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The Impacts of Body Condition, Microclimate, Wind Speed, and Air Pollutant on Physiological Response of Laying Hen Reared under Tropical Climate

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ABSTRACT

The environmental changes in the animal's body status could manifest as a physiological response. The present study investigated the impact of body condition, microclimate, wind speed, and air pollutants on the physiological response of laying hens. Therefore, a total of 172 laying hens at 16 weeks of age from Isa Brown were investigated for 5 days. Data on body condition, microclimate, wind speed, and physiological response were recorded and then analyzed using the SEM model by Partial Least Square- Structural Equation Modeling using smartPLS. The obtained result revealed that 59.71% of the physiological response of the chickens (respiratory rate and rectal temperature) reared at the open house system could be predicted by the independent. The microclimate (γ = 0.465) was found to be more effective than body condition (γ = 0.237), wind speed (γ = -0.364), and air pollutant (γ = 0.08). Moreover, it was found that as much as 83.1% of the air pollutants in the open house system could be predicted by the independent variables, and wind speed (γ = -0.890) was more effective than microclimate (γ = 0.074) variables.

Keywords: Laying hen, Microclimate, Physiological response, Tropical climate

INTRODUCTION

Indonesia is a tropical country with two rainy and dry seasons due to wind direction effects from two continents. Consequently, climate is a crucial aspect and becomes a limiting factor in livestock management. Temperature and humidity in Indonesia are relatively high. In East Java, in the year 2017, the temperature ranged from 20.7°C to 35.9°C, while the humidity ranged from 42% to 99% (Indonesia Statistical Bureau, 2017). This climate does not match the requirements to achieve a better poultry production performance. The comfort zone for chicken ranges between 18°C and 22°C and between 60 and 70% for temperature and humidity, respectively (Diaz et al., 2018; Kim et al., 2021; Mascarenhas et al., 2022). Temperature and humidity are manifested in the temperature and humidity index (THI). The best THI for poultry, especially laying hens, is below 70, (Olivares et al., 2013). Paliadi et al. (2015) revealed that the average THI in two regions at West Java (Kuningan and Cililin) was 86 and 72, respectively. Hence, the Indonesian environment is characterized by high temperature and relative humidity, which are higher than the requirement.

Most Indonesian farmers running businesses on laying hens have relied on a naturally ventilated open house system (Susanti et al., 2022). The microclimate involving temperature, humidity, and airflow in the open house system fluctuates. Thus, the microclimate inside the house relies on a region's macroclimate. On the other hand, chicken house produces harmful gas emissions resulting from raising poultry, considering that rearing of laying hens takes a very long time in one production period, which is normally 100 weeks, even more in traditional farmers (Reddy et al., 2007; Hedrix Genetics, 2021). Pollutant gas concentrations, such as ammonia, carbon dioxide, and dust particles, are major factors to be concerned about (Al-Kerwi et al., 2022). The magnitude of these components inside the house that exceeds the threshold can disrupt livestock metabolism, reducing the productivity of laying hens (Li et al., 2020).

Laying hens are a commodity that has long been developed in Indonesia with such a climate. Although, climatically, this country has a big obstacle, the population of laying hens in Indonesia is increasing from year to year (Hartono et al., 2021), and Indonesia is the ninth producer of poultry products in the world (Fun and Wu, 2022). The main reason for this issue is that poultry needs certain requirements for better production, but their adaptive behavior allows them to adapt to environmental changes (Gerken et al., 2006). Therefore, this research aimed to study the physiological response of chicken rearing in hot and humid climates with open-house systems to all factors that contribute to their performance.

MATERIALS AND METHODS

Study location

This research was performed at Pojok Village, Wates Sub-district, Kediri Regency, East Java Province, Indonesia, from January to February 2022. The elevation of this region is 77 meters above sea level (MASL), -7.781 latitude and 112.071 longitude, with a rainfall rate of 1860 mm per year and an average daily temperature of 27°C (Indonesia Statistical Bureau, 2017).

