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Effects of sidewall opening areas on the performance of broiler chickens and the indoor climatic conditions of backyard poultry building

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ABSTRACT. Sidewall openings play an important role in the indoor conditions of livestock buildings. It influences airflow patterns, air velocity distribution at the animal-occupied zones and the illumination level in the naturally ventilated animal building. However, there is a paucity of information on the effects of sidewall opening areas on the performance of broiler chickens. Hence, this study investigated the effect of sidewall opening areas on the indoor condition and the body growth of broilers. Two buildings with different sidewall opening areas were developed with broiler chickens reared in them for 28 days. The results showed that air temperatures and relative humidity of the buildings were influenced by the outdoor temperature. The indoor air temperatures of the building exceeded the recommended thermal conditions (18 to 24ºC) for broiler chickens. Similarly, the temperature-humidity index of the building exceeded 21.0ºC recommended for broilers which could result in heat stress and poor performance of broiler chickens during extremely hot weather periods. It was also found in this study that broiler chickens could not perform optimally though they were fed ad libitum. Therefore, further studies are required to ascertain the impact of sidewall opening areas on broiler performance, behaviour and physiological responses.

Keywords: air temperature; relative humidity; body weight; temperature-humidity index; thermal condition; broiler performance.

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Introduction

The poultry industry has for some time occupied a leading role in the agricultural industries (Jongbo, 2020). In livestock production, poultry meat production has witnessed higher growth compared to other meat sources in the past decade due to the growing population (Mottet & Tempio, 2017). However, there are several constraints to the future development of the poultry meat industry in hot climate regions. One of the constraints is climate change which has resulted in higher temperatures and higher humidity. Climate change has imposed severe stress on birds, leading to poor performance, poor health, poor welfare, and high mortality (Kim, Lee, Kim, & Lee, 2021).

When ambient temperatures are within the thermoneutral zone, the risk of thermal discomfort is minimal or completely removed in birds. However, as the indoor temperature increases coupled with higher humidity, most especially in naturally ventilated animal buildings, the risk of thermal discomfort could set in, it could result in a higher temperature-humidity index (THI) and birds tend to drink more water to restore thermal regulatory balance (Jongbo, Olajide, Deniz, & Frederico, 2024; Wasti, Sah, & Mishra, 2020). Birds subjected to high air temperatures display several behavioural changes such as frequent resting, standing on one leg or both, crouching closer to the walls or water lines, and wings spreading (Butcher & Miles, 2019). These behaviours allow them to easily adjust their heat balance with their microclimate.

The size of sidewall openings of poultry buildings has a greater influence on the thermal distribution, air quality and animal comfort in naturally ventilated buildings. To determine the air change rate within a naturally ventilated building, Shen, Su, Ntinas, and Zhang (2016) employed the tracer gas method while the size and the location of sidewall openings were varied. They indicated that the air change rate was influenced by the opening size of the inlet and outlet and the location of the opening had minimal impact on the air change rate. The effect of sidewall opening size on the discharge coefficient of a dairy building was examined by Yi et al. (2018b). They reported that the discharge coefficient varied from about 0.60 to 0.90 as the opening size increased from about 18 to 63%. Airspeed within the naturally ventilated dairy building was reported to be uniformly distributed in the animal-occupied zone with a high sidewall opening size during hot weather conditions (Yi et al., 2018b). Li, Rong, Zong, and Zhang (2017) indicated that the airspeed in the animal-occupied zone was mainly influenced by the inlet airspeed and opening angle and not the opening heights. In all the studies, it is clear that the indoor condition of the animal buildings is mostly influenced by the conditions of the sidewall openings. However, there is a paucity of information on the effect of sidewall opening size on the growth performance of broilers in humid climatic conditions.

Therefore, the objectives of this study were to evaluate the effect of the sidewall opening area on (1) indoor climatic conditions, (2) the temperature-humidity index of poultry building and (3) the growth performance of broiler chickens.

