Research Article

The Effects of Cage Location on Hy-Line Laying Hens Growth Performance, Microclimate, NH_3 and CO_2 Concentration, and Dust Particle

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Abstract | This study aims to evaluate effect cage location in closed house system on Hy-Line laying hens growth performance, microclimate, ammonia (NH_3) and carbon dioxide (CO_2) concentration, and dust particle.. A total 5,051 heads laying hens used were Hy-line laying hens aged 28 weeks reared for 28 weeks on the experimental diet. A completely randomized design (CRD) with three treatments and twelve replications. The parameters observed was growth performance, microclimate, and health. The cage location consisted Z1: near inlet; Z2: middle of housing; Z3; near outlet. Result were analyses general linear model (GLM) and if there is a significant effect (p < 0.05) continued with Duncan multiple ranged tests. The effect of cage locations was presented significant differences (p < 0.05) on the average daily feed intake (ADFI), egg mass, temperature, NH_3 and CO_2 concentration. the first cage location (near inlet) in the closed-house system resulted the highest egg mass, the lowest temperature, and the lowest of ammonia and carbon dioxide concentration. It can be concluded first cage location near the inlet were the best one to support good production performance of Hy Line Laying hens.

Keywords | Cage locations, Production performance, Hy-line hens, Microclimate

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INTRODUCTION

The house is an important part of the management of laying hens since it was site for laying hens' activities. Either environmental and genetic were influenced the growth performances and egg quality of laying hens (Kang et al., 2016). Indonesia has fluctuated climate, temperature, and humidity which is significantly influenced the health and level stress of laying hens. A closed housed established in order to preventing fluctuated climate in housing. There are several type housings on the laying hens as follows: closed housed, open house, and semi-open house. The closed house system has exhaust fan and a cooling pad as the cooling system (Amijaya et al., 2018). Furthermore, the closed house has zoning inside as follows: the cage location close to the cooling pad/inlet, the middle cage location, and the cage location close to the exhaust fan/outlet. The distribution of airflow, temperature, and humidity in the house will be different from the point of the inlet to the outlet (exhaust fan) (Amijaya et al., 2018). Where the cage location near the cooling pad has a lower temperature than the cage location near the exhaust fan, the house cage location near the inlet has a cooler temperature (Renata et al., 2018). Differences in the house environment which include temperature, humidity, and air velocity result in differences in the effective temperature of laying hens at the inlet to outlet points (Renata et al., 2018).

Environmental temperature is the main non-genetic factor that affects the genetic potential of the laying hens

(Oguntunji and Alabi 2010). Temperature is one of the most important environmental factors that can affect the health, behavior and productivity of poultry (Webster and Czarick 2000). Poultry behaviors can significantly affect its growth (Kuzniacka et al., 2014). Different temperatures will affect the production activity and the quality of the eggs produced. Egg production is susceptible to heat stress problems because concentrated feeding and laying hens are mostly raised in cages with high stocking densities (Li et al., 2020). Rizzi et al. (2006) stated that when heat stress increasing, contrary findings would be reduced feed intake, egg production, and increasing mortalities. The comfort cage location for chickens is 18-25 ºC, in this temperature range heat stress can be suppressed and a normal body temperature of 41 ºC can be maintained. Temperatures above 25 ºC result in increased and inefficient body heat loss. Under these conditions, the evaporation of water from the respiratory tract becomes the most important heat release mechanism (Adli et al., 2022). The process of evaporation of 1 gram of water requires 540 calories of body heat (Adli et al., 2020). At temperatures above the comfort cage location, birds will need more energy to maintain body temperature and normal metabolic activity. Under these conditions, energy is not utilized for growth and egg production, resulting in decreased production performance (Hyline International 2016). Therefore, this study aims to evaluate effect cage location in closed house system on Hy-Line laying hens growth performance, microclimate, ammonia (NH_3) and carbon dioxide (CO_2) concentration, and dust particle.

