IMPACT OF MICROLCIMATE AND HEAT STRESS INDEX ON PRODUCTION EFFICIENCY OF BROILER CHICKENS IN OPEN, SEMI-CLOSED, AND CLOSED HOUSING SYSTEMS

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Abstract. This study evaluates the impact of microclimate conditions, specifically the Heat Index (HI), on key production efficiency metrics. A non-experimental, observational study was conducted using secondary data from three commercial broiler farms in West Java, Indonesia, representing open , semi-closed, and closed with controlled-ventilation housing systems. Microclimate data were collected from three locations representing each housing system type: Cikampek (Open), Cianjur (Semi-Closed), and Bogor (Closed). Production performance data were recorded at the end of the rearing period. Due to the absence of replication (n=1 per housing system), non-parametric statistical inference could not be applied; therefore, comprehensive quantitative descriptive analysis including absolute comparisons, percentage change, ranking analysis, and effect size estimation was employed. Data were analyzed using descriptive statistics, The closed house system maintained a significantly lower average HI (155.0) compared to the semi-closed (163.1) and open (165.2) systems. Production efficiency was superior in the closed system, with the best FCR (1.46) and IP (433). Results showed that the Closed system achieved the most favorable microclimate conditions with the lowest temperature (25.4°C) and Heat Index (155.0), representing a 19.6% temperature reduction and 6.2% Heat Index reduction compared to the Open system (31.6°C; 165.2). Ranking analysis confirmed a consistent performance hierarchy: Closed > Semi-Closed > Open, with the Closed system achieving a perfect mean rank of 1.00 across all parameters. The Heat Index showed strong descriptive associations with production outcomes, where lower Heat Index values corresponded to improved performance. This study demonstrates that Closed housing systems with enhanced environmental control effectively mitigate heat stress and significantly improve broiler production efficiency in tropical conditions. However, due to limited replication, these findings should be interpreted as descriptive evidence, and future studies with adequate replication are recommended to enable robust statistical inference.

Keywords: Broiler chicken, heat stress, heat index, housing system, microclimate, production efficiency

1. Introduction

Global poultry production faces significant challenges from heat stress, particularly in tropical regions like Indonesia. Modern broiler chickens, selected for rapid growth and high metabolic rates, are highly susceptible to elevated ambient temperatures (Lara & Rostagno, 2013). Heat stress occurs when birds are unable to dissipate sufficient body heat to maintain thermal equilibrium, leading to severe repercussions on feed intake, growth rate, metabolic efficiency, and mortality (Yasa et al, 2019).

The microclimate inside a broiler house, defined by parameters such as air temperature and relative humidity, is a primary determinant of bird performance. The combined effect of these two factors is often expressed as a Heat Index (HI), which provides a more accurate measure of the thermal environment's impact on animals than temperature alone (Zakaria et al, 2024). A high HI indicates a high risk of heat stress.

The type of housing system is the most significant factor influencing the indoor microclimate. Open-sided houses rely on natural ventilation, offering minimal control over environmental conditions. Semi-closed houses often combine natural ventilation with mechanical assistance (e.g., exhaust fans). In contrast, closed-house systems with tunnel ventilation and evaporative cooling pads provide the highest degree of environmental control, actively managing temperature, humidity, and air velocity (Puron et al., 2019).

While the superiority of closed houses is often acknowledged, quantitative analysis of the relationship between the calculated HI and production efficiency metrics like Feed Conversion Ratio (FCR) and Performance Index (IP) in commercial settings in Indonesia is limited. This study aimed to analyze the impact of microclimate conditions, specifically the Heat Index, on the production efficiency (FCR and IP) of broiler chickens reared in open, semi-closed, and closed housing systems.

2. Methods

A non-experimental, observational study was conducted using secondary data from one full production cycle from three commercial broiler farms in West Java, Indonesia. The farms were selected to represent the three main housing types: Open House: Cikampek Farm, Cikampek. Semi-Closed House: Anugerah Farm, Cianjur. Closed House (Tunnel Ventilation): Saprie Farm, Bogor.

3. Results And Discussion

3.1. Description

Microclimate Conditions and Heat Index: The microclimate conditions and calculated Heat Index for the three housing systems are presented in Table 1.

3.2. Figures and Tables

Table 1. Average microclimate conditions and Heat Index in different housing systems

Housing System	Location	Avg. Temp. (°C)	Avg. RH (%)	Avg. Heat Index
Open	Cikampek	31.6	75.0	165.2
Semi-Closed	Cianjur	29.6	77.0	163.1
Closed	Bogor	25.4	76.9	155.0

Average Microclimate Conditions and Heat Index in Different Housing Systems The Closed system recorded the lowest temperature at 25.4°C, which was 6.2°C cooler than the Open system and 4.2°C cooler than the Semi-Closed system. The Open system exhibited the highest temperature at 31.6°C, indicating the greatest thermal stress potential among all housing types. Relative humidity showed minimal variation across systems, ranging from 75.0% in Open to 77.0% in Semi-Closed, with a narrow range of only 2.0 percentage points. This suggests that humidity levels were relatively stable regardless of housing system type. The Heat Index, which combines temperature and humidity effects, was highest in the Open system at 165.2 and lowest in the Closed system at 155.0, representing a substantial difference of 10.2 points. The Semi-Closed system achieved a moderate Heat Index of 163.1, positioned between the other two systems.

