



## DEVELOPMENT AND EVALUATION OF THE CLIMATIC CONDITIONS INSIDE A SUSTAINABLE BACKYARD POULTRY BUILDING

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Article history: Received 11 August 2020; Received in revised form 19 September 2020; Accepted 21 September 2020; Available online 30 September 2020.

### ABSTRACT

Small scale backyard poultry buildings, which could be of any shape and design, are very important and every household in Nigeria should embrace. However, it is difficult for most households to plan and design appropriate buildings for their poultry birds. This study was carried out to design a building which could allow birds to exhibit their natural behaviours without being exposed to hazards and predators. The building with dimensions 2.8 m long, 2.3 m wide and 1.9 m height at the front and 1.3 m at the back was developed using local materials. The building comprised of resting room and a free space for poultry to exhibit their natural behaviours such as dust bathing, wing flapping and preening. There were perches inside the building where birds could roost at night. The indoor and outdoor climatic conditions (air temperature and air relative humidity) were evaluated. The result of the study showed that the highest mean indoor air temperature (30.60 °C) and highest mean indoor air relative humidity (83.88 %) were obtained in the afternoon and night respectively. The lowest mean indoor air temperature (24.23 °C) and mean indoor air relative humidity (66.64 %) were obtained in the night and afternoon respectively. The building was considered affordable (\$280.00) and suitable for poultry grown for egg and meat production in the tropical humid climate.

**Keywords:** Air temperature; Air relative humidity; Poultry; Sustainability; Tropical humid climate.

### DESENVOLVIMENTO E AVALIAÇÃO DAS CONDIÇÕES CLIMÁTICAS DENTRO DE UM EDIFÍCIO DE AVES SUSTENTÁVEL

#### RESUMO

Aviários domésticos em pequena escala, de qualquer formato e desenho, são muito importantes, e todas as famílias na Nigéria deveriam ter acesso. No entanto, é difícil para a maioria das famílias planejar e projetar aviários apropriados para suas aves. Este estudo foi realizado para projetar uma construção que pudesse permitir que as aves exibissem seus comportamentos naturais sem serem expostas a perigos e predadores. O edifício com dimensões de 2,8 m de comprimento, 2,3 m de largura e 1,9 m de altura na frente e 1,3 m de

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fundo foi desenvolvido com materiais locais. A edificação é composta por sala de descanso e espaço livre para que as aves exibam seus comportamentos naturais como banho de poeira, batimento de asas e alisamento. Havia poleiros dentro do prédio onde as aves podiam pousar à noite. Foram avaliadas as condições climáticas internas e externas (temperatura e umidade relativa do ar). Os resultados do estudo mostraram que a maior temperatura média do ar interno (30,60 ° C) e a maior umidade relativa média do ar interno (83,88%) foram obtidas no período da tarde e à noite, respectivamente. As menores médias de temperatura do ar interno (24,23 ° C) e umidade relativa do ar interno (66,64%) foram obtidas no período da noite e da tarde, respectivamente. O prédio foi considerado acessível (US \$ 280,00) e adequado para criação de aves para produção de ovos e carne em clima tropical úmido.

**Palavras-chave:** Temperatura do ar; Umidade relativa do ar; Aves; Sustentabilidade; Clima tropical úmido.

## INTRODUCTION

Poultry meat production across the world has greatly increased compared to other types of meat during the past decade. The potential growth, short time of production and affordability of birds are directly related to its value in human diets.

Annually, over ten billions of poultry meat are globally produced (Mench, 2018). However, some factors namely; poor poultry production as a result of diseases, poor ventilation and inadequate floor space (Baracho et al., 2019) are inhibiting the growth of the poultry meat industry in the humid tropical climate such as Nigeria.

Other factors that had been shown to influence poultry production include genetic strain, climatic conditions (Baracho et al., 2019), stocking density (Jones, et al., 2005), price of feed (Adebayo & Adeola, 2005), diet, veterinary care (Cernicchiaro et al., 2016), and environmental enrichment (Riber, et al., 2018).

Small-scale poultry production, which comprises mainly the chickens, is mostly practised in the rural areas, which are categorised as poor-resource regions (Wong et al., 2017). It contributes greatly to the poverty alleviation and food security of the rural areas (Alders & Pym, 2009).