MATERIALS AND METHODS

Ethical approval

Ethical approval for the study was given by the Animal Care and Use Committee, University of Brawijaya, No. 996/UN10.F05/PN/2021

Experimental design

A total 5,051 heads laying hens used were Hy-line laying hens aged 28 weeks reared for 28 weeks on the experimental diet. A completely randomized design (CRD) with three treatments with four laying hens each twelve replications. The cage location consisted Z1: near inlet; Z2: middle of housing; Z3; near outlet. All laying hens were placed in the closed environmentally controlled house with 4x80 m² in 55x35x35 cm cage. All laying hens were allowed *ad libitum* access to water through adjustable nipple drinkers, automatic feeding bunker, and installed microclimate controller. The housing was divided into two sides as follows: Side A (Consisted 32 horizontally with 4 tiers vertically), and Side B (consisted 32 horizontally with 4 tiers vertically). SumberSekar (1200 meters above sea levels) (7°54'57.0"S 112°34'47.9"E or -7.91584040052, 112.579960105). The housing layout can be seen in Figure 1, 2, and 3. The formulated feed was provided by Charoen Pokphand Tbk. consisted yellow maize, soybean meal, bone meal, meat meal, soy oil, leaf meal, and custom mineral mix. The nutrient composition as follows dry matter 87%, crude protein 18.5%, ether extract 3.0%, crude fibre 7.0%, ash 14%, sodium 4.25%, Phosphor 0.55%, and aflatoxin 12 ppb.

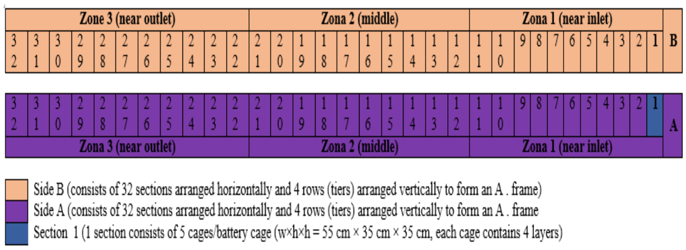

Figure 1: Lay out cage/battery placement (top view)

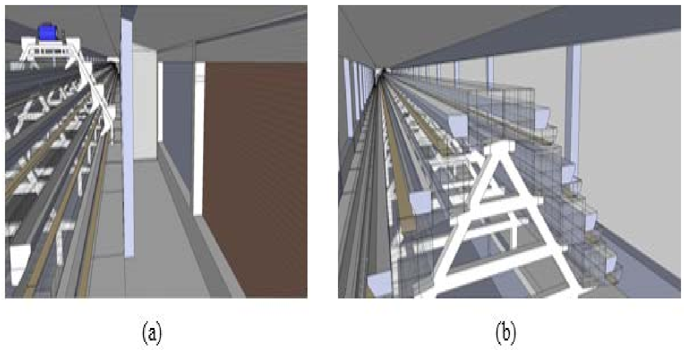

Figure 2-3: Cage layout (a) cages layer section A, (b) cage layer frame A

Production Performance

Hen day production was recorded on a daily as the number of eggs produced divided by the total laying hens) population on that day (%). Average daily feed intake was recorded as the difference between feed offered and feed refusal divided by the number of days of feeding and the number of laying hens . Feed egg ration was expressed by dividing amount of feed given by the total number collection of the eggs. In the end, egg mas was recorded by percentage of egg production multiple with mean egg weight (g) in that day following (Adli 2021; Ardiansyah et al., 2022).

Microclimate, NH_3 And CO_2 Concenration, And Dust Particle.

Either temperature (ºC) and relative humidity (%) was recorded using Anemometer (Kestrel 3000) three times in a day 06.00 A.M., 12.00 P.M., and 18.00 P.M.). Furthermore, air velocity was expressed (m/s). Either, ammonia gas (NH_3) concentration and CO_2 concentration recorded three times daily with parts per million (ppm) observed.

Links Researchers

Data analysis

A statistical analysis was conducted using analysis of variance using Proc Mixed with general linear model (GLM) using SAS studio for academics Online Edition (https://odamid-apse1.oda.sas.com/SASStudio/). An error was expressed as standard error mean (SEM). At the end, probabalities values were subjected in Duncan Multiple Range Test. The following model was used:

$Y_{ij} = \mu + T_i + e_{ij}$

Where Y_{ij} was parameters observed, μ was the overall mean, T_i was the effect different cage location at the closed house, and e_{ij} was the amount of error number.

