



Comparative performance of broiler chickens reared under three different housing systems in the tropical climate of Indonesia

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ABSTRACT

Housing system is a main issue in developing broiler farm businesses in the tropical developing countries. The present study aimed to evaluate the performance of broilers reared in three different housing systems in the hot tropic regions. The study was conducted from February to March 2024, with the environmental temperature ranging from 32–35°C during the daylight. A total number of 18,000 broilers, strain MB-202P, kept up to 4 weeks of age in closed house with a concrete deep litter floor (CH-LF), open side house with concrete deep litter floor (OH-LF), and open side house with stage slatted floor (OH-SF) at Japfa Teaching Farm Ie Suum, Indonesia, were evaluated for their performances. Parameters measured included final body weight (FBW), body weight gain (BWG), weekly feed intake (WFI), feed conversion ratio (FCR), depletion rate (DR), performance index (PI), whole carcass, cuts-up, and external and internal organs. The data was analyzed using analysis of variance and continued by Duncan's multiple range test when the means of the treatments indicated a significant ($p < 0.05$) difference. The results showed that BWG was significantly ($p < 0.05$) higher in the CH-LF, WFI was very significantly ($p < 0.01$) higher in the OH-SF, and both FCR and PI were non-significantly ($p > 0.05$) affected, but DR was very significantly ($p < 0.01$) higher in the OH-LF and OH-SF. The whole carcass was significantly ($p < 0.05$) higher in the CH-LF than in the OH-LF and OH-SF. Relative to live weight (LW), the whole carcass percentage was significantly ($p < 0.05$) higher in the CH-LF and OH-LF. Breast was significantly ($p < 0.05$) higher in the CH-LF, while back was significantly ($p < 0.05$) higher in the CH-LF and OH-SF, but thighs and wings were non-significantly ($p > 0.05$) affected. External organs were significantly ($p < 0.05$) different in the shank and feather percentages but not in the head and neck. Internal organs were significantly ($p < 0.05$) different in the intestine and spleen percentages, while the rest were not significantly ($p > 0.05$) different. In conclusion, raising broilers for up to four weeks could use closed or open houses without negatively affecting the performance index. If the broilers are marketed after more than four weeks, the closed housing system would be better since most performance parameters tend to be better in the closed house than in the open house.

Keywords: Broiler, Housing, Performance, Tropical Climate, Yield

Broiler chicken industries have grown rapidly in most developing countries. According to the latest data (Info GPTN 2025), the average broiler population growth in Indonesia is 1.45% per year. By 2027, chicken meat production is estimated to reach 3.65 million tons, in line with the increase in public consumption of animal protein.

Housing systems is a main issue in broilers production, especially in hot climates. According to Rath *et al.* (2015), heat stress is major restraint for the future development of the broiler industry, mainly in the hot and humid parts of the world. Therefore, poultry producers in tropical countries must design their animal houses according to the conditions experienced within their tropical zone (Mabbet 2009) along with frequently monitoring for their performance, which

may be useful for the stakeholders. A performance index (PI) has been used for a long time by commercial broiler producers and research workers (Bird 1955). Recently, this parameter has been reported in contrast by researchers who found that broilers living in CH had better PI than those living in OH (Package *et al.* 2020, Paly *et al.* 2023), but others found it vice versa (Nuryati 2019, Sumarno *et al.* 2022).

Therefore, this study aimed to compare the performances of broilers reared under different housing systems in the tropical climate of Indonesia.

MATERIALS AND METHODS

Location of the study: This research was conducted at a broiler chicken farm of Japfa Teaching Farm Ie Suum, Mesjid Raya District, Aceh Besar Regency, Indonesia. Aceh Besar Regency is located 5.05°–5.75° North Latitude and 94.99°–95.93° East Longitude, and has wide variations in MSL (6–113 m MSL), in which Mesjid Raya District has

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an average of 8 m MSL. Rainfall ranges from 53.70–603.70 mm/month. The minimum and maximum temperatures are 20.40–23.20°C and 32.60–36.30°C, respectively. The minimum and maximum humidity are 30–59% and 98–100%, respectively.