The rural dwellers engage in small-scale poultry production to provide meat and eggs for their scarce animal protein

and also for sale to meet essential family needs which include children school fees, medicine and clothing (Alders & Pym, 2009; Wong et al., 2017).

However, it could be difficult to meet all their essential needs due to some constraints such as inappropriate building design, diseases, feed price fluctuations, inadequate biosecurity, predators and climatic conditions (Blatchford, 2017; Wong et al., 2017). The climatic condition to which the poultry is subjected could pose severe problems for them (Jacob et al., 2017).

The conditions could adversely affect the feed intake, egg production most especially during hot weather periods (Jacob et al., 2017). Therefore, developing appropriate backyard poultry buildings could reasonably minimise the impact of harsh weather on poultry.

Generally, in Nigeria, almost all households practice small-scale poultry production (Chia & Ugwuishiwu, 2014).

However, they either raise the poultry in buildings not properly designed to meet the necessary requirements of the birds or leave the poultry to scavenge for feed and also sleep anywhere they found (Adeyemo & Onikoyi, 2012). The reason for such an approach, allowing birds to scavenge for feed by themselves, could be related to the unattractive economic incentive of the

backyard poultry production (Adeyemo & Onikoyi, 2012).

Although Mikulski et al. (2011) had indicated some advantages of free ranged birds such as higher nutrient intake, low feeding cost, higher omega-3 fatty acids, vitamins in eggs and poultry meat, and the taste of the poultry meat, it is still necessary to develop a backyard poultry building that would consider all the

essential needs of the poultry for their optimum production.

Therefore, the objectives of the study were to (1) design and develop a backyard poultry building for small-scale households in Nigeria and; (2) evaluate the environmental conditions inside and outside the building.

## MATERIALS AND METHODS

### Design details and component description of the poultry building.

The conceptual design of the poultry building was carried out with the AutoCAD 15. The building comprised of a frame, ventilation ports, floor space for birds, perches, resting box and the nest boxes. The dimensions of the frame were 2.8 m long, 2.3 m wide and 1.9 m height at the front and 1.3 m at the back (Figure 1).

The floor space was designed as 0.33 m<sup>2</sup> per bird (Poultry production, 2013). A staircase with a few steps was designed to provide birds with an opportunity to access the nest boxes and the resting box. The ventilation rate required inside the building was estimated as 0.43 m<sup>3</sup>s<sup>-1</sup> using the equation for ventilation rate in Jongbo and Falayi (2013).

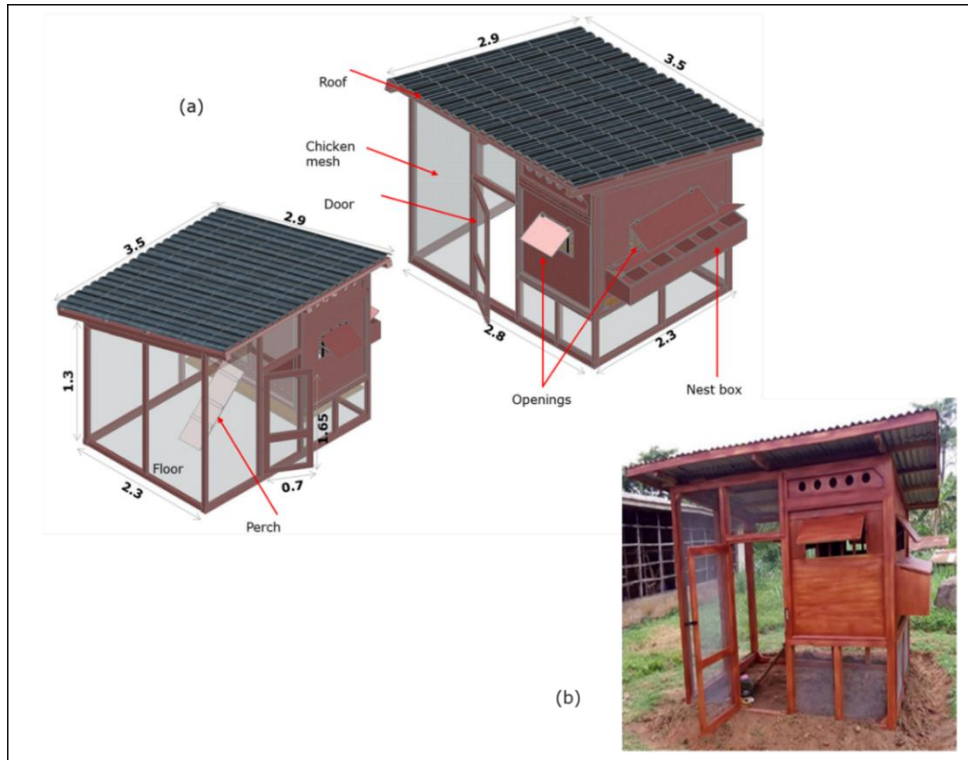
There were five nesting boxes with total dimensions of 1.6 m long, 0.19 m wide, and 0.12 m height (Figure 2). The resting box for the birds was designed with a wire floor and manure collector of dimensions 2.15 m by 0.6 m for easy maintenance (Figure 3). Two perches inside the resting room were constructed with 0.02 m diameter galvanised pipe