Experimental animals and management

One hundred and seventy-two 16-weeks-old pullets were selected randomly from three hundred chickens of the population of chickens in a rearing house as Slovin’s equation from litter floor housing (Ryan, 2013). This research was conducted at an open house system in dimensions of 15 m x 4 m x 3.5 m (length x depth x height) with a battery aligned in six rows with 60 chickens per row (three rows face to face/V-shaped liked). The battery was arranged 1.5 m above the floor. A lighting program of 14Light/10Dark was applied. Laying hens have *ad libitum* access to water. Feeding was confinity given as a feeding program prescribed from manual guidance of commercial laying hens for tropical countries (Hendrix Genetics, 2021). The commercial diet was from PT. Cargill Indonesia “Q MAX DEDEVOPER COMPLETE” (16% of crude protein and metabolizable energy of 2700-2970 Kcal/kg). The chickens were vaccinated during the rearing as a protocol from Medion company (Medion, 2018).

Measured parameters

Body weight was collected at the age of 16 weeks prior to the placement in the battery cage. The body weight of the chicken was measured in grams (g) using a digital scale weight. The fleshing score was determined according to Polley (2016) at once during weighing. Respiratory rate was counted first before data collection for rectal temperature. The abdominal region was observed to count respiratory movements within one minute with the aid of a stopwatch. Rectal temperature was obtained by introducing Kruuse digital thermometer Digi-Vet SC 12 (Zimbabwe) into the cloaca of chickens until the stability of reading. House temperature and humidity were recorded with mi-sol DS 102 data logger (China) at five different spots inside the house. Ammonia gas level was measured using ammonia detector AR8500 at five different spots inside the house. Number of Dust particles was measured using Fluke 985 Particle Counter (USA) at 5 different spots inside the house. Wind speed and direction were performed by Kestrel 3000 (USA). Data on microclimate, air pollutants, wind speed, and physiological response were collected simultaneously at four different times (2 am, 8 am, 2 pm, 9 pm) for 5 days.

Statistical analysis

Data analysis on this research was performed using the Partial Least Square-Structural Equation Model (PLS-SEM) using SmartPLS (v.3.3.9). The assessment of model results was made as recommended by Hair et al. (2021) and the significance level was considered at 0.05.

RESULTS AND DISCUSSION

Most studies evaluated the physiological responses of the chicken just based on certain variables. However, the chicken will respond physiologically to any environmental changes such as microclimate (Muharlien et al., 2020), harmful gases (Kristensen and Wathes, 2000), and the body weight of the chicken (Nascimento et al., 2017). The PLS-SEM is a statistical method that makes it possible to analyze observed and unobserved variables effectively in many fields, such as agriculture and livestock (Yalçin et al., 2021). Therefore, this study presented a four-structure with a nine-indicator model to evaluate the physiological responses of the chicken. The summary result of data analysis from SmartPLS is available in Figure 1. The readout from SmartPLS analysis comprising indicator weights/loadings, composite reliability (CR), average variance extracted (AVE), path coefficients, cross-loading, variance Inflation Factor (VIF), t-value, and p-value are presented in tables 1, 2, and 3.