Animals, feeds, and other ingredients: 18,000 broiler chickens, unsexed, strain MB-202P, were used in this study. The broilers were divided into three groups- 9,000 birds in a closed house with a concrete deep litter floor (CH-LF), 4,000 birds in an open house with a concrete deep litter floor (OH-LF), and 5,000 birds in an open house with a stage slatted floor (OH-SF). All houses were constructed in the same size of 8 x 70 m (560 m²) each. Birds were fed as per the feeding program under farm management, with the feed codes consisting of SB10 (mash), SB11 (crumble), and SB12 (pellet). Other ingredients used were sugar water, turmeric, multivitamins (vitakur, astresvit, agrimox 50, carnyvit), sawdust, and disinfectants (agricid, floxamycine, and rodalon).

Equipment: The CH-LF was facilitated by an automatic feeding system with two hoppers installed at the end of the feed line to supply feeds continuously to automatic pan feeders. In the OH-LF and OH-SF, feeding was facilitated by a manual feeding system, and barn workers transferred feeds manually into the hanging pan feeders. Feeds are delivered *ad libitum* at 8:00 AM and 3:30 PM daily. Broilers feed consisted of SB-10 mash diet at age 1–7 days, SB-11 crumble diet at age 8–19 days, and SB-12 pellet diet at 20 days old-harvest. All houses are equipped with an automatic drinking system for distributing drinking water *ad libitum* through the auto cup drinkers in the CH-SF and bell drinkers in OH-SF and OH-SF. The drinking program supplied drinking water + sugar for the first two hours of placement, and then drinking water + turmeric, and subsequently drinking water + multivitamins *ad libitum*. The CH was equipped with a temperature control system, where the indoor temperature was adjusted to 30, 28, 26, and 24°C in weeks 1, 2, 3, and 4, respectively. In the OH, the indoor temperature followed the natural climate, which was recorded as 28.6–29.1°C during this study.

Treatment and experimental design: The treatment was designed in a completely randomized design (CRD)

consisting of three treatments and five replications. The treatment was variation in housing systems as follows- CH-LF = closed house with concrete deep litter floor, OH-LF = open side house with concrete deep litter floor, and OH-SF = open side house with stage slatted floor (Figure 1).

Experimental design: Sawdust covered the concrete floors in the CH-LF and OH-LF for up to four weeks but none in the OH-SF. Each cage was completed by the brooders, drinkers, and feeders.

Floor space allocated per bird was 0.062 m²b⁻¹ in the CH-LF, 0.140 m²b⁻¹ in the OH-LF, and 0.112 m²b⁻¹ in the OH-SF. Feeds were distributed automatically in the closed house but manually in the open house.

Recording of parameters/data collection: Twenty chicks in every pen from each house were selected randomly to obtain the average body weight, and then reweighted weekly. Body weight at the end of the fourth week was recorded as the final body weight (FBW). Amount of given feed (GF) per bird per pen was calculated by dividing the total amount of distributed feed into all feeders by the number of living birds (LB) in a house. Therefore, the GF per pen per bird was equal in the same house type. At the end of each week, the number of residual feeds (RF) in the feeders was weighed by sampling 20 feeders in each pen. The numbers of feeders in each pen were 90 units in the CH-LF, 45 units in OH-SF, and 30 units in OH-LF. The average RF weight of sampling feeders was multiplied by the number of feeders in its pen and then divided by the number of LB in its pen, thus resulting in an average RF per bird. The difference between the GF and the RF each week was recorded as the FI. Total feed intake (TFI) per bird during 4 weeks of rearing was obtained by accumulating the FI each week.

Depletion was recorded by collecting the number of dead and culled birds every week. The overall depletion was calculated by accumulating the depletion rate each week during 28 days of rearing and then dividing by the number of placing birds multiplied by 100%. Body weight gain (BWG) was determined from the body weight. The FCR was calculated from the FI and BWG, and PI was calculated from the depletion, body weight, and FCR.

