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Research Article

Motorbike Powered Trailer for Transporting Poultry Birds

Ayoola Olawole JONGBO[a]* ID Timothy Oluwatimilehin ADELAJA[a] ID

[a]*Department of Agricultural and Environmental Engineering, School of Engineering and Engineering Technology, Federal University of Technology, PMB 704, Akure, Ondo State, NIGERIA*

(*): Corresponding author, aojongbo@futa.edu.ng

ABSTRACT

The demand for poultry products has made it necessary for farmers to transport poultry birds from farmhouses to where they could be processed for the consumers. However, transporting poultry birds over a long distance, and under unfavourable conditions, could cause a shift in their behaviours, and biochemical reactions, resulting in an increase in birds' traumatic injuries, weight loss, and poor meat quality. Therefore, a motorbike powered trailer was developed, having an average loading capacity of 50 to 54 broiler chickens, with a live body weight of 1.5 kg, for small-scale farmers. The climatic conditions (temperature and relative humidity) within the trailer were evaluated when the trailer was tested on the motion for 35 minutes during the hot period of the day (1:30 pm to 2:05 pm). The result showed that the indoor temperatures ranged between 29.3°C and 31.6°C and the outdoor temperatures ranged from 31.0°C and 33.3°C. Similarly, the indoor relative humidity was between 61 and 69% while that of outdoor relative humidity was between 56% and 64%. The mean apparent equivalent temperature (AET) of the trailer was estimated as 30.45 ± 0.54°C. This implies that the thermal zone within the trailer could be considered safe for poultry birds during hot weather periods in the humid tropical climate. The total production cost of the trailer was two hundred and forty-three US dollars, eighty cents ($243.80).

RESEARCH ARTICLE

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- Apparent equivalent temperature,
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- DHT sensors

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INTRODUCTION

Livestock, according to Thornton, (2010) occupies about 30% of the planet's ice-free terrestrial surface area, serves as a source of animal-based protein (Jongbo, 2020), and their production has contributed immensely to the economic growth of any nation especially in ensuring food security (Nabarro and Wannous, 2014). They are the source of employment for over 1.3 billion people worldwide, contribute about 40% of the global income from agricultural products and also support the livelihoods of over 600 million poor small-scale farmers in developing countries (Nabarro and Wannous, 2014; Thornton, 2010). Poultry is one of the sectors of livestock production which has greatly contributed to the animal-based protein source for humans. Large numbers of poultry birds have been slaughtered for consumption compared to other livestock (Weeks, 2014). To meet up with the increased demand for poultry globally, there has been an increase in the poultry production intensification and transportation of livestock (Minka and Ayo, 2007).

The transportation system is an important component of livestock production (Schwartzkopf-Genswein *et al.*, 2012) and its efficiency depends on the economic, environmental perspectives and animal welfare (Frisk *et al.*, 2018). Livestock could be transported from the farm to other places outside the farm for veterinary treatment, marketing and slaughtering purposes (Broom, 2019; Frisk *et al.*, 2018). During transportation, animals could be subjected to situations that could negatively affect their welfare which could be assessed using welfare indicators such as animal behaviours, animal physiological response and carcass quality measures (Broom, 2019). Some of the factors affecting the welfare of animals during transportation include human attitudes to livestock, journey planning, a mixture of animals from different social groups, method of driving and road conditions, and floor space per animal on the vehicle (Broom, 2019; Frisk *et al.*, 2018). Others include journey distance, animal inspection during the journey, time that the journey starts, number of pick-ups and stops along the journey and the climatic condition of the vehicle during the journey (Broom, 2019; Frisk *et al.*, 2018). Although subjecting animals to the transport of long journeys may not negatively affect the animal welfare, it is appropriate to ensure that the health, feed and water intake, rest and the thermal condition of the animal environment are critically considered (Frisk *et al.*, 2018; Nielsen *et al.*, 2011). Similarly, subjecting animals to short-distance journeys could reduce the cost of transportation, animals' injury and environmental pollution (Frisk *et al.*, 2018).