Materials and methods

Experimental site

The study was carried out at the Teaching and Research Farm of the Federal University of Technology, Akure, Ondo State, Nigeria. The research site is located on a latitude between 7° 19' 03" N and 7° 19' 16" N and longitude between 5° 07' 02" E to 5° 09' 05" E. The location has a minimum temperature of 22.0 and above 30.0°C during the hot periods. More details of the location can be found in the report of Jongbo (2020).

The design of the poultry building

The poultry buildings used for the study were designed with SolidWorks 2021 software (Figure 1). The floor space of the small-scale poultry building was designed to accommodate ten (10) birds at the rate of 0.19 m^2 $bird^{-1}$ for broiler chickens (Clauer, 2016).

The building was developed using hardwood with the properties specified in the study carried out by Adejuwon, Olomo, Falayi, and Jongbo (2020). The isometric and pictorial views of the poultry building are shown in Figure 2. The design and development of the building were necessary due to the unavailability of poultry buildings with the specifications suitable for the research.

In this study, the space for the feeder and drinker required was estimated as 0.10 m $bird^{-1}$ as indicated by Clauer (2016). The floor of the building was covered with fresh wood shavings of 50 mm thickness and was subject to replacement when it became wet due to drinking water spillage and chicken droppings.

Figure 1. Small-scale poultry building. All dimensions are in mm.

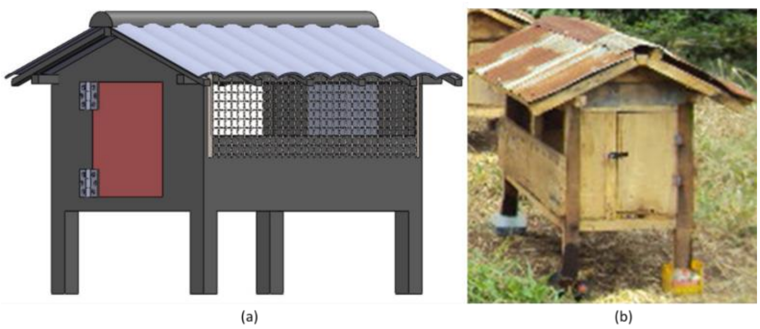

Figure 2. (a) The isometric view and (b) the pictorial view of the poultry building.

Environmental design

Two (2) sidewall opening areas of 0.48 m^2 (0.29 by 1.65 m) and 0.76 m^2 (0.46 by 1.65 m) were considered in this study. The sidewall opening area of 0.48 m^2 was named V290 while that of 0.76 m^2 was named V460. For this study, a total of six (6) poultry buildings were developed with each opening area having three (3) replicates. A total of seventy-day-old broiler chickens were acquired from the hatchery and raised for four weeks (28 days) under a controlled environment starting with a temperature of 33.0°C in the first week and later reduced by 3.0°C in each of the subsequent weeks until the birds were 28 days old. The temperature of the brooding house was monitored and the heating system was adjusted appropriately. The birds were then divided into six (6) groups of ten (10) birds each and placed in the six poultry buildings, randomly arranged as shown in Figure 3. In each building, five (5) birds were selected for experimental purposes and were marked with non-invasive (i.e. feather surface marking) animal markers for clear identification when taking measurements. The birds were fed ad libitum with broiler finisher and were daily supplied with clean water.

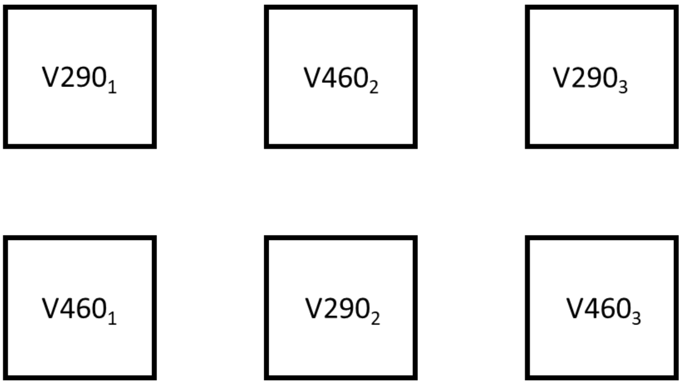

Figure 3. Experimental arrangement of the poultry building.