placed across the room. They were located at 0.45 m above the wire floor and spaced 0.40 m apart. The galvanised pipe was considered suitable as it could be cold and provide leg cooling for birds during the day and night (Gates et al., 2014).

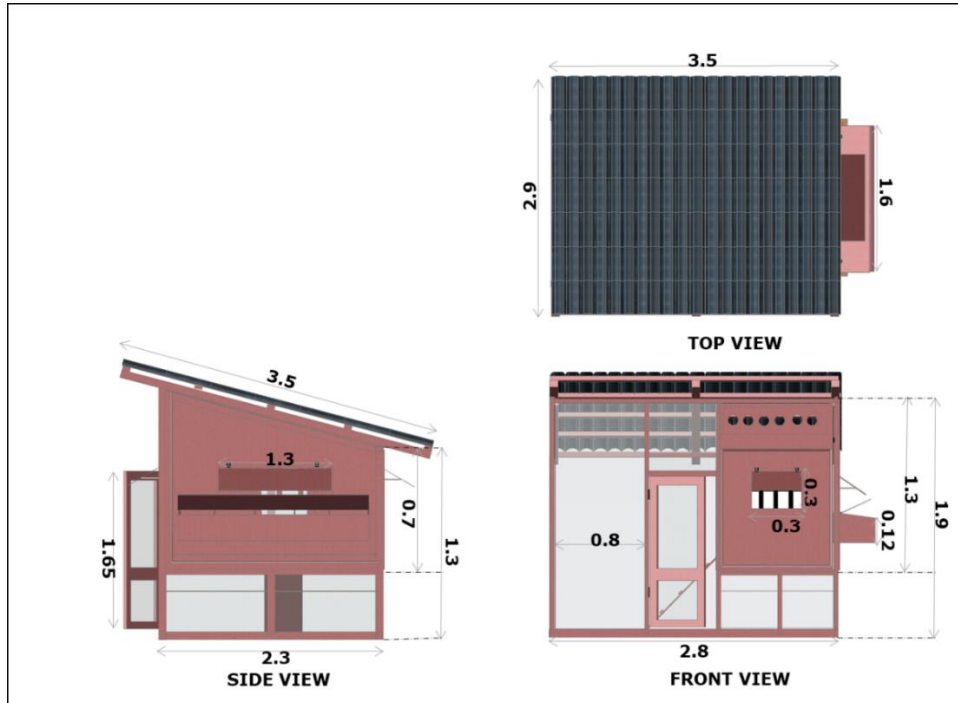
The beams, trusses and the surface cover of the poultry building were made of Bilinga wood (*Nauclea diderrichii*), locally known in Nigeria as Opepe. The mechanical properties of the wood include; crushing strength, static bending strength and modulus of elasticity of 63±7 MPa, 95±11 MPa and 14660±1934 MPa respectively (Cirad, 2012). The physical properties of the wood include; specific gravity, coefficient of volumetric shrinkage, fibre saturation point of 0.76±0.07, 0.55±0.05 % and 25 % respectively (Cirad, 2012).