Transportation in poultry production could cause various degrees of stress, varying from discomfort to death of birds (Schwartzkopf-Genswein *et al.*, 2012). For broiler chickens, thermal stress is the major problem confronting them during transportation and its directly related to their poor welfare signs shown when in transit (Strawford *et al.*, 2011). In a study conducted by Vosmerova *et al.* (2010), they indicated that pre-transport handling procedures of broilers such as catching, crating and loading and low ambient temperature during transportation caused more stress to broilers than high temperature (35°C) during transportation. The higher percentage of dead on arrival (DoA) of broiler, reported by Chauvin *et al.* (2011) and Schwartzkopf-Genswein *et al.* (2012), was shown to be caused by the climatic conditions broiler were subjected to before the slaughtering process. While Arikan *et al.* (2017) and Voslarova *et al.* (2007) reported that long transportation distances caused more broiler losses than short transportation distances. This shows that potential stressors such as extreme temperatures, variable vehicle speeds, noise pollution, water and feed deprivation, vibration due to poor road and overcrowding that could cause fear, discomfort and high mortality during transportation (Mitchell and Kettlewell, 2014; Vosmerova *et al*., 2010) are more pronounced when subjecting broilers to long-distance under extreme weather conditions.

The thermal condition of the microclimate within the vehicle is a major concern as regards the problems associated with the stress birds are subjected to and that the problem could only be minimised by improving vehicle designs to provide the environmental conditions required by the on-board birds (Mitchell and Kettlewell, 2014). There are a few studies on different designs and development of road transportation systems for poultry. Hui (2013) developed and evaluated an actively heated and ventilated transport vehicle for broiler chickens transported under harsh Canadian Prairies winter conditions. He reported that the integration of active ventilation and heating system in poultry transportation vehicles improved the climatic conditions of the microclimate of broilers during harsh winter conditions. In a study carried out by Aldridge *et al.* (2019), they reported that dual boarding of the external part of the transport vehicle maintained the indoor temperature at about 8.0°C when the outdoor temperature was as cold as -16°C during winter. However, during the summer conditions, introducing double boarding to the exterior part of the transport trailer resulted in a temperature gain of 2.0°C within the trailer. Norton *et al.* (2013) used computational fluid dynamics (CFD) to simulate the environmental heterogeneity in a dual-mode ventilated (naturally and mechanically) ferry transportation. They indicated that the naturally ventilated deck of the ferry transport was hotter and highly humid compared to that of the mechanically ventilated deck. Most of the studies in the literature are either for commercial purposes or the developed countries and less or no consideration was given to the small-scale farmers in the developing countries who could not afford the available trailers for transporting their animals. Therefore, there is a need for the development of a less expensive trailer that an average farmer in developing countries could afford and used for transporting their poultry birds.

Therefore, the specific objectives of this study were to (i) design and develop a motorbike powered trailer for transporting small animals such as poultry birds and (ii) evaluate the indoor environmental conditions and (iii) evaluate the thermal zone (AET) of the trailer using internet of things (IoT) based instrumentation.

MATERIALS AND METHODS

The design and development of the trailer were considered necessary after a feasibility study was carried out across some places in Ondo State, Nigeria to understand the transportation system used by the small-scale farmers for transporting their animals. Figure 1 shows the way an average farmer used to convey their poultry birds using a crate or cage fastened to the back of a motorbike. Figure 1a shows a farmer trying to take a ride with some birds in a crate. Figure 1b shows a bike man conveying matured broiler chickens with a cage that was not properly fastened to the bike. Figure 1c shows a bike carrying a well-sited broiler cage but with a small sitting space for the bike man to sit on. Figure 1d shows a half stand motorbike carrying a broiler crate at an angle that could cause discomfort for the birds. Considering the figures, it could be observed that transporting poultry birds in crates/cages, fastened to the back of the motorbike, could cause discomfort for both the farmers and the birds. In addition, it could result in poor welfare and thermal stress for birds during transportation.

Figure 1. Transportation of poultry birds using the motorbike.

Design details and the description of the trailer

A motorcycle powered trailer was designed using SOLIDWORKS 2021 and fabricated in the Department of Agricultural and Environmental Engineering workshop, Federal University of Technology, Akure, Nigeria (Figure 2). The trailer was designed to aid the transportation of poultry birds from one location to another considering the stress involved in the existing poultry transportation system earlier discussed. This trailer would, in the process, reduce the stress undergone by the farmer and the poultry birds being transported.

