lead to increased competition for resources, potentially resulting in lower overall production (Skrbic *et al*., 2022). The nutritional management in battery cage can also play a significant role in production outcomes. Diets formulated for hens in battery cage are often designed to maximize egg production, incorporating specific nutrient ratios that enhance reproductive performance (Rocha *et al*., 2013). In contrast, cage-free hens may not always be fed the same diet potentially leading to variations in egg production rates (Tůmová and Gous, 2012).

Battery cage system is designed to optimize feed efficiency by providing hens with a controlled environment that minimizes waste and maximizes nutrient absorption. In this system, hens have consistent access to feed and water, which can lead to more effective feed conversion (Prakash *et al*., 2023). The confinement in battery cage reduces the energy expenditure associated with movement, allowing hens to allocate more energy towards egg production rather than maintenance activities. This results in a lower FCR, as less feed is required to produce a given amount of eggs (Gamba *et al*., 2015). In cage-free hens, hens have more space to move and engage in natural behaviors such as foraging, perching, and dust bathing. These behaviors are beneficial for welfare, but can also lead to increased energy expenditure and potentially lower feed conversion efficiency (El-Gobary *et al*., 2016). The increased activity levels in cage-free hens may result in higher feed intake without a corresponding increase in egg production, leading to a higher FCR compared to battery cage system (Englmaierová *et al*., 2014).

The increased activity can lead to better overall health and body condition, which may contribute to larger egg sizes. In contrast, battery cage system often restricts movement and may not allow full expression of natural behaviors, potentially leading to smaller egg sizes (Galic *et al*., 2019). Hens kept in an enriched environment tend to produce heavier eggs compared to those in restrictive housing systems (Ahammed and Ohh, 2013). Battery cage system may lead to higher levels of stress due to confinement and social hierarchy issues, which can negatively impact reproductive performance and egg quality (Şekeroğlu *et al*., 2014). Stress leads to hormonal changes that affect egg production and size. In contrast, cage-free hens tend to provide a more enriched environment that supports better welfare, leading to improved egg quality and larger sizes (Banaszewska *et al*., 2020). Several studies have indicated that hens in less stressful environment tend to produce heavier eggs due to better overall health and reproductive performance (Mayer *et al*., 2023). As hens mature, reproductive systems become more efficient, leading to the production of larger eggs (Roy *et al*., 2022). The data indicating that cage-free eggs were heavier than battery cage eggs at specific weeks is consistent with the typical production peak observed, where older hens generally produce larger eggs (Zaazaa *et al*., 2023). This increase in egg size is often associated with the development of larger ovarian follicles, which contribute to greater yolk size and overall egg weight (Li *et al*., 2012).

The higher IOFC for battery cage system can be attributed to efficiency in egg production. Battery cage typically allows for higher stocking densities and optimized feed utilization, leading to increased output and lower feed costs per egg produced (Galic *et al*., 2019; Parker *et al*., 2017). This efficiency often translates into higher immediate profits when egg prices are equalized across both systems. However, the reality of market pricing, where cage-free eggs command a premium price, shifts the economic advantage towards cage-free hens (Küçükyılmaz *et al*., 2012). The willingness of consumers to pay more for cage-free eggs reflects growing concerns about animal welfare and the perceived quality of hens raised in more humane conditions (Karsten *et al*., 2010; Roy *et al*., 2022). The higher market price for cage-free eggs is indicative of changing consumer preferences, where there is an increasing demand for products consistent with ethical considerations regarding animal welfare (Englmaierová *et al*., 2014; Sharma *et al*., 2021). As consumers become more informed about the conditions under which food is produced, there is an increased willingness to pay a premium for eggs that are marketed as cage-free or organic. This trend is supported by studies showing consumers are increasingly prioritizing animal welfare in purchasing decisions, which can significantly impact the profitability of different egg production systems (Jones and Anderson, 2013; Mayer *et al*., 2023). Indonesia's cage-free egg market is emerging and experiencing a significant upward trend. This shift reflects broader global movements towards more humane animal husbandry practices, driven by increasing consumer awareness and demand for ethically produced food. Despite the current limited availability of cage-free eggs in the Indonesian market, the growth potential is significant as consumers become more educated about the benefits of cage-free hens, both in terms of animal welfare and egg quality (de Luna *et al*., 2022).

The rising awareness of animal welfare issues has led to a growing consumer preference for cage-free eggs. Studies indicate that consumers are increasingly willing to pay a premium for products consistent with values regarding animal treatment (Rakonjac *et al*., 2018). This trend is particularly relevant in Indonesia, where traditional practices are being challenged by modern ethical considerations. As consumers become more informed about the conditions under which food is produced, the demand for cage-free eggs is expected to rise, potentially leading to a more significant market presence (Stojčić *et al*., 2022).

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, cage-free laying hens had greater body weight, egg weight, and income over feed cost value compared to battery cage laying hens. However, battery cage laying hens had higher day production and feed efficiency than cage-free. Future research should explore behavioral and hormonal responses to housing systemsof laying hens with different housing are needed to explore the possible relationship between the performance and housing system.

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NOVELTY STATEMENTS

This study fills a gap by comparing the performance of laying hens in battery cage versus cage-free housing systems under tropical conditions, an area seldom explored. While research on these systems in temperate climates exists, few studies address their performance in tropical environments. Additionally, this study is the first to incorporate an economic analysis, offering insights into both the productivity and cost-effectiveness of each housing system in tropical settings.

AUTHOR'S CONTRIBUTIONS

Anom Yusuf Tri Bambang Susilo: Collected the data and drafted the manuscript.
Muhammad Fathin Hanif: Analysed the data and drafted the manuscript.
Ali Agus: Designed study concepts and modified the manuscript.
Bambang Ariyadi and Ahmad Romadhoni Surya Putra: Supervised the experiment and modified the manuscript.

Conflict of Interest

The authors have declared no conflict of interest.

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