The wood could be used without preservatives as it has a high resistance to fungi, wood borers and termites (Cirad, 2012). The roof was made of aluminium zinc, installed at a slope of 15 °.

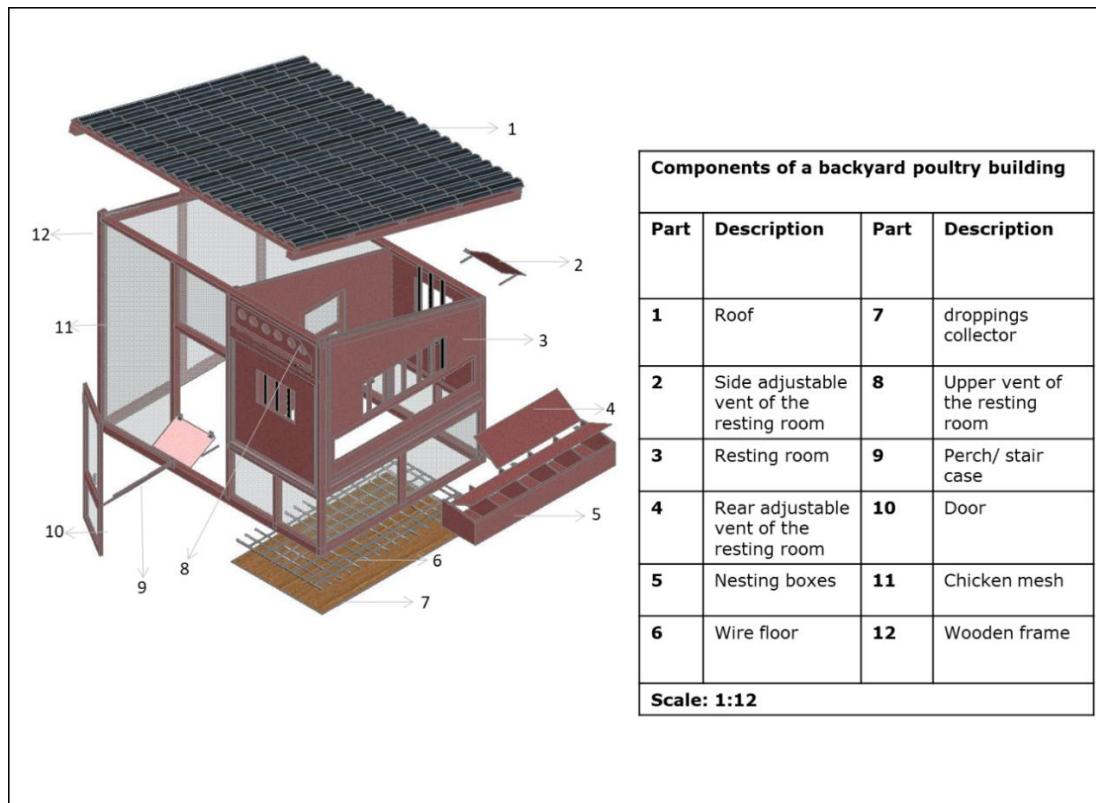
The total cost of construction of the poultry building was approximately 280 US dollars (\$280.00)