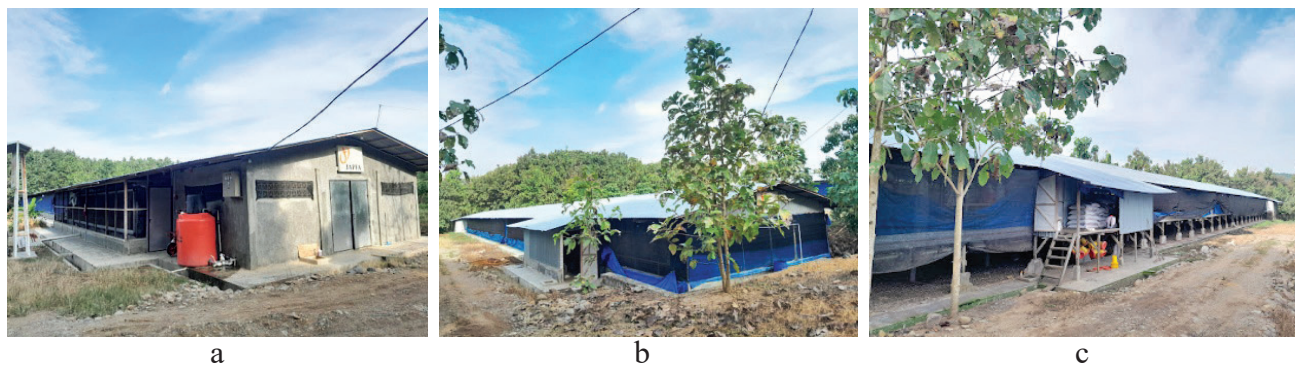


Fig. 1 Three broiler house types: (a) CH-LF= closed house with concrete deep litter floor, (b) OH-LF= open side house with concrete deep litter floor, and (c) OH-SF= open side house with stage slatted floor

The way of calculating different parameters measured in this study is given below.

$$\text{Feed intake (g)} = \frac{\text{Given feed (g)} - \text{residual feed (g)}}{\text{Final body weight (FBW)}}$$

$$\text{Average weekly BWG} = \frac{\text{FBW} - \text{BW doc}}{(4 \text{ weeks})} \times 100\%$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Feed intake (g)}}{\text{BWG (g)}}$$

$$\text{Depletion rate (\%)} = \frac{\left(\frac{\text{The number of dead and culled birds}}{\text{The number of placing chicks}} \right) \times 100\%}{\text{FCR}}$$

$$\text{Performance index (PI)} = \frac{\left(\frac{(100\% - \text{Depletion}) \times \text{FBW (kg)}}{\text{harvested age (days)} \times \text{FCR}} \right) \times 100\%}{\text{FCR}}$$

$$\text{Whole carcass percentage (\%)} = \frac{\text{Whole carcass weight (g)}}{\text{BW (g)}} \times 100\%$$

$$\text{Carcass cuts-up percentage (\%)} = \frac{\text{carcass retail weight (g)}}{\text{Whole carcass weight (g)}} \times 100\%$$

$$\text{Internal organ percentage (\%)} = \frac{\text{Internal organ weight (g)}}{\text{Body weight (g)}} \times 100\%$$

$$\text{External organ percentage (\%)} = \frac{\text{External organ weight (g)}}{\text{Body weight (g)}} \times 100\%$$

Statistical/Data analysis: The data were analyzed using analysis of variance (ANOVA). Duncan's multiple range test (Steel and Torrie 1991) was used to compare the significant differences between different groups.

RESULTS AND DISCUSSION

The performances of broilers reared in different housing systems at Japfa Teaching Farm Ie Suum are presented in Table 1. ANOVA showed that variation in broiler housing significantly ($p < 0.05$) affected final body weight (FBW), average weekly body weight gain (BWG), total feed intake (TFI), and depletion rate of broilers, but did not significantly ($p > 0.05$) affect feed conversion ratio

Table 1. Performance of broiler reared in different housing systems

Parameters	Housing systems			SEM	p-value
	CH-LF	OH-LF	OH-SF		
FBW (kg b ⁻¹)	1,868.09 ^a	1,711.39 ^b	1,798.70 ^{ab}	26.331	0.037
BWG (g b ⁻¹ w ⁻¹)	455.94 ^a	416.82 ^b	438.55 ^{ab}	6.575	0.037
FI (kg b ⁻¹)	2,428.54 ^A	2,347.74 ^C	2,483.74 ^B	15.525	0.000
WFI (g b ⁻¹ w ⁻¹)	607.13 ^A	586.93 ^C	620.93 ^B	3.881	0.000
FCR	1.33	1.41	1.42	0.021	0.173
DR (%)	1.85 ^A	3.47 ^B	3.49 ^B	0.239	0.000
PI	492.22	421.41	438.11	13.281	0.063

^{a, b} means in the same row with different superscripts indicated significantly different ($p < 0.05$); ^{A, B} means in the same row with different superscripts indicated very significantly different ($p < 0.01$); FI = feed intake, WFI = weekly feed intake, FBW = final body weight, BWG = weekly body weight gain, FCR = feed conversion ratio, DR = depletion rate, PI = performance index SEM = standard error of means; CH-LF = closed house with concrete deep litter floor, OH-LF = open house with concrete deep litter floor, OH-SF = open house with stage slatted floor



Fig 2. Broilers reared in three different house types: (a) CH-LF= closed house with concrete deep litter floor, (b) OH-LF= open side house with concrete deep litter floor, and (c) OH-SF= open side house with stage slatted floor

(FCR) and performance index (PI).