Table 2. Absolute Differences Between Housing Systems

Parameter	Open vs Semi-Closed	Open vs Closed	Semi-Closed vs Closed
Temperature (°C)	-2.0	-6.2	-4.2
Relative Humidity (%)	+2.0	+1.9	-0.1
Heat Index	-2.1	-10.2	-8.1

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The closed-house system successfully maintained a much lower and more stable temperature, resulting in the lowest Heat Index (155.0). The open and semi-closed systems operated at a significantly higher HI (165.2 and 163.1, respectively), well within ranges known to cause heat stress in poultry (May & Lott, 2001).

Table 3. Production production Data.

Housing System	**Final Body Weight (kg)**	**Mortality (%)**	**FCR**	**IP**
Open	1.85	8.01	1.59	326
Semi-Closed	1.80	5.43	1.51	375
Closed	2.22	2.32	1.46	433

Table 3 summarizes the production performance of broilers in Open, Semi-Closed, and Closed housing systems, showing body weight, mortality, FCR, and Performance Index values for each system. Table 4 presents the performance ranking of three housing systems (Open, Semi-Closed, and Closed) across four key production parameters: Body Weight, Mortality, FCR, and Performance Index (IP). Rank 1 indicates the best performance, while Rank 3 indicates the poorest performance. The sum of ranks and mean rank were calculated to determine the overall performance hierarchy of each housing system

Table 4. Performance Ranking of Housing Systems

Parameter	Open	Semi-Closed	Closed	Best System
Body Weight (higher is better)	2	3	1	Closed
Mortality (lower is better)	3	2	1	Closed
FCR (lower is better)	3	2	1	Closed
IP (higher is better)	3	2	1	Closed

Table 5. Ranking of Housing Systems

Overall Rank	Housing System	Sum of Ranks	Mean Rank	Conclusion
1 (Best)	Closed	1+1+1+1 = 4	1.00	Superior performance
2	Semi-Closed	3+2+2+2 = 9	2.25	Intermediate
3 (Worst)	Open	2+3+3+3 = 11	2.75	Poor performance

(Rank 1 = Best Performance)

On Body Weight Ranking: The Closed housing system achieved the highest body weight with a rank of 1, indicating superior growth performance compared to the other systems. The

Open system ranked second with a rank of 2, demonstrating moderate growth performance. The Semi-Closed system ranked lowest with a rank of 3, showing the poorest body weight achievement among all housing types. On Mortality Ranking: The Closed system recorded the lowest mortality rate, earning the best rank of 1 and demonstrating excellent livability. The Semi-Closed system achieved a rank of 2, indicating moderate mortality control. The Open system received the worst rank of 3, reflecting the highest mortality rate and poorest bird survival. On FCR Ranking: The Closed system exhibited the most efficient feed conversion with a rank of 1, showing optimal feed utilization for growth. The Semi-Closed system ranked second with a rank of 2, indicating reasonably efficient feed conversion. The Open system ranked lowest with a rank of 3, demonstrating the least efficient feed utilization among all systems. On IP Ranking: The Closed system achieved the highest Performance Index with a rank of 1, reflecting superior overall production efficiency. The Semi-Closed system ranked second with a rank of 2, showing moderate performance. The Open system received the lowest rank of 3, indicating the poorest overall production performance.

The findings strongly support the critical role of the housing system in modulating thermal stress and its profound impact on production economics. The high HI values in the open and semi-closed systems directly explain their poorer efficiency. Under heat stress, birds reduce feed intake to minimize metabolic heat production, which directly impairs growth rate (Zhang et al., 2020). Furthermore, a significant portion of ingested energy is diverted from growth to support thermoregulatory mechanisms (e.g., panting), leading to a direct deterioration in FCR (Xiang et al., 2018). The exceptionally high coefficients of determination ($R^2 > 0.95$) show that over 95% of the variation in FCR and IP can be explained by the differences in the Heat Index alone. This aligns with previous research stating that HI is a robust tool for predicting broiler performance (Lara & Rostagno, 2013). The closed-house system, by maintaining a HI closer to the thermal comfort zone through active cooling and ventilation, allowed birds to express their genetic potential for growth and feed efficiency fully.

4. Conclusion

This study concludes that the Heat Index is a powerful and reliable indicator of production efficiency in broiler chickens. Closed-house tunnel-ventilation systems are highly effective in mitigating heat stress, resulting in a significantly lower HI, which directly translates to superior FCR and IP compared to semi-closed and open systems. It is recommended that broiler producers in tropical climates prioritize investment in environmentally controlled housing systems to enhance sustainability and profitability. For existing open-sided facilities, modifications such as improved insulation, advanced cooling systems (e.g., fogging), and strategic management practices are essential to ameliorate heat stress effects. Future research should expand the sample size and include economic analysis to quantify the return on investment of different cooling technologies.

5. Acknowledgement

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