**Figure 1.** The (a) isometric view and (b) pictorial view of the backyard poultry building. All dimensions in metres.



**Figure 2.** Orthographic view of the backyard poultry building. All dimensions in metres.



**Figure 3.** Exploded view of the backyard poultry building.

**The experimental site, instrumentation and data acquisition.**

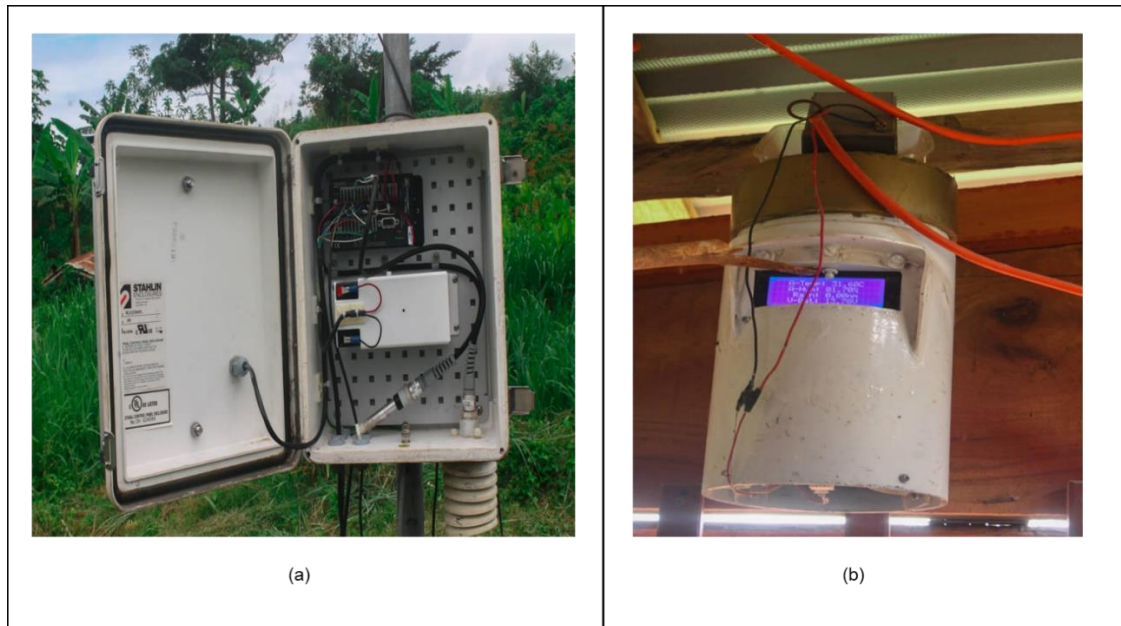
The poultry building was constructed and evaluated at Poultry Research Farm of the Federal University of Technology, Akure, Ondo State, Nigeria. The location is on the latitudes 7° 17' 03'' N to 7° 19' 06'' N and longitudes 5° 07' 02'' E to 5° 09' 05'' E. It falls into the humid tropical climate region, having a high temperature, ranging from 22°C to above 30°C and two major seasons namely; rainy season (April to October) and dry season (November to March). Its annual rainfall is about 2400 mm.

The air temperature and the air relative humidity data inside and outside the building were monitored and logged using a CS215 temperature and relative humidity probe in a weather station and a DHT22 temperature and relative humidity sensor respectively. The measurements from the CS215 temperature and relative humidity

probe were recorded using a Campbell CR200X-series data logger (Campbell Scientific, Inc, USA) installed in the weather station.

The CS215 temperature and relative humidity probe has accuracies of ±0.9 °C and ±4 % for temperature and relative humidity respectively and measurement ranges of -40 to 70 °C and 0 to 100 % for temperature and relative humidity respectively.

The DHT22 temperature and humidity sensor module was built and calibrated for this study (Figure 4b). The DHT22 sensor has accuracies of ±0.5 °C and ±2 % for temperature and relative humidity respectively, resolutions of 0.1 °C and 0.1 % for temperature and relative humidity respectively and measurement ranges of -40 to 80 °C and 0 to 100 % for temperature and relative humidity respectively.



**Figure 4.** Measurement of air temperature and air relative humidity using (a) CS215 probe and Campbell CR200X-series datalogger (b) DHT22 sensor module.

The weather station, comprising CS215 temperature and humidity sensor and the Campbell CR200X-series was installed at about 5 m away from the poultry building to measure and log the outdoor condition of the building.

The data logger was programmed using a PC200W software (Campbell Scientific Inc, USA) to log the air temperature and air relative humidity data from the CS215 probe.

The DHT22 sensor module was installed inside poultry building at 0.6 m above the wire floor to measure the indoor air temperature and the indoor air relative humidity in the building.

The module was programmed using Arduino UNO and an SD memory card was installed in the module for storing the air temperature and air relative humidity data. The data from the two sensors (CS215 probe and DHT22 sensor) were continuously recorded and logged at one hour interval for 25 days.