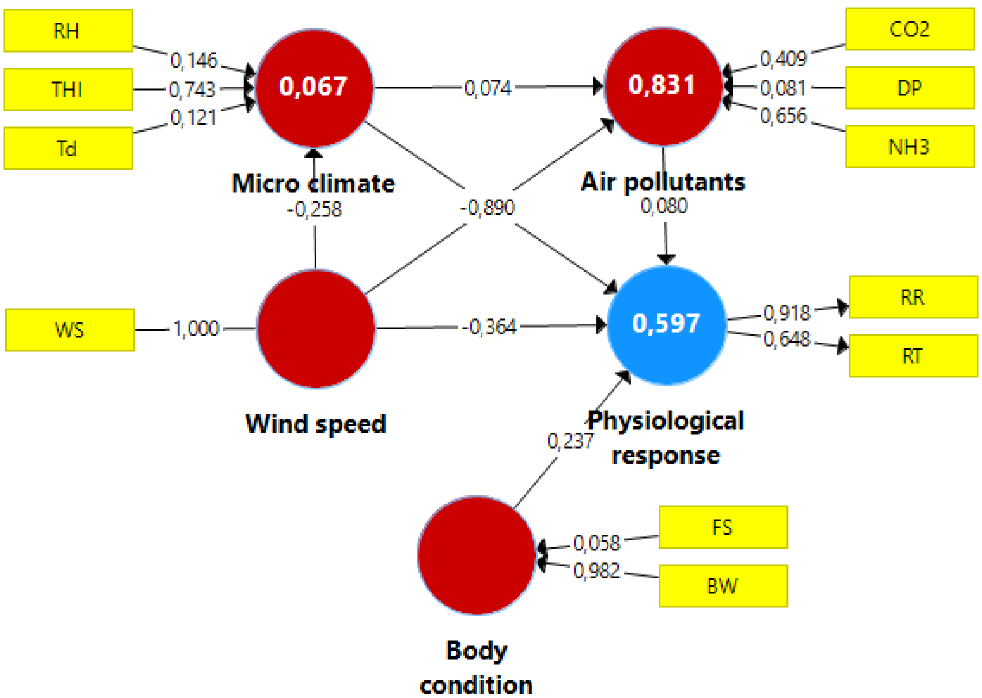

Figure 1. Modelling of the construct of body condition, microclimate, and wind speed analyzed by SmartPLS model of laying hen reared under tropical climate in Indonesia. BW: Body weight, FS: Fleshing score, Td: Dewpoint temperature, RH: Relative humidity, THI: Temperature and humidity index, NH3: Ammonia, CO2: Carbon dioxide, DP: Dust particle, RR: Respiratory rate, RT: Rectal temperature.

Table 1. Assessment of the physiological responses of laying hens for five days of observation (reflective measurement model)

	Reflective indicators	Convergent validity			Internal consistency reliability			Discriminant validity	t Value	p value
		Loadings	Indicator reliability	AVE	Composite reliability	Cronbach's Alpha	Rho_A			
		>0.5	>0.5	>0.5	0.70-0.95					
Physiological response	RR (beat/min)	0.918	0.797	0.631	0.768	0.451	0.574	Yes	24.18	p<0.05
	RT (°C)	0.648	0.415						3.97	p<0.05

RR: Respiratory rate, RT: Rectal temperature, AVE: Average variance extracted, Loading: Correlation value between physiological response, respiration rate, and rectal temperature, Cronbach's Alpha: A measure of internal consistency of a test, Rho_A: Measurement the strength of association between two variables, less than 0.05 show significant.

Table 2. Assessments of body condition, microclimate, wind speed, and air pollutant (formative measurement models) of laying hen reared under tropical climate in Indonesia

Parameters	Formative indicators	Outer loadings	t Value	Significance	95% bootstrap confidence interval	Outer VIF
Body condition	BW (g)	0.982	5.220	Yes	[0.182, 1.000]	1.093
	FS	0.058	1.056	No	[-0.171, 0.985]	1.093
Microclimate	Td (°C)	0.121	24.151	Yes	[0.908, 1.000]	889.88
	RH (%)	0.146	18.807	Yes	[0.831, 0.995]	143.79
	THI	0.743	33.771	Yes	[0.889, 0.999]	1639.0
Gas condition	NH3 (ppm)	0.656	52.255	Yes	[0.867, 0.991]	2.086
	CO2 (ppm)	0.409	26.853	Yes	[0.621, 0.922]	2.091
	DP (µg/m3)	0.081	1.666	No	[-0.996, -0.898]	1.005

BW: Body weight, FS: Fleshing score, Td: Dewpoint temperature, RH: Relative humidity, THI: Temperature and humidity index, NH3: Ammonia, CO2: Carbon dioxide, DP: Dust particle, VIF: Variance inflation factor, ($p < 0.05$).

Table 3. The result from the Partial Least Square-Structural Equation Model cross-loadings test for discriminant validity, air pollutant, body condition, microclimate, and physiological response of laying hen reared under tropical climate in Indonesia

Factors	Air pollutant	Body condition	Microclimate	Physiological response
BW	0.042	0.998	0.057	0.285
FS	0.077	0.345	0.085	0.098
Td	0.295	0.065	0.984	0.591
RH	0.297	0.044	0.944	0.554
THI	0.302	0.063	0.999	0.599
NH3	0.954	0.001	0.287	0.559
CO2	0.888	0.095	0.260	0.470
DP	0.140	0.074	0.109	0.041
RR	0.691	0.105	0.562	0.918
RT	0.029	0.485	0.361	0.648

BW: Body weight, FS: Fleshing score, Td: Dewpoint temperature, RH: Relative humidity, THI: Temperature and humidity index, NH3: Ammonia, CO2: Carbon dioxide, DP: Dust particle, RR: Respiratory rate, RT: Rectal temperature.