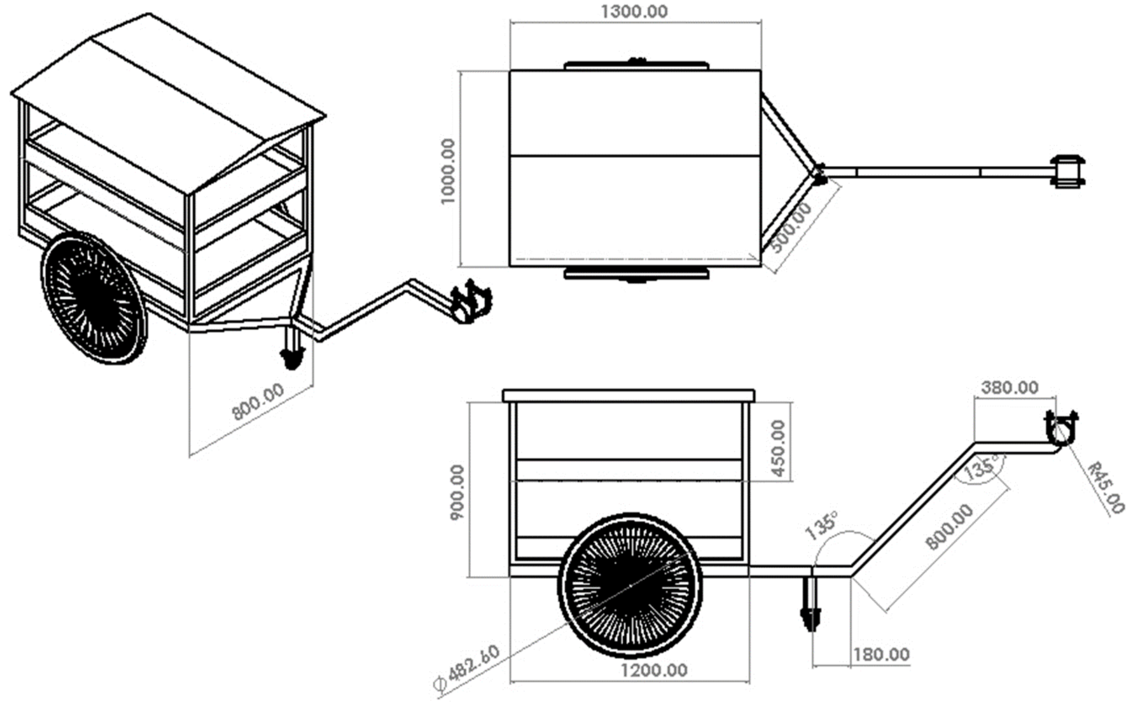

Figure 2. Trailer for transporting poultry birds. All dimensions are in mm.

Design of the trailer's shaft (axle)

The shaft (axle) of the trailer with a total length of 1.10 m, carrying a uniformly distributed cage of an average weight of 1.03 kN m^{-1} and a total estimated poultry weight of 1.155 kN m^{-1}, was designed and calculated. The total uniformly distributed load, carried by the trailer was estimated as 2.731 kN m^{-1}. To estimate the total shear force and the bending moment of the axle of the trailer, the weights of the axle's components were mathematically estimated. The maximum bending moment (M_b) was estimated as 0.392 kN m^{-1} while the torsional moment (M_t) of the axle was calculated as 0.011 kN m^{-1} using;

$$M_t = \frac{60 \times P}{2\pi N} = \frac{9550 \times P}{N} \text{ Nm} \quad (1)$$

where P is the average power (5.0 kW) of the motorbike pulling the trailer and N, the number of revolutions (1300 rpm) of the bike's wheel.

The diameter (d) of the trailer's axle was estimated as 34.11 mm using;

$$d^3 = \frac{16}{\pi Ss}\sqrt{(k_b M_b)^2 + (k_t M_t)^2} \quad (2)$$

where Ss is the allowable stress (55.0 MPa), K_b is the bending stress factor (1.5), K_t is the torsional stress factor (1.0), M_b is the maximum bending moment, and M_t is the torsional moment. The factor of safety considered suitable for the shaft diameter was 0.09. In this study, a standard shaft diameter of 35 mm was selected for the trailer since a 34.11 mm diameter shaft was not readily available for the study.

Description of the trailer

The trailer, as shown in Figure 3, consists of a frame, two wheels, a hitching point, wire gauze as a side covering, two floors (upper and lower), a supporting stand, openings and a top cover. With the hitching point, the trailer could easily be attached to the motorcycle. The frame with a length of 1200 mm, a height of 900 mm and a width of 800 mm, was fabricated using 45 x 45 mm angle iron. The frame was set on two wheels with a rim diameter of 482.6 mm. The trailer has two floors/ layers (upper and lower) which serve as compartments for poultry birds. The floors were made of wood of 20 mm thickness. A supporting stand, made of a universal swivel caster, was attached to the frame at the front to ensure that the trailer could stand when not hauled and to make the attachment of the trailer to the motorcycle very easy. The sidewalls of the trailer were covered with 20 x 30 mm wire gauze. The average loading capacity of the trailer was estimated as 50 to 54 broiler chickens, with a live body weight of 1.5 kg. This was achieved based on the stocking density of 42 kg m^{-2} reported by Giersberg *et al.* (2016). The total production cost of the trailer was two hundred and forty-three US dollars, eighty cents ($243.80).