Final body weight and weight gain: The BWG of broilers raised in the CH-LF, OH-LF, and OH-SF was 455.94, 426.82, and 435.55 g b¹ w¹, respectively. The FBW and BWG of broilers raised in the CH-LF were significantly ($p < 0.05$) heavier than those in the OH-LF but not significantly ($p > 0.05$) different from those in the OH-SF. There was no significant ($p > 0.05$) difference in the FBW and WBWG of the broilers living in OH-LF vs. those living in OH-SF. It meant that the flooring system in the open housing system did not significantly ($p > 0.05$) affect the FBW of broilers at 4 weeks of age. The slatted floor predictably generated higher broiler body weight than the litter floor at 4 weeks age. According to Soliman and Hassan (2020), broilers housed on slatted floors grow faster than broilers housed on litter.

Regardless of the floor types, the housing system significantly ($p < 0.05$) affected FBW and BWG. Most previous studies (Nuryati 2019, Pakage *et al.* 2020, Muharlién *et al.* 2022) reported that broilers reared in the CH had BWG higher than those in the OH. In contrast, Hamiyanti *et al.* (2023) reported that FBW was significantly ($p < 0.05$) higher in the OH than in CH. On the other hand, Sumarno *et al.* (2022) found no significant ($p > 0.05$) difference in FBW between both housing plan. Except for Murhalien *et al.* (2002) presenting the concrete litter floor of OH in their study, the others did not clearly describe the flooring systems of the OH. We assumed that all differences observed in the study could be attributed to the concrete floors with deep litter.

The achievement of BWG may be related to feed intake, but this is not always relevant. The WFI of broilers raised in CH-LF, OH-LF, and OH-SF was 607.13, 586.93, and 620.93 gb⁻¹w⁻¹, respectively. Broilers in CH-LF consumed significantly ($p < 0.01$) more feed than those in the OH-LF, which was highly suspected to cause the difference in their BW. However, this argument was not valid for differences observed between CH-LF vs. OH-SF, in which significantly ($p < 0.01$) higher FI in the latter did not support increasing significantly ($p < 0.01$) rise in BWG. Therefore, another factor, such as the FCR needs to be considered. The FI of broilers reared in different house types was inconsistent. Marom *et al.* (2017) found FI was higher in OH than in CH, but vice versa was reported by others (Nurhayati 2019, Sumarno 2022) .

Feed conversion ratio: Contradictive results were observed on the FCR of broilers reared in different housing systems. The FCR of broilers raised in CH-LF, OH-LF, and OH-SF was 1.33, 1.41, and 1.42, respectively. Most researchers (Adnyana *et al.* 2020, Pakage *et al.* 2020, Muharlién *et al.* 2022, Laili *et al.* 2022, Sumarno *et al.* 2022, Paly 2023) reported better FCR in CH than in OH, but Nuryati (2019) reported it contrary. Hamiyanti *et al.* 2023 reported no significant ($p > 0.05$) difference in the FCR amongst the housing types and agreed with the observations of the present study. Statistically, a significant ($p < 0.01$) difference in FI of the broilers in CH vs. in OH,

which caused non significant ($p > 0.05$) difference in FBW, was not reflected in the FCR.

Depletion: Depletion is the number of culled and dead birds. Commonly, farms may include culled birds in mortality. The depletion rate of broilers raised in the CH-LF, OH-LF, and OH-SF was 1.85, 3.47, and 3.49%, respectively. The depletion rate was significantly ($p < 0.05$) higher in both open-house types than in the closed-house. Most earlier studies (Susanti *et al.* 2016, Nuryati 2019, Package *et al.* 2020, Adnyana *et al.* 2020, Sumarno *et al.* 2022, Laili *et al.* 2022, Supartini 2022, Paly 2023) reported that broilers kept in OH had higher mortality than those kept in CH, and this was also observed in this study.