#### Data analysis

The data obtained were processed into day periods namely; morning (0600H to 1100H), afternoon (1200H to 1700H), evening (1800H to 2300H) and night (0000H to 0500H) using Microsoft Excel Professional Plus 2016 and were analysed using JMP<sup>®</sup> Pro 13.0.0 (SAS Institute Inc, USA).

Some data analyses such as t-test, ANOVA and Turkey-Kramer HSD were conducted. The t-test analysis was carried out to determine the level of significance between the indoor and outdoor conditions during the afternoon. The ANOVA analysis was conducted to examine the effect of day periods on the thermal conditions inside the building at different day periods.

Finally, a Turkey-Kramer HSD analysis was carried out to compare the means of the indoor and outdoor conditions (air temperature and air relative humidity) with respect to the day periods. The data analyses were carried out at a significance level of 5%.

## **RESULTS AND DISCUSSION**

### **Air temperature**

The indoor and outdoor air temperature of the poultry building were evaluated. The results of the average air temperature inside and outside the poultry building, over the period of 25 days are shown in Figure 5.

The average indoor air temperatures in the morning, afternoon, evening and night were, 25.35 °C, 30.60 °C, 26.77 °C and 24.23 °C respectively (Figure 5). The mean outdoor air temperature in the morning, afternoon, evening and night were 29.02 °C, 32.47 °C, 27.56 °C and 26.71 °C respectively. It could be observed in Figure 5 that the air temperature inside the building, in some of the days, were about 22 °C at all periods of the day. These were the days when short period of sunshine was experienced.

The result of the ANOVA analysis indicated that there was a significant difference ( $p < 0.0001$ ) between the mean indoor air temperatures of the day periods.

However, further analysis conducted using Turkey-Kramer HSD showed that there was no significant difference ( $p = 0.084$ ) between the mean indoor air temperatures in the morning and evening. In addition, Turkey-Kramer HSD also indicated that there was no significant difference ( $p = 0.245$ ) between the mean indoor air temperatures in the morning and night.

A t-test analysis was conducted for better understanding of the difference between the indoor and outdoor conditions during the afternoon. The result showed that there was a significant difference ( $p = 0.017$ ) between the mean indoor and outdoor air temperatures.

It could be generally observed from Figure 5 that the indoor condition of the building was lower than that of the outdoor except in the evening where there were overlaps. In the night, outdoor air temperature was a few degrees higher than that of the indoor.

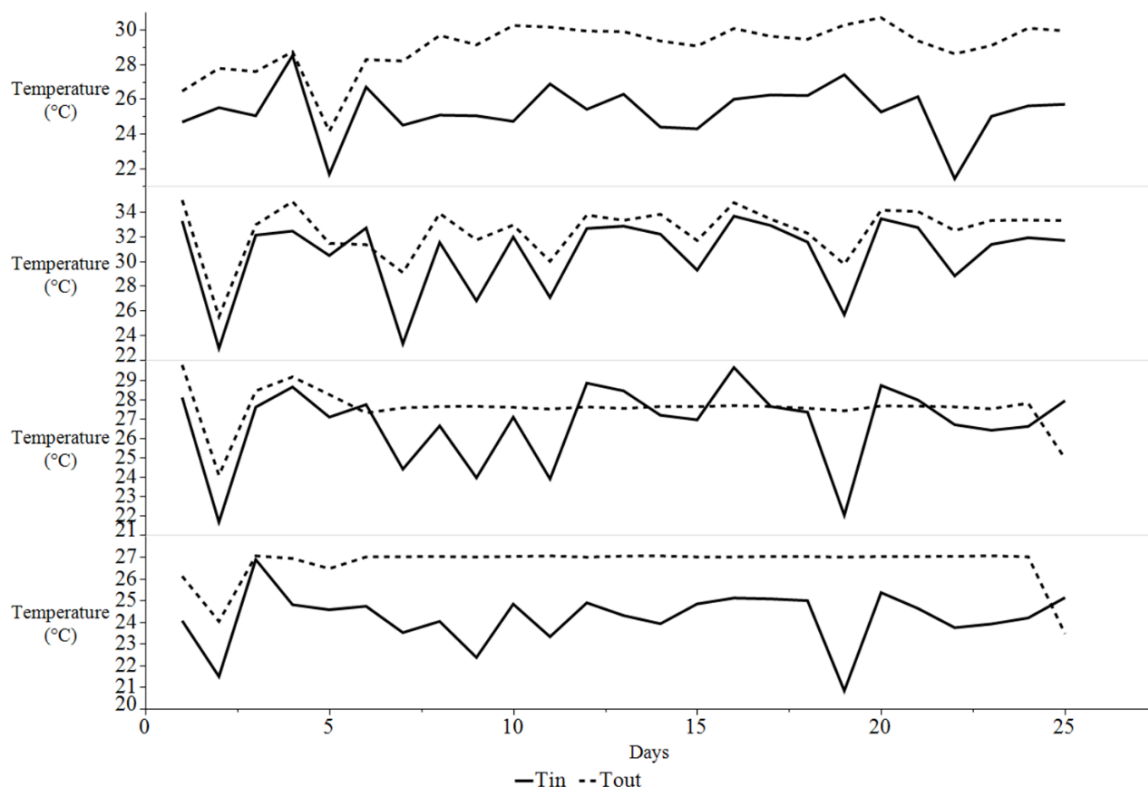
Similar results had been reported by Teye et al. (2008) who indicated that indoor air temperature could be a few degree higher or lower than the outdoor air temperature of an uninsulated animal buildings.