Instrumentation and data acquisition

The environmental parameters (air temperatures and relative humidity) and body weight of broilers were measured and recorded during the study. The air temperatures (indoor and outdoor) and relative humidity (indoor and outdoor) of the building were daily measured with temperature-hygrometer sensors (HTC-1). The measurement ranges of the temperature-hygrometer sensor are -10 to +50°C for temperature and 10 to 99% for humidity. Its accuracies are ±2.0°C for air temperature and 10 % for humidity. The weekly body weights of broiler chickens were measured with a 20,000 g (20.0 kg) spring scale which has an accuracy of 100 g (Figure 4).

Figure 4. Pictures showing the measurement of the body weight of a broiler chicken.

The daily indoor and outdoor temperature and relative humidity of the poultry building were in the morning (between 0600 and 0800H), afternoon (between 1200 and 1400H) and evening (between 1800 and 2000H).

The thermal comfort (temperature-humidity index) of broilers reared in the poultry building was estimated using an equation developed by Tao and Xin (2003) and also utilised in some other studies (Ajakaiye, Pérez, & Mollineda, 2011; Behura et al., 2016).

$$THI_{broiler} = 0.85(T_{db}) + 0.15(T_{wb})$$

where:

$THI_{broiler}$ is the temperature-humidity index (°C) of broiler chicken;
T_{db} is the dry-bulb temperature (°C) and;
T_{wb} is the wet-bulb temperature (°C).

The wet bulb temperature was estimated by the expression developed by Stull (2011) since it could not be measured directly. The equation indicates that

$$T_{wb} = T_{db}[0.151977(rH + 8.313659)^{0.5}] + (T_{db} + rH) - (rh - 1.676331) + 0.00391838(rH)^{1.5} \times (0.023101rH) - 4.686035$$

where:

rh is the relative humidity (%).

Data analysis

The data collected were processed using Microsoft Office Excel version 2019 and subjected to statistical analysis using SAS JMP Pro 14. A t-test analysis was carried out on the processed data to determine the significant difference between the means of the values obtained in the buildings with different sidewall opening areas considered in the study. The analysed data was also subjected to a 5% level of significance.

Results and discussion

Figure 5 shows the daily outdoor and indoor air temperature of the backyard poultry building for morning, afternoon and evening. As shown in the figure, the outdoor air temperature in the morning, afternoon and evening varied from 23.5 to 28.3, 22.3 to 38.4 and 21.0 to 34.0°C respectively. In the morning, afternoon and evening, the building with sidewall opening area V290 had air temperatures of 22.1 to 28.4, 21.8 to 38.2 and 20.6 to 32.9°C respectively. For building with V460 sidewall opening area, the air temperatures ranged from 22.5 to 27.7, 22.1 to 38.8 and 20.1 to 32.7°C for the morning, afternoon and evening respectively. The results of the statistical analysis indicated that there was no significant difference (p > 0.05) between the means of the air temperatures obtained inside the buildings V290 and V460 in the morning, afternoon and evening.