Performance index: Performance index is one of the indicators used to evaluate a successful broiler farm business. It involved several performance measurements, such as livability, body weight, FCR, and harvesting age. The PI of broilers raised in CH-LF, OH-LF, and OH-SF was 492.22, 421.41, and 438.11, respectively. Package *et al.* 2020 and Paly *et al.* 2023 reported better PI in CH than in OH, while Nuryati 2019 and Sumarno *et al.* 2022 reported it the other way. Hamiyanti *et al.* (2023) found no significant ($p > 0.05$) difference in IP between both houses, which agreed with the present study. Absence of a significant ($p > 0.05$) difference in PI of broilers in the present study might be due to the earlier marked ages (4 weeks). However, the PI tended to be better in CH-LF, which was predicted to be significantly ($p < 0.05$) higher in this flock, had the birds continued to live up to 5 weeks.

According to Santoso and Sudaryani (2009), PI is classified into: <300= poor, 301–325= fair, 326–350= good, 351–400= very good, and > 400= excellent. Based on these categories, all housing systems generated excellent PI of rearing broilers at the market age of 4 weeks. The depletion is likely to increase sharply in both OH during the last phase of rearing, resulting in lower livability and bad FCR. Many farms in open housing systems cease rearing broilers at 4 weeks of age to reduce the risk.

Whole carcass and cuts-up: The effect of the housing system on the weights and percentages of whole carcass and retail cuts-up of broilers is presented in Table 2. ANOVA showed that different house types significantly ($p < 0.05$) affected the weight and percentage of the whole carcass. The effect on whole carcass weight was similar to that on the FBW. Broilers delivered from CH-LF had a significant ($p < 0.01$) whole carcass weight higher than those from both OH, which agreed with findings of Muharlién *et al.* (2022). Correlation was observed between BW and carcass weight (Olawumi 2013, Behiry 2019), heavier live weight should yield a heavier carcass.

The carcass percentage of broilers raised in CH-LF, OH-LF, and OH-SF was 71.54, 69.18, and 70.74%, respectively. Relatively to BW, the carcass percentage of broilers from CH-LF showed no significant ($p > 0.05$) difference from that of OH-SF but was significantly ($p < 0.05$) higher than that from OH-LF. No significant ($p > 0.05$) difference in carcass percentages of broilers living in both houses was

Table 2. Average weight and percentage of whole carcass and retail cut-up of broilers reared in different housing systems

Parameters		Broilers' housing systems			SEM	p-value
		CH-LF	OH-LF	OH-SF		
LW sampling	(kg b ⁻¹)	1,886 ^a	1,728 ^b	1,797 ^{ab}	19.440	0.042
Whole carcass	(kg b ⁻¹)	1,350 ^a	1,196 ^b	1,271 ^{ab}	17.004	0.012
	(%)	71.54 ^a	69.18 ^b	70.74 ^a	0.313	0.010
Retails cut-up						
Breast	(g b ⁻¹)	559 ^a	481 ^b	491 ^b	10.365	0.027
	(%)	41.31	40.22	38.65	0.453	0.123
Thighs	(g b ⁻¹)	366	333	344	5.658	0.148
	(%)	27.13	27.83	27.03	0.246	0.247
Wings	(g b ⁻¹)	127	125	126	2.036	0.974
	(%)	9.41	10.50	9.94	0.174	0.068
Back	(g b ⁻¹)	298 ^A	256 ^B	310 ^A	6.418	0.003
	(%)	22.16	21.46	24.39	0.443	0.046

^{a, b} means in the same row with different superscripts indicated significantly different ($p < 0.05$); ^{A, B} means in the same row with different superscripts indicated very significantly different ($p < 0.01$); LW = live weight; SEM = standard error of means; CH-LF = closed house with concrete deep litter floor, OH-LF = open house with concrete deep litter floor, OH-SF = open house with stage slatted-floor

also reported by Muharlieni *et al.* (2022). It meant that birds living in the OH-LF utilized feed less efficiently, as indicated by their FCR.

Cuts-up: The breast weight of broilers raised in CH-LF, OH-LF, and OH-SF was 559, 481, and 491 gram, respectively. Retail weight was significantly ($p < 0.05$) affected by breast and back weight. Broilers delivered from CH-LF had significantly ($p < 0.05$) heavier breast than those from OH-LF. However, between open house types, there was no significant ($p > 0.05$) difference. Back was significantly ($p < 0.01$) lower in the carcass of broilers from OH-LF than from OH-SF and CH-LF. Other cuts-up, such as thighs and wings, had no significant ($p > 0.05$) difference among different house types. Behiry (2019) stated high correlation between breast weight and carcass weight. Similar findings were also reported by Marapana (2016), where most of the other primal cuts, such as breast

and back, increased linearly ($p < 0.05$) as slaughter weight increased.