Data were collected through observation of bird samples in each experimental unit. Microclimate data was obtained by direct measurement using a thermohydrometer. Data that is recorded every day is climatic data including temperature (°C), humidity, ammonia gas concentration, CO2 gas concentration, and dust particle.

RESULTS AND DISCUSSION

Effects of the cage locations on microclimate of Hy-line laying hens

Table 2 showed that cage location insignificantly (p >0,05) on relative humidity.The average temperature has increased from cage location 1, cage location 2 and cage location 3. This study in agreement with Amijaya et al. (2018) who stated that the temperature inclined increasing either nearest inlet and outlet. These conditions appear since the cage location was nearest with cooling pad. The cooling pad was act as received the air to the closed-house. The cold air that enters through the cooling pad due to being sucked in by the fan at the end of the cage causes the air to move directly to the fan because it has a greater pressure. At this moment, the cold air that enters through the cooling pad to move continuously toward the fan. According to Pimaditya et al. (2015) the advantages using closed-housing system was can be controlled-environmentally-room. Indonesia faces fluctuated climate using closed-housing system would be reduced the stress at laying hens. In addition, Natali et al. (2012) recommended the ideal humidity for laying hens approximately 60-70%..The relative humidity in this study were 70.43; 70.13; and 70.00, respectively.

The relative humidity showed curvilinear increased at 06.00 A.M., 12.00 P.M., and 18.00 P.M. Table 3 showed that average concentrations of ammonia (NH3) and carbon dioxide (CO2) gases in different cage cage locations. This is in line with previous research at the 09.00 A.M. the temperature at the housing slowly increasing (Kaasik and Maasikmets 2013). In line with Shen et al. (2018) that the humidity inclined slightly increased at the evening when recorded the data. humidity. In line, there was a negative correlation between temperature and humidity on the closed-house laying hens (Kaasik and Maasikmets 2013; Kumari and Choi 2014). The result showed that the air velocity at the first, second, and third cage location was 1.65;1.52;1.55 m/s (Table 2), respectively. Air exchange (ventilation) is increased to improve air quality in the cage when the ambient temperature increases., Therefore, closed-house systems have become a contributor to material particles classified based on their size (Bonifacio et al., 2015). The composition of the particles in the house is different from the composition of the particles in the atmosphere. The material particles collected from poultry houses contain high concentrations of organic matter. The organic matter is sourced from feed, feces, feathers, and skin (Shen et al., 2018; Sjofjan et al., 2018b). The concentration of particulate matter and ammonia gas in poultry houses has a significant effect on the health of workers and poultry. Microclimate variables consisted of temperature, relative humidity, ventilation rate, and lighting which affect the concentration of material particles and NH_3 contained in the cage.

Effects of the cage locations on average concentrations of ammonia (NH_3) and carbon dioxide (CO_2) gase

Cage location significantly (p<0.05) affected the concentrations of NH_3 and CO_2 (Table 3). The current result showed that the amount of NH_3 in the first, second, and third cage location was 2.77;3.31;3.38 ppm, respectively. Shen et al. (2018) stated that the NH_3 concentration was higher at the bottom compared with entrance and middle cage location. This condition might correlation with the gas flow. The cage location near the inlet would be advantages. The NH_3 concentration were influenced by air velocity, particle concentration, and NH_3 components (Shen et al., 2018). During the study, the dust particles were higher at near entrance compare with bottom cage locations. The organic matter and mineral materials were from feed, excreta, and dust were combined together into smallest particle that increasing stress of laying hens (Shen et al., 2018). The average number of matter particles in first, second, and third cage location was 75.615.68; 78.251.49; and 83.397.05 particles, respectively (Table 4). There is no correlation between humidity and particle size. The dust particle mainly found in the closed-house systems with carbon and oxygen as an element (Shen et al., 2018). During the study the entrance are presented greater result compared with inlet and outlet cage location. Either dust and coarse fraction was potential to harm the alveoli of the lungs laying hens. In addition, large numbers of pathogenic bacteria were also found attached to material particles in poultry cages (Li et al., 2020). It is reported that the size of materials was approximately 2.5 nm since their can attract the respiratory systems of laying hens (Li et al., 2020).