The air temperatures obtained in the building were higher than the recommended air temperatures for mature poultry in CIGR (1984) and Holik (2015) for tropical climate. This indicates that poultry raised in this building could be subjected to high indoor air temperatures during the afternoon periods (Jongbo, 2020).

At high air temperature, most especially in the afternoon, there is a possibility for the feed intake, performance and feed conversion rate of the birds to reduce (Gu et al., 2008). The fluctuation in the indoor air temperature is directly related to the period of exposure of animal buildings to the sunshine (Herbut et al., 2015).

This study, in conjunction with other work (Al-Aqil et al., 2009), has shown that it could be difficult to maintain an optimum air temperature inside the naturally ventilated poultry buildings in the tropical climate countries.

According to Schauburger et al. (2019), the constant increased air temperature, in the tropical climate, could cause an increase in heat stress as a result of anthropogenic warming.



**Figure 5.** Air temperature inside (Tin) and outside (Tout) the poultry building

**Relative humidity**

The results of the air relative humidity obtained inside and outside the poultry building are shown in Figure 6. The results showed that the average indoor air relative humidity of 81.85 %, 66.64 %, 76.72 % and 83.88 % were obtained in the morning, afternoon, evening and night respectively.

The mean outdoor air relative humidity of 78.01 %, 65.35 %, 81.76 % and 84.44 % were measured in the morning, afternoon, evening and night respectively. As it could be noted in Figure 6, air relative humidity was mostly greater than 80 % during the morning and night but mostly lesser than 80 % during the afternoon and evening during most of the days.

The ANOVA analysis indicated that there was a significant difference ( $p < 0.0001$ ) between the mean indoor air relative humidity of the day periods. However, the analysis conducted with Turkey-Kramer HSD which compared the

means of the air relative humidity of the day periods showed that there was no significant difference ( $p = 0.448$ ) between the mean indoor air relative humidity in the morning and night. A t-test analysis was carried out to determine the difference between the mean indoor and outdoor air relative humidity in the afternoon and the result indicated that there was no significant difference ( $p = 0.542$ ) between the mean indoor and outdoor air relative humidity during the afternoon.

It could be observed in Figure 6 that the air relative humidity inside the building is higher than that of the outdoor air relative humidity. The higher indoor air relative humidity obtained inside the building could be as a result of the lower air temperature inside the building (Jongbo, 2020).