Assessment of outer model (reflective and formative measurement models)

According to the measurement model, physiological response contained two factors with loading of 0.918 and 0.648 for respiratory rate (RR) and rectal temperature (RT), respectively. This result indicated that respiratory rate contributes more to the construct than rectal temperature. Respiration is the first step for birds in maintaining body temperature which assists in the evaporation of water from the moist linings of the respiratory system instead of by radiation, convection, and conduction (Chandrasekar, 2011). Richards (1970) reported that respiratory rate increases linearly with body temperature. Basuony (2011) also wrote that Birds have no sweat glands, and under heat stress, they rely upon increased evaporation from the respiratory system as a major avenue for heat dissipation. Respiratory rate and rectal temperature are two variables related to each other in regulating body temperature (Bianca and Kunz, 1978; Son et al., 2022). Nurmeiliasari et al. (2020) explained that respiratory symptoms and stress are observable parameters. Therefore, the indicator of respiratory rate has higher reliability (0.918) compared with the rectal temperature indicator (0.648).

The value of AVE for the physiological response construct was 0.631, which exceeded the cut of 0.5 (Table 1). This means that the latent variable of physiological response could explain 63.1% of indicators on average. Based on the value of loading and the AVE, the outer model of reflective measurement from physiological response met the criteria for convergent validity. For the discriminant validity, the construct of physiological response appeared to meet the criteria since the internal consistency reliability (using composite reliability-CR) was 0.768, Table 1). Furthermore, based on the cross-loading rate of each indicator in the latent variable (Table 3), it has produced greater cross-loading rates. Therefore, the latent variable of physiological response was valid as discriminant validity. All the two indicators of the physiological response (respiratory rate and rectal temperature) were found to be significant based on the bootstrapping procedure ($p < 0.05$). All indicators used in the assessment of the outer model seem to be appropriate to measure the latent variables (physiological response). Dewpoint temperature, RH, and THI posed multicollinearity with a score exceeding 5, but the rest showed no multicollinearity. This is due to the equation of THI, which includes two indicators within the same latent variable. However, since THI is an indicator of the thermal regime that an environment presents, it is still carried out from the assessment of the measurement model.

Wind speed or air velocity is a very important component in the management of poultry rearing because it can affect the microclimate inside the house, air pollutants, and the chickens' physiological response, which in turn can reduce the production performance of the poultry. Sohsuebngarm et al. (2019) reported a significant association between air velocity and body temperature of broiler chickens. Purswell et al. (2013) reported that air velocity impacts hen day production, feed consumption, and feed consumption per dozen eggs. However, there was no significant difference in feed conversion ratio and egg weight for laying hen production from 24 to 27 weeks ($p > 0.05$). Therefore, the current study put wind speed as a single indicator in the model to find out the interaction between wind speed and microclimate, air pollutants, and the physiological response of chickens.

Assessment of structural model

Based on the proposed model in Figure 1, five constructs and their seven path coefficients represent the relationships between constructs. The assessment of path coefficients of the structural model is available in Table 4. Body condition, microclimate, wind speed, and air pollutants gave a moderate contribution of 59.71% (R^2 = 0.597) of the total variability in the physiological response of the chicken. Among those four latent variables, microclimate had the most key role in the physiological response of the chicken (γ=0.465, $p < 0.05$, and f^2 = 0.486). These findings agree with the work of Sohsuebngarm et al. (2019), who reported that microclimate (involving ambient temperature, relative humidity, and heat index) significantly affected the chicken's body temperature. Nascimento et al. (2012) reported that broilers under different microclimate stress conditions (temperature and humidity) significantly affected the physiological parameters of the chicken at the time of exposure between the third and sixth weeks of age. However, broilers were able to significantly decrease their respiratory breaths after exposure to the comfort condition. This indicates that the chicken will respond physiologically to the changes in the microclimate condition. Thomas et al. (2021) wrote that microclimate is the climate directly surrounding the chickens, which is the only important parameter for the chickens.