Table 1: Effect of different cage locations in closed house system on production performance

Parameters	Treatment			
	T_1	T_2	T_3	SEM
FI (g/bird/day)	117.31^b	117.66^c	115.65^a	0.35
HDP (%)	78.83	82.61	78.72	0.87
Egg mass (g/bird)	65.83^c	65.37^b	64.16^a	0.26
FCR	1.78	1.80	1.81	0.13

$^{a, b, c, d}$ Means with different superscripts in the row differ significantly ($p \leq 0.05$). T_1 = zone 1 (near inlet), T_2 = middle house zone, T_3 = near outlet, FI = Feed Intake HDP = Hen Day Production, FCR = Feed Conversion

Table 2: Average temperature, humidity, and air velocity in different cage zones

Parameters	Treatment			
	T_1	T_2	T_3	SEM
Temperature (°C)	23.49^a	24.19^b	24.91^c	0.213
Relative Humidity (%)	70.43	70.13	70.00	0.739
Air velocity (feet/second)	1.65	1.53	1.55	0.046

$^{a, b, c, d}$ Means with different superscripts in the row differ significantly ($p \leq 0.05$). T_1 = zone 1 (near inlet), T_2 = middle house zone, T_3 = near outlet

Table 3: Average concentrations of ammonia (NH_3) and carbon dioxide (CO_2) gases in different cage zones

Parameters	Treatment			
	T_1	T_2	T_3	SEM
NH_3 concentration (ppm)	2.77^a	3.32^b	3.78^c	0.092
CO_2 concentration (ppm)	448.79^a	482.17b	542.21^c	9.529

$^{a, b, c, d}$ Means with different superscripts in the row differ significantly ($p \leq 0.05$). T_1 = zone 1 (near inlet), T_2 = middle house zone, T_3 = near outlet

Table 4: Average of dust particle in closed house

Parameters	Treatment			
	T_1	T_2	T_3	SEM
0.3 micrometer (particles)	221727.10	229485.74	244746.86	21749.02
2.5 micrometer (particles)	5101.76	5250.00	5424.62	469.61
10 micrometers (particles)	18.74	19.67	18.87	1.61

$^{a, b, c, d}$ Means with different superscripts in the row differ significantly ($p \leq 0.05$). T_1 = zone 1 (near inlet), T_2 = middle house zone, T_3 = near outlet

It is reported that major contributor of pollution in the closed-house system was NH_3 which is generated from excreta. Higher amount of ammonia caused problem in the respiratory systems, distracted eyes, paranasal sinuses, and damaged skin (Kearney et al., 2014; Shen et al., 2018). NH_3 produced in closed-housed can be affected on reducing growth performance, livestock welfare, feed intake, and growth rate (Fabbri et al., 2007). Decreased daily body weight gain and feed conversion when the NH_3 concentration level is above 25 ppm (Miles et al., 2006). In addition, the abundant concentration of NH_3 may be in the form of secondary inorganic particles such as NH_4^+ under conditions of high humidity (Robarge et al., 2002). In particular, ventilation is the most dominant factor affecting the formation, concentration, emission, and distribution of material particles in the cage. High ventilation rates cause the emission rate of matter particles to also increasing and vice versa (Hinz and Linke 1998; Redwine et al., 2002). In closed-houses system the total solids particles are affected by temperature and relative humidity (Vučemilo et al.,, 2008).