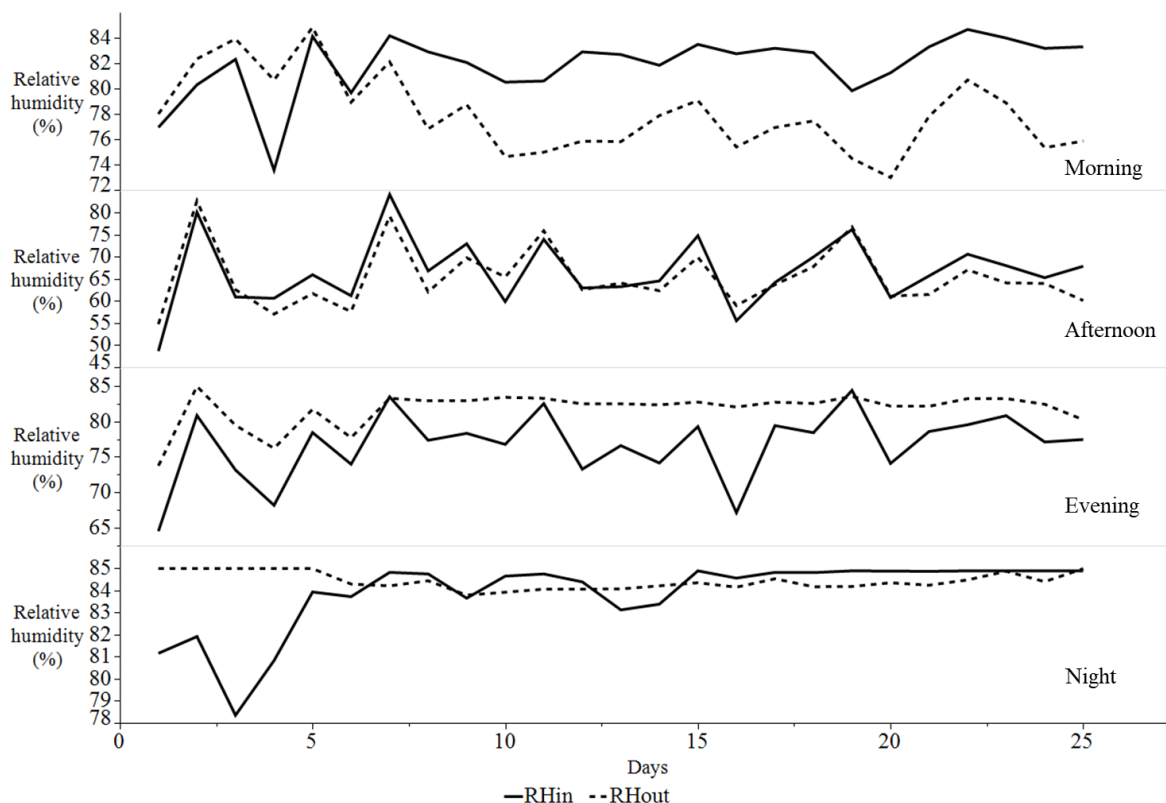
As also indicated by Pedersen et al. (1998) the latent heat loss which greatly depends on the air relative humidity could be reduced when the indoor air relative humidity is high (80 %). Similarly, high



air relative humidity could aggravate the negative effect of high air temperature on poultry (Gu et al., 2008).

High air relative humidity inside animal building, if not properly controlled,

could significantly contribute to the fast spread of an influenza virus (Lowen et al., 2007).



**Figure 6.** Air relative humidity inside (RHin) and outside (RHout) the poultry building

## CONCLUSION

The indoor and outdoor of a sustainable backyard building developed for households in Nigeria was evaluated.

The building is affordable and all materials used are readily available locally. The evaluation of the climatic condition, both inside and outside showed that the building could provide suitable conditions for the enclosed animals in tropical humid climate.

However, the conditions were discovered to be above the recommended climatic conditions for poultry despite the fact that the climatic conditions could be lessened when lesser sunshine is experienced.

With the constant effect of global warming on the climatic conditions of livestock buildings, there is possibility for the air temperature and air relative humidity of the animal building to keep increasing.

Therefore, to minimise the impact of hot weather on the welfare and performance of livestock, there is a need for a provision of cooling fans for providing cooling for the poultry during hot periods.

Further study would include testing the building with live domestic fowls and the effect of the building stocked with poultry on the indoor climatic conditions would be evaluated.

## ACKNOWLEDGEMENTS

There was no financial support for this study. However, the author would like to appreciate the staff of the Animal

Research and Teaching Farm, Federal University of Technology, Akure, Nigeria for their technical support.

## DECLARATION OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have

appeared to influence the work reported in this paper.

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