Relatively to carcass weight, cut-up percentages had no significant ($p > 0.05$) differences among the flocks, although birds from OH-LF had significantly ($p < 0.05$) lower whole carcass percentages they did not differ in carcass cuts-up percentages. Heavier carcass parts did not always result in higher percentages. It depended on the ratio of the increasing weights between carcass parts and the whole carcass. The findings of the present study did not agree with Marapana (2016), who found that yield percentages of thigh, breast, back, and wings were significantly ($p < 0.05$) affected by dress carcass weight. Reduced breast and back in OH-LF were predicted just due to the impact of reduced carcass weight resulting from a lower BW, plausibly caused by a reduced FI. There was no indication that broilers from OH-LF underwent a harsh nutrient deficiency.

Table 3. Average weight and percentage of external non-carcass organs of broilers reared in different housing systems

Parameters		Broilers' housing systems			SEM	p-value
		CH-LF	OH-LF	OH-SF		
Head	(g b ⁻¹)	40.90	38.70	40.00	0.457	0.176
	(%)	2.17	2.24	2.23	0.021	0.403
Neck	(g b ⁻¹)	35.70	36.10	33.50	1.227	0.630
	(%)	1.89	2.08	1.87	0.065	0.245
Shank	(g b ⁻¹)	64.70 ^{ab}	58.80 ^a	69.10 ^b	1.381	0.013
	(%)	3.43 ^a	3.40 ^a	3.85 ^b	0.071	0.015
Feathers	(g b ⁻¹)	102	118	101	3.271	0.131
	(%)	5.41 ^a	6.85 ^b	5.66 ^a	0.206	0.032

^{a, b} means in the same row with different superscripts indicated significantly different ($p < 0.05$); SE = standard error of means; CH-LF = closed house with concrete deep litter floor, OH-LF = open house with concrete deep litter floor, OH-SF = open house with stage slatted floor

Table 4. Average weight and percentage of internal non-carcass organs of broilers reared in different housing systems

Parameters		Broilers' housing systems			SEM	p-value
		CH-LF	OH-LF	OH-SF		
Crop	(g b ⁻¹)	4.30	5.00	4.80	0.407	0.808
	(%)	0.23	0.29	0.27	0.023	0.660
Proventriculus	(g b ⁻¹)	6.40	6.60	6.90	0.237	0.793
	(%)	0.34	0.38	0.38	0.014	0.492
Gizzard	(g b ⁻¹)	29.20	29.10	28.80	0.679	0.975
	(%)	1.55	1.68	1.60	0.037	0.354
Intestinal tract	(g b ⁻¹)	48.20	49.20	43.50	1.129	0.227
	(%)	2.56 ^{ab}	2.84 ^b	2.42 ^a	0.057	0.021
Liver	(g b ⁻¹)	40.90	36.00	37.20	1.090	0.108
	(%)	2.17	2.08	2.07	0.056	0.620
Pancreas	(g b ⁻¹)	5.30	4.60	4.60	0.173	0.286
	(%)	0.28	0.27	0.26	0.009	0.606
Spleen	(g b ⁻¹)	1.60	1.80	2.50	0.155	0.051
	(%)	0.08 ^a	0.10 ^{ab}	0.14 ^b	0.009	0.022
Hearth	(g b ⁻¹)	7.40	6.40	6.40	0.219	0.555
	(%)	0.39	0.37	0.41	0.011	0.241
Blood	(g b ⁻¹)	45.10	42.10	54.40	0.813	0.088
	(%)	2.39	2.45	3.03	0.183	0.115
Abdominal fat	(g b ⁻¹)	18.80	19.40	22.20	1.137	0.472
	(%)	1.00	1.12	1.24	0.065	0.386

^{a,b} means in the same row with different superscripts indicated significantly different ($p < 0.05$); SEM = standard error of means; CH-LF = closed house with concrete deep litter floor, OH-LF = open house with concrete deep litter floor, OH-SF=open house with stage slatted floor