Figure 3. Developed motorbike powered trailer for transporting poultry birds.

Instrumentation and data collection

For this study, an environmental monitoring device was developed to monitor the temperature and relative humidity within and outside of the trailer. The device comprised DHT-11 sensors, an ESP8266 Wi-Fi module (NodeMCU), an OLED and a LED display. The block diagram of the system is shown in Figure 4. The NodeMCU, a Wi-Fi communication module ESP8266, is an IoT platform open-source (Pasika and Gandla, 2020). It collects the temperature and relative humidity from the DHT-11, processed the data and uploads the data to the ThingSpeak server (Pasika and Gandla, 2020). The ThingSpeak is an open-source application. It is an IoT data collection application, capable of analysing and transmitting the data in real-time (Pasika and Gandla, 2020). The system was designed in an Embedded-C and simulated using Arduino IDE. On the ThingSpeak server, the authorised users could gain access to the uploaded data by signing into their account using the user ID and password.

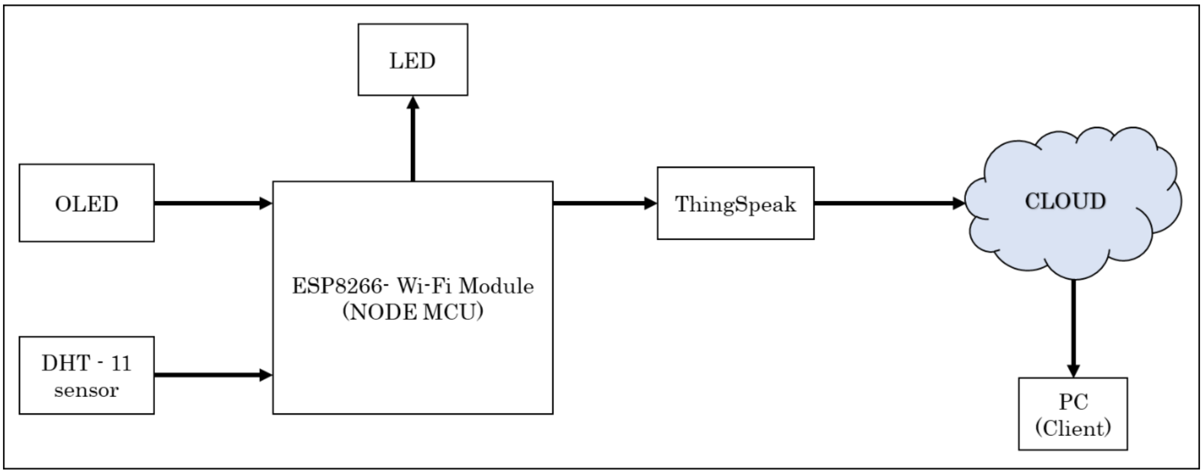

Figure 4. The block diagram of the system for the environmental monitoring.

The technical specifications of the DHT-11 sensors used in this study are shown in Table 1. The DHT-11 has already been calibrated by the manufacturing industry. Therefore, there was no need for further calibration before the sensors were deployed for environmental parameter monitoring. However, the reliability of the sensors was tested by comparing its data with that of the data obtained from HTC-1, a temperature and humidity sensor. The result of the test showed that there was no significant difference between the data of DHT-11 and that of HTC-1. Therefore, the DHT-11 was deployed directly without further calibration.

Table 1. Technical specifications of the DHT-11 sensor

Technical specifications	DHT 11 sensor					
	Temperature			Relative humidity		
	Minimum	Typical	Maximum	Minimum	Typical	Maximum
Measurement range	0°C	-	50°C	20%	-	90%
Accuracy	±1°C	-	±2 °C	-	±4 %	±5 %
Resolution	1°C, 8 Bit	1°C, 8 Bit	1°C, 8 Bit	1%, 8 Bit	1%, 8 Bit	1%, 8 Bit
Response time	6 s	-	30 s	6 s	10 s	15 s
Sampling interval	60 s					