Wind speed and microclimate substantially contributed to 83.1% (R^2 = 0.831) of the total variability in air pollutants. Wind speed had a more key role in air pollutants (γ = -0.890, $p < 0.05$, and f^2 = 4.832) than microclimate (γ = 0.074, $p < 0.05$, and f^2 = 0.030). These findings agree with the work of Huda et al. (2021), who reported that the higher the air velocity in different zones inside the closed house, the lower the ammonia detected. This is in line with the fact that the increase in wind speed could decrease or eliminate the presence of hazardous gases, such as NH_3 and CO_2 (Kilic and Yaslioglu, 2014; Longley, 2014).

Table 4. Assessment of path coefficients of the structural model on all latent variables of laying hen reared under tropical climate in Indonesia

Constructs	Path coefficients	t values	Sig. (p < 0.05)	95% bootstrap confidence interval	f^2 Value (Effect size)
AQ → PR	0.08	0.524	<0.05	[-0.176, 0.422]	0.003 (small)
BC → PR	0.237	2.882	<0.05	[0.036, 0.352]	0.136 (medium)
MC → AQ	0.074	2.196	<0.05	[0.011, 0.139]	0.030 (small)
MC → PR	0.465	5.426	<0.05	[0.273, 0.596]	0.486 (large)
WS → AQ	-0.890	55.295	<0.05	[-0.916, -0.857]	4.832 (large)
WS → MC	-0.258	3.800	<0.05	[-0.400, -0.141]	0.071 (medium)
WS → PR	-0.364	3.581	<0.05	[-0.543, -0.135]	0.057 (medium)

AQ: Air pollutant, PR: Physiological response, BC: Body condition, MC: Microclimate, WS: Wind speed

CONCLUSION

The results clarify the open house system in Kediri regency, the wind speed predisposes to many components such as respiratory rate, microclimate, and air pollutants. The microclimate and wind speed of the house contribute significantly to the air pollutants of the house in terms of ammonia, carbon dioxide, and dust particles. Body condition, microclimate inside the house, and wind speed contribute significantly to the physiological response of the chicken in terms of respiratory rate and body temperature. It is suggested to perform the same study with more houses in different elevations.

DECLARATIONS

Availability of data and materials

The data of this study are available from the corresponding author upon reasonable request.

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Authors' contributions

Heni Setyo Prayogi contributed to the conceptualization, investigation, data curation, writing, review, and editing of the manuscript. Suyadi, V.M. Ani Nugiartiningsih, and Osfar Sofjan were involved in the conceptualization of the study, data curation, analysis, resource provision, and supervision. All authors checked and approved the final version of the manuscript for publishing in the present journal.

Competing interests

The authors have declared that there are no competing interests.

Ethical considerations

All the authors checked for ethical issues such as plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy.

REFERENCES

Al-Kerwi MSM, Mardenli O, Jasim MRM and Al_Majeed MA (2022). Effects of harmful gases emitted from poultry houses on productive and health performance. IOP Conference Series: Earth and Environmental Science, 1060: 012082 Available at: https://iopscience.iop.org/article/10.1088/1755-1315/1060/1/012082/pdf

Basuony HAAM (2011). Effect of seasonal variations on thermoregulation of ostrich. PhD Thesis, Al-Azhar University, Cairo. Available at: https://inis.iaea.org/collection/NCLCollectionStore/_Public/44/079/44079122.pdf

Bianca W and Kunz P (1978). Physiological reactions of three breeds of goats to cold, heat and high altitude. Livestock Production Science, 5(1): 57-69. DOI: https://www.doi.org/10.1016/0301-6226(78)90007-6

Chandrasekar KV (2011). Combating heat stress to keep birds productive. Available at: https://www.poultryworld.net/poultry/combating-heat-stress-to-keep-birds-productive/

Diaz AR, Ramirez RA, Caballero MC, Castillo FC, Bernabé JLM, and Rivera MES (2018). Analysis of hygrothermal conditions for laying hens in the state of oaxaca. Revista Mexicana de Ciencias Agrícolas, 21: 4317-4327. DOI: https://www.doi.org/10.29312/remexca.v0i21.1533