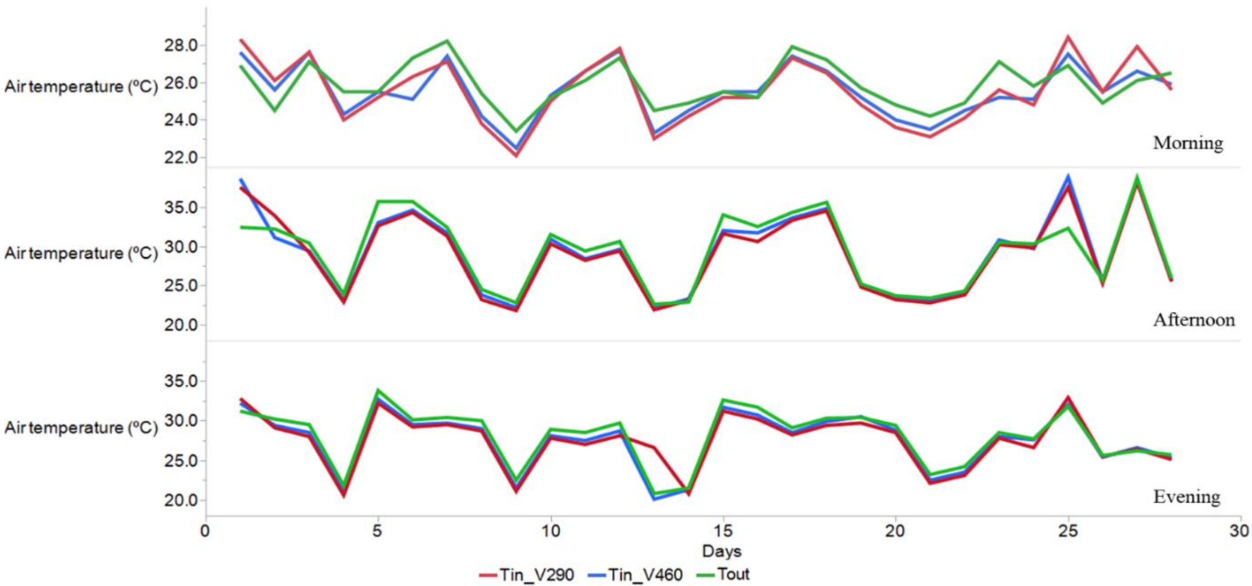

Figure 5. Relationship between outdoor and indoor temperatures of the building with different sidewall opening areas in the morning, afternoon and evening respectively.

The results obtained in the study are similar to those obtained in the study conducted by Adejuwon et al. (2020). As indicated by Yi et al. (2018a), birds subjected to a warm environment could experience heat stress which could affect their health, welfare and productivity. This study indicated that there was no significant difference between the mean air temperatures in the V290 and V460 buildings and the outdoor conditions. This shows that the indoor conditions of the buildings were strongly connected to the outdoor, supporting the findings of Pajumägi, Poikalainen, Veermäe, and Praks (2008) who indicated that indoor and outdoor conditions are strongly connected. The reason for no significant difference between the mean air temperatures of V290 and V460 could be that the air in the small opening area building (V290) had a better mixture compared to the building with V460, resulting in similarity in the air temperatures of the two building as also reported in Yi et al. (2018a). Subjecting poultry birds to high air temperatures of about 30°C could result in about a 50% decrease in the ability of sperm to fertilise the egg (Vandana et al., 2021). To minimise the impact of heat stress during summer periods, a study (Vandana et al., 2021) showed that poultry birds could only be fed up to 1200 noon while the feed is withdrawn from birds between 1:00 and 4:00 pm.

Figure 6 shows the results of the outdoor and indoor relative humidity of the buildings with V290 and V460 in the morning, afternoon and evening. As shown in the figure, the outdoor relative humidity ranged from 74.6 to 88.5, 42.4 to 86.6 and 62.3 to 89.1% in the morning, afternoon and evening respectively. The indoor relative humidity of the building with V290 sidewall opening area showed that the morning, afternoon and evening data were between 71.5 and 87.9, 45.9 and 86.1, 62.6 and 88.3% respectively. The indoor relative humidity of the building with V460 sidewall opening area for morning, afternoon and evening ranged from 73.8 to 88.2, 46.7 to 86.1 and 62.8 to 88.8% respectively. The result of the t-test analysis indicated that there was no significant difference ($p > 0.05$) between the mean relative humidity of the two buildings.