The difference in the concentration of matter particles is influenced by the measurement method used, the season, and the age of the laying hens. Several studies indicate that the concentration of material particles can be influenced by various factors, including roof type, climate, varieties of laying hens, laying hens cage structure (Reynold et al., 1998; Ellen et al., 2000). Geographical and altitude might affect the concentration of material particles in the cage. The principle of negative air pressure is used in the ventilation system of the research enclosure. A breath of fresh air that is low in particulate matter content is directed to the middle and back of the cage. This explains why the concentration of matter particles in the front of the cage is lower than in the middle and back of the cage. This was also found in a study conducted by (Guarino et al., 1999) in a closed cage of laying hens with a negative pressure ventilation system. Livestock activity is quieter at night and becomes active when the lighting in the pen is activated. This increases the concentration of dust particles in the pen (Costa et al., 2012). In addition. the activity of feeding and cage workers in the morning resulted in the movement of dust particles in the cage. Air movement correlates with two microclimate variables. namely the concentration of matter particles and air humidity. Differences in ammonia concentration (NH_3) in closed laying hens are influenced by maintenance management, type of machine used in the production unit, variety and age of livestock (Costa et al., 2012). The cage is equipped with conveyor manure, which NH_3 gas created will bind to the water molecules in the front of the cage (inlet) and flow to the back of the cage. There is a significant correlation between the concentration of NH_3 and particulate matter which can be explained because NH_3 can be adsorbed by material particles in livestock production units (Stamp et al., 2004).

Effects of the cage locations on growth performance and egg quality of Hy-line laying hens

Cage locations significant ($p<0.05$) affected ADFI and Egg Mass. Meanwhile, cage locations did not affect ($p>0.05$) on HDP and FCR (Table 1). The temperature, humidity, and volume of air change the amount of feed intake (Lin et al., 2005). The increasing of the temperature caused the feed intake decrease and increasing the water intake (Natali and Yuwanta, 2008). In line, the growth of performance and egg production were decreasing (Primaditya et al., 2015). Hy-line International (2016) stated that Hy-Line aged 28-29 can be produced 94% of total egg production. Even though, didn't differ significantly the first cage location better compared with another cage location. The Hy-Line were facing the maturity of reproductive organ at 28-29 weeks old with approximately can produced 94% of egg production (Hy-line International, 2016). Our hen day production was under 94% of total egg production it may related to microclimate conditions during experimental. Even though, insignificant difference there is correlation between hen day production (%) on cage location and temperature (Figure 4). Conditions of high environmental temperature followed by high humidity are generally conditions during the summer or in the tropics. Heat stress will generally be found in livestock kept in groups. At ambient temperatures above 33^0 C the number of mortalities increases and productivity declines. In line, extreme environmental temperatures. these conditions will result in low growth and decreased egg production and egg quality. Conversely with Sjofjan et al. (2021a) that chicken exposed with 32°C was reported higher abdominal fat, and relative organ weight compared with control group 22°C.

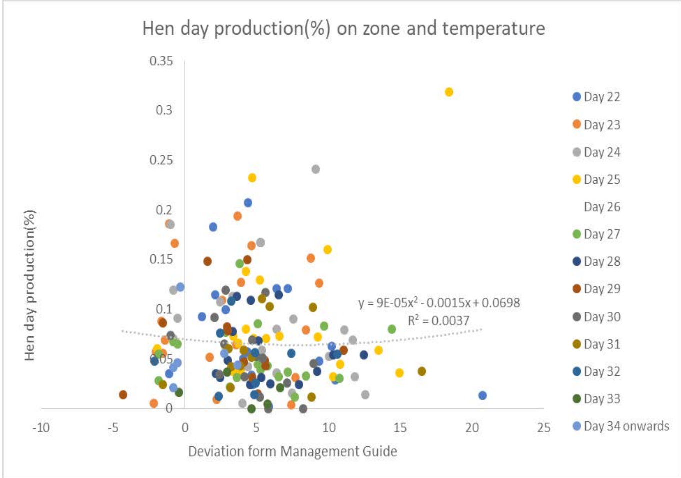

Figure 4: Hen day production (%) on zone and temperature

CONCLUSIONS

It is concluded that the first cage location (near inlet) in the closed-house system resulted the highest egg mass, the lowest temperature, and the lowest of ammonia and carbon dioxide concentration.

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

NOVELTY STATEMENT

There has been no research published about effect of cage location on the closed-housed system for the specific strain for laying hens. The importance of the cage location of the closed-house system might can be used as additional for Hy-Line management guide in the future.

AUTHOR'S CONTRIBUTION

ES conceptualization and supervision; MM conceptualization; OS review the manuscript, validation; DNA writing the original manuscript, drafting manuscript, revise grammatically, creating illustration, and validation; DLY conceptualization, collecting data, writing the draft manuscript, data curation

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