Fun H and Wu J (2022). Conventional use and sustainable valorization of spent egg-laying hens as functional foods and biomaterials: A review. Bioresources and Bioprocessing, 9: 43. DOI: https://www.doi.org/10.1186/s40643-022-00529-z

Gerken M, Afnan R, and Dörl J (2006). Adaptive behavior in chickens in relation to thermoregulation. Archiv für Geflügelkunde, 70(5): 199-207. Available at: https://www.european-poultry-science.com/artikel.dll/m06-38mk_ge3tgnztha.pdf?UID=AAF5D1D88241E3DC5E11E3B38AADEC030EF3090584ED84

Hair JF, Hult GTM, Ringle CM, Sarstedt M, Danks NP, and Ray S (2021). Partial least squares structural equation modeling. Springer Nature., Switzerland, pp. 4-27. Available at: https://library.oapen.org/bitstream/handle/20.500.12657/51463/9783030805197.pdf?sequence=1

Hartono B, Febrianto N, and Akhiroh P (2021). Socio-economic profile of small-scale laying chicken farmers in Blitar Regency Indonesia. IOP Conference Series: Earth and Environmental Science, 788: 012210. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/788/1/012210/pdf

Hedrix Genetics (2021). Commercial management guide hot and tropical climates. Available at: https://layinghens.hendrix-genetics.com/en/news/management-guide-hot-and-tropical-climates/

Huda NKF, Sarjana TA, and Edjeng Suprijatna E (2021). Atmospheric ammonia changes on different zone placement from the closed house inlet affecting broiler chicken performance in the rainy season. IOP Conference Series: Earth and Environmental Science, 803: 012011. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/803/1/012011/pdf

Indonesia statistical Bureau (2017). Rata-rata suhu dan kelembaban udara menurut bulan di stasiun meteorologi Juanda Jawa Timur [Average air temperature and humidity by month at the Juanda Meteorological Station, East Java]. Available at: https://jatim.bps.go.id/statictable/2019/10/11/1826/rata-rata-suhu-dan-kelembaban-udara- menurut-bulan-di-stasiun-meteorologi-juanda- jawa-timur-2017.html

Kilic I and Yaslioglu E (2014). Ammonia and carbon dioxide concentrations in a layer house. Asian-Australasian Journal of Animal Sciences, 27(8): 1211-1218. DOI: https://www.doi.org/10.5713/ajas.2014.14099

Kim DH, Lee YK, Kim SH, and Lee KW (2021). The impact of temperature and humidity on the performance and physiology of laying hens. Animal, 11(1): 56. DOI: https://www.doi.org/10.3390/ani11010056

Kristensen HH and Wathes CM (2000). Ammonia and poultry welfare: A review. World's Poultry Science, 56(3): 235-245. DOI: https://www.doi.org/10.1079/WPS20000018

Li D, Tong Q, Shi Z, Zheng W, Wang Y, Li B, and Yan G (2020). Effects of cold stress and ammonia concentration on productive performance and egg quality traits of laying hens. Animal, 10(12): 2252. DOI: https://www.doi.org/10.3390/ani10122252

Longley M (2014). Air velocity management for optimum broiler performance. The Poultry Site. Available at: https://www.thepoultrysite.com/articles/air-velocity-management-for-optimum-broiler-performance

Mascarenhas NMH, Furtado DA, Souza BB, Oliveira AG, Costa ANL, Feitosa JV, Calvacanti CR, Dornelas KC, Silva RS, and Rodrigues RCM (2022). Thermal environment characterization of laying hen-housing systems. Animal Behaviour and Biometeorology, 10(2): 1-5. DOI: http://www.doi.org/10.31893/jabb.22008

Medion (2018). Program pemeliharaan Kesehatan ayam petelur [Health maintenance program for laying chickens]. Indonesia, pp. 1-6. Available at: https://www.medion.co.id/wp-content/uploads/2021/04/Program-Pemeliharaan-Kesehatan-Ayam-Petelur-2018.pdf

Muharlien, Sudjarwo E, Yulianti DL, and Hamiyanti AA (2020). Microclimate Analysis of Opened House and Closed House in Broiler Rearing. IOP Conference Series: Earth and Environmental Science, 478: 012078. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/478/1/012078/pdf