External non-carcass: The effect of the housing system on the weights and percentages of external non-carcass organs of broilers is presented in Table 3. The weights and percentages of head and neck had no significant ($p > 0.05$) differences among the slaughtered broilers from different flocks, but feet weight was significantly ($p < 0.05$) different. The feet percentage of broilers living in CH-LF, OH-LF, and OH-SF was 3.43, 3.40, and 3.85%, respectively. Broilers living in OH-SF had significantly ($p < 0.05$) heavier feet than those in OH-LF, which was plausibly caused by the difference in BW. Usually, the weight of external non-carcass organs followed BW linearly, but in this study, a significant ($p < 0.01$) difference occurred exclusively in feet weight. Dzungwe *et al.* (2018) had earlier reported that shank length could be the best predictor of body weight. However, relative to BW, the feet percentage was significantly ($p < 0.05$) higher in the OH-SF than in the other houses. Therefore, factors excluding BW, such as the flooring system, should also be considered as the causes of the bias in feet percentage. Birds had spent more energy on their feet to forage on a slatted floor rather than on a smooth litter floor, possibly causing an increase in foot muscle mass.

Feather weight was insignificantly ($p > 0.05$) different. However, relative to BW, the feather percentage of the broilers living in OH-LF was significantly ($p < 0.05$) higher

than those living in CH-LF and OH-LF. The feather percentage of broilers living in the CH-LF, OH-LF, and OH-SF was 5.41, 6.85, and 5.66%, respectively. It could be to compensate for the reduced carcass proportion. Birds in OH-LF used nutrients less efficiently to form meat. Another reason may be the interest in bird activity, in which broilers in OH-LF spent more time dust bathing to remove the excessive heat and indirectly development of unduly feathers. Broilers in the litter system exhibited more preening and wing-flapping behaviors (Fortomaris *et al.* 2007). These actions were not needed by the chickens in the CH-LF because they lived in a comfort area.

Internal non-carcass organs: The effect of different housing systems on the weights and percentages of internal non-carcass organs of broilers is presented in Table 4. There were insignificant ($p > 0.05$) differences in all observed internal organ weights of the broilers living in the CH vs. in the OH. Relatively to BW, only the intestinal tract and spleen were significantly ($p < 0.05$) different among the broilers from different flocks, in which broilers living in OH-LF had significantly ($p < 0.05$) higher intestinal tract percentage as compared to those living in OH-SF, but had insignificant ($p > 0.05$) difference with those in CH-LF. Marapana (2016) found that the percentage of gizzards, heart, liver, and total giblets was significantly ($p < 0.05$) affected by dress carcass weight. In the present study,

those were insignificantly ($p > 0.05$) different, except for the spleen and intestine.

The internal organ percentage may relate to carcass weight. Decreasing the carcass proportion may increase the non-carcass (intestinal) percentage in the birds from the OH-LF. However, increasing the spleen percentage should signal to other factors. The spleen percentage was significantly ($p < 0.05$) higher in the birds from OH-SF vs. those from the CH-LF, but between CH-LF and OH-LF, and between OH-SF and OH-LF, those were insignificantly ($p > 0.05$) different. Heat stress affects immune function, such as the immune response and metabolic disorders, causing spleen atrophy and leading to low productivity of the chickens (Arimbi *et al.* 2010, Ohtsu *et al.* 2015). Birds living in open houses are more likely to be exposed to heat stress, and have spleen shrinkage, but in this case, it emerged inversely. Therefore, broilers housed in OH in this study should be considered not to have undergone severe heat stress since they had been harvested earlier (4 weeks old). Above 4 weeks, they would have faced heat problems since the average environmental temperature in the tropical region was usually higher than a comfort zone 32°C outdoors and 28°C indoors, which was 24–26°C in week 4 and 18–24°C in week 5 (Avila 2004).

Spleen plays a pivotal role in the immune system, in which the splenic ellipsoid functions as a barrier for filtering and phagocytosis (Zhang *et al.* 2015). The open housing system may be highly exploited by germ invasions. Spleen would be more active in fighting infectious agents, causing its enlargement (Ressang 2005). It would have been more reasonable to argue the cause of increasing spleen weight in OH in the present study. However, the spleen size was still in the normal range. As reported by the previous researchers, the broiler spleen weight (5 weeks old) was 0.12–0.14% (Sekeroğlu *et al.* 2011) or 0.13–0.19% (Zulfan *et al.* 2022).

In conclusion, raising broilers for up to four weeks could use closed or open houses without negatively affecting the performance index. If the broilers are to be marketed after four weeks, the closed housing system would be better used since most performance parameters tend to be better in the closed house than in the open house.

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