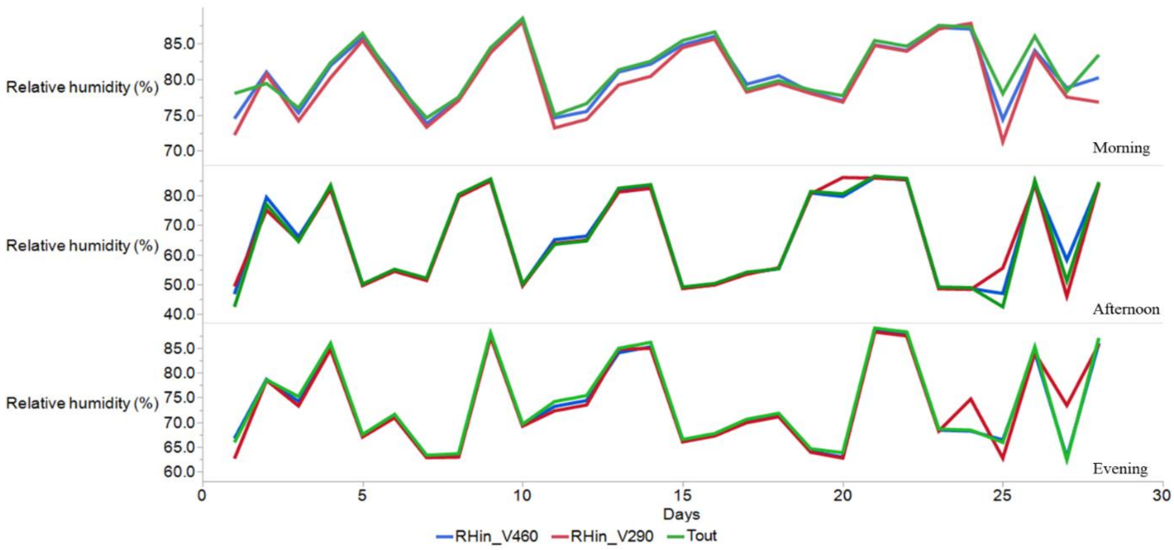

Figure 6. Relationship between indoor and outdoor relative humidity of the buildings with different sidewall opening areas in the morning, afternoon and evening respectively.

Similar to the study conducted by Polat (2015), who showed that indoor relative humidity of above 80% was recorded during the summer, this study has shown that building design, most especially the sidewall opening area, does influence the thermal conditions within poultry building during the hot periods in the humid tropical climate. A study carried out by Adejuwon et al. (2020) showed that relative humidity, higher than 80% could be obtained in the backyard poultry building which is similar to the results of this study. As shown by Kim, Lee, Lee, and Lee (2022), the feed consumption of birds could decrease as the relative humidity exceeds 75% which could induce a stress response in birds. Studies (Okpara, Egbu, & Ani, 2016; Jongbo, 2020) have reported various adverse effects of rearing birds under high air temperatures and high relative humidity. As shown in this study, no significant difference was found between the mean relative humidity of the two buildings with different sidewall opening areas, it has also been reported by Paepe et al. (2013), that inlet opening height had an insignificant effect on the air velocity at the centre of cattle building. This shows that there could be a possibility for the thermal condition of the building not to have been affected by the sidewall opening area.

Figure 7 illustrates the temperature-humidity index (THI) of broiler chickens reared in the two buildings with different sidewall opening areas. As could be observed in the figure, the THI ranges in the morning, afternoon and evening for broilers in the building with V290 sidewall opening area were 21.9 to 27.7, 21.6 to 37.1 and 20.3 to 32.1°C respectively. The building with V460 sidewall opening area had THI ranging from 22.1 to 27.2, 21.7 to 37.5 and 20.7 to 31.9°C in the morning, afternoon and evening respectively. The result of the analysis of the THI between the two buildings with different sidewall opening areas indicated that there was no significant difference ($p > 0.05$) between the THI of broiler chickens in the morning, afternoon and evening.