Nascimento ST, da Silva IJO, Mourão GB, and de Castro AC (2012). Bands of respiratory rate and cloacal temperature for different broiler chicken strains. Revista Brasileira de Zootecnia, 41(5): 1318-1324. DOI: https://www.doi.org/10.1590/S1516-35982012000500033

Nascimento ST, Maia ASC, Gebremedhin KG, and Nascimento CCN (2017). Metabolic heat production and evaporation of poultry. Poultry Science, 96(8): 2691-2698. DOI: https://www.doi.org/10.3382/ps/pex094

Nurmeiliasari, Fenita Y, Een Zitriyani E, and Firdaus F (2020). Physiological responses and blood profile of broiler chicken supplemented with red dragon fruit peel (*Hylocereus polyrhizus*) subjected to transportation stress. Advances in Biological Sciences Research, 13: 182-189. DOI: https://www.doi.org/10.2991/absr.k.210609.030

Olivares BO, Guevara E, Oliveros Y, and López L (2013). Estimation of thermal comfort index as an indicator of heat stress in livestock production. Zootecnia Tropica, 31(3): 209-224. Available at: https://ve.scielo.org/scielo.php?pid=S0798-72692013000300004&script=sci_abstract&tlng=en

Paliadi T, Wijastuti A, and Mushawwir (2015). Thermoregulation and hen day production of laying hen in difference of temperature humidity index. Student e-Journal, 4(4): 1-8. Available at: http://jurnal.unpad.ac.id/ejournal/article/view/8089

Polley C (2016). Preparing breeder pullets correctly for light stimulation. International Hatchery Practice, 30(5): 9-12. Available at: http://www.positiveaction.info/pdfs/articles/hp305p9.pdf

Purswell JL, Branton SL, Luck BD, and Davis JD (2013). Effects of air velocity on laying hen production from 24 to 27 weeks under simulated evaporatively cooled conditions. Transactions of the ASABE, 56(6): 1503-1508. Available at: https://elibrary.asabe.org/abstract.asp?aid=44138

Reddy AR, Praveen P, Prasadini P, and Anuradha (2007). Assessment of air quality in poultry house. Industrial Pollution Control, 23(2): 369-372. Available at: https://www.icontrolpollution.com/articles/assessment-of-air-quality-in-a-poultryhouse-.pdf

Richards SA (1970). Physiology of thermal panting in birds. Annales de Biologie Animale, Biochimie, Biophysique, 10(2): 151-168. Available at: https://hal.science/hal-00896587

Ryan TP (2013). Methods of determining sample sizes. Sample size determination and Power. John Wiley & Son Inc., Chapter 2, pp. 17-55. DOI: https://www.doi.org/10.1002/9781118439241.ch2

Sohsuebngarm D, Kongpechr S, and Sukon P (2019). Microclimate, body weight uniformity, body temperature, and footpad dermatitis in broiler chickens reared in commercial poultry houses in hot and humid tropical climates. World's Veterinary Journal, 9(4): 241-248. DOI: https://www.doi.org/10.36380/scil.2019.wvj30

Son J, Kim HJ, Hong EC, and Kang HK (2022). Effects of stocking density on growth performance, antioxidant status, and meat quality of finisher broiler chickens under high temperature. Antioxidants, 11(5): 871. DOI: https://www.doi.org/10.3390/antiox11050871

Susanti F, Haryuni N, and Lestariningsih (2022). Effect of age and type of cage (close house and open house) on hen house, feed efficiency, mortality and liveability of laying hens. Journal of Development Research, 6(1): 125-130. DOI: https://www.doi.org/10.28926/jdr.v6i1.209

Thomas KS, Jayalalitha V, and Jagatheesan PNR (2021). Optimum micro-climate maximizes production potential in poultry farms. Poultry Punch Magazine. Available at: https://thepoultrypunch.com/2021/01/optimum-micro-climate-maximises-production-potential-in-poultry-farms/

Yalçin H, Doğan Z, Şen S, Çetin M, Göçmen M, and Koçyiğit A (2021). The assessment of poultry welfare using partial least squares-path modeling (PLS-SEM): A modeling the effects of physical activity and stress on growth. Harran Tarım ve Gıda Bilimleri Dergisi, 25(1): 109-119. DOI: https://www.doi.org/10.29050/harranziraat.842308