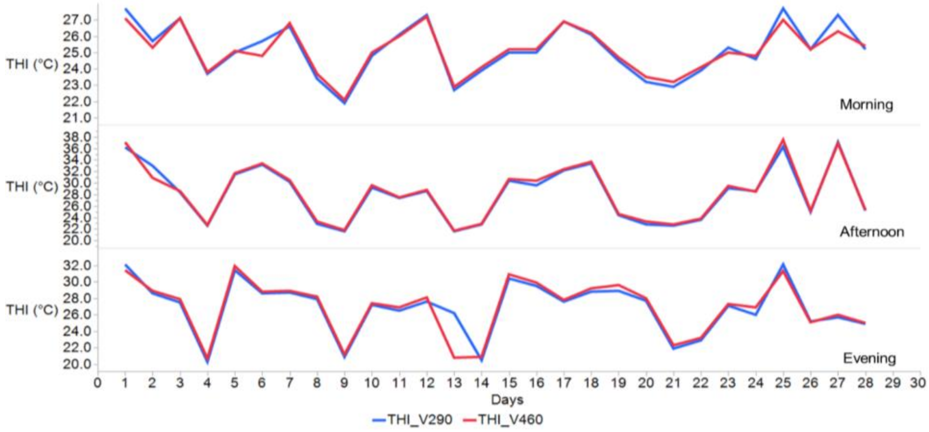

Figure 7. The temperature-humidity index of the buildings with V290 and V460 sidewall opening areas.

As indicated in the report of Jongbo et al. (2024), rearing birds in an environment with high THI could cause thermal discomfort in them. This study has also shown that thermal discomfort could occur in broiler chickens reared in an environment with THI exceeding 21.0°C. This could also affect their performance as they would reduce feed intake and be less active to maintain body temperature within the thermal comfort zone (Mohammed, Jacobs, Murugesan, & Cheng, 2018; Jongbo & Atta, 2019). An opportunity for poultry growers to minimise the THI of broiler chickens in the warm climate would result in a decrease in economic losses (Purswell, Branton, Luck, & Davis, 2013). As indicated in this study, it is evident that animals reared in the humid tropical climate are constantly exposed to heat stress conditions throughout their lifetime.

Figure 8 shows the body weight of broiler chickens reared in the buildings with V290 and V460 sidewall opening areas. As shown in the figure, it could be observed that the average body weight of broilers reared in the building with a V290 sidewall opening area was 0.13 kg higher than that reared in the building with a V460 sidewall opening area. The average weight of broiler chickens in the building with a V290 sidewall opening area was 1.94 kg compared to that of the building with a V460 sidewall opening area that had a 1.80 kg final body weight. However, the result of the analysis showed that there was no significant difference ($p > 0.05$) between the mean body weight of the broilers in the two buildings with different sidewall opening areas. Information on the effect of sidewall opening area/size on the growth performance of broiler chickens is scarcely available. However, some studies have shown that sidewall opening size could affect indoor airflow (Jongbo, Atta, & Moorcroft, 2021 Yi et al., 2018a) and the indoor illumination of naturally ventilated broiler buildings (Olanrewaju et al., 2006).

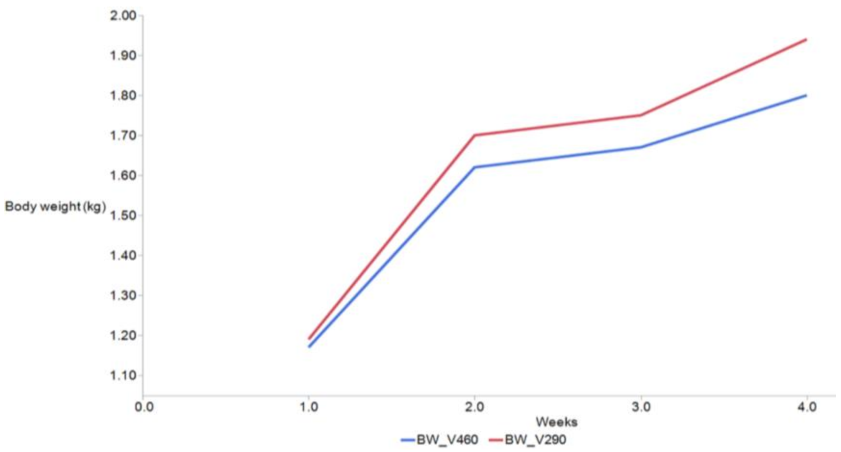

Figure 8. Relationship between body weights of broilers per day.

Conclusion

This study found that sidewall openings do not significantly affect indoor conditions or broiler performance. The temperature-humidity index is vital for assessing broiler thermal comfort in humid climates. Further research should focus on the impact of sidewall openings on broiler behaviour and performance, considering temperature variations. Detailed studies are necessary to determine the effects of sidewall openings on broilers' body and surface temperatures in tropical climates, ensuring optimal environmental conditions for their well-being.

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