To evaluate the thermal conditions of an empty motorbike powered trailer, as shown in Figure 5, before using it for poultry transportation, the environmental monitoring device was installed inside and outside the trailer to monitor the air temperature and air relative humidity of the trailer. The outdoor DHT-11 sensor was placed 0.10 m above the cover of the trailer while the inside DHT-11 sensor was placed inside the upper floor of the trailer. The motorbike-powered trailer was driven on an off-road track, a typical Nigeria road, for thirty-five (35) minutes from 1:30 pm to 2:05 pm during which the environmental condition was monitored and recorded. The period of the study was considered appropriate because the weather in the humid tropical climate starts to get warm, according to Jongbo (2020), from midday (noon) to around 4:00 pm and the warm condition was considered to negatively affect the microclimate of the animals. It is necessary to clearly state that the trailer was tested without poultry birds inside. Only the environmental parameters (air temperature and air relative humidity) were evaluated to understand the climatic condition within the trailer. Likewise, the effect of motorbike speed on the indoor environmental parameter was not evaluated since there was no animal in the trailer. Consequently, varying the motorbike speed was not considered necessary and the speed was maintained at a speed range of 30 to 40 km h^{-1} during the period of the road test.

The data from the sensors was immediately monitored by an assistant through a ThingSpeak chart on an android phone. The application enables the user to easily visualise the data in the ThingSpeak channels. The data was later downloaded in the form of a Google spreadsheet or CSV file format on a laptop (HP ProBook 4540s) for further processing.

Figure 5. Road testing of the motorbike powered trailer and data acquisition.

Data analysis

The data acquired from the trailer was processed on Microsoft Excel Professional Plus 2019 and analysed using JMP® Pro 13.0.0 (SAS Institute Inc. USA). A t-test analysis was conducted to determine the significance level between the mean indoor and outdoor climatic conditions of the trailer when not occupied by poultry birds. To determine the thermal zones for the trailer during transportation, an Apparent Equivalent Temperature (AET), a physiological stress response model, expressed by Mitchell (2006) and used by Aldridge *et al.* (2019), was adopted and used. The AET (Equation 3) was estimated from the air temperature and the relative humidity obtained from within the trailer. The AET within the trailer could assist in understanding the level of physiological stress, and the changes in the deep body temperature of broiler chickens during transportation (Mitchell, 2006). It is clear that as the AET reaches 45°C, mild thermal stress could set in during transportation. However, with the AET reaching 65°C and above, severe thermal stress and high mortality could occur (Mitchell, 2006).

$$AET = T_i + \frac{10^{\left(30.5905 - 8.2 \times log_{10}(K) - \frac{3142.31}{K}\right)} \times \left(\frac{rH}{100}\right)}{0.93 \times (0.0006363601K + 0.472)} \qquad (3)$$

where T_i is the measured air temperature (°C), K is the air temperature corrected to Kelvin (°C + 273.15), and rH is the measured relative humidity (%).

RESULTS AND DISCUSSION

The suitability of the trailer for poultry bird transportation was tested and evaluated based on the climatic conditions (air temperatures and air relative humidity) within the trailer on a road similar to a typical farm road in Nigeria. The air temperatures (within and outside) of the trailer are illustrated in Figure 6. It could be observed in the figure that the air temperatures of both the outdoor and the indoor had a similar pattern. From Figure 6, as the outside air temperature varied between 31°C and 33.3°C, the indoor air temperature was observed to vary between 29.3°C and 31.6 °C. This indicates that the trailer was able to minimise the indoor temperature by about 2°C. The mean air temperatures observed both within and outside the trailer were 30.4 ± 0.54°C and 31.9 ± 0.56°C respectively. The result of the t-test carried out to determine the level of significance between the indoor temperature and that of the outside air temperatures showed that there was a significant difference ($p < 0.0001$) between the mean indoor air temperature and that of the outside air temperature. According to Schwartzkopf-Genswein *et al.* (2012), the indoor temperature of the trailer for transporting small animals should not exceed 30°C to prevent heat stress. However, in the humid tropical climate, achieving such thermal conditions inside the vehicle could be difficult since air temperature is usually above 30°C (Jongbo, 2020). Therefore, in this study, an average air temperature of 30.4°C was observed at an average motorbike speed of 30 to 40 km h^{-1} within the trailer. This thermal condition could be considered safe for the poultry birds when transported on Nigerian roads under humid tropical climatic conditions. Higher live shrinkage and higher core body temperature of broiler during transportation should be prevented by not exposing broiler chickens to higher indoor temperatures (Schwartzkopf-Genswein *et al.*, 2012). In the reviewed work of Broom (2019), transporting small animals such as turkeys under an indoor air temperature of 35°C could negatively affect the behaviour, physiology and carcass quality of the birds. Therefore, the air temperature (high or low), to which small animals are subjected during transportation, could result in suffering, poor welfare and sudden death of the animals (Nielsen *et al.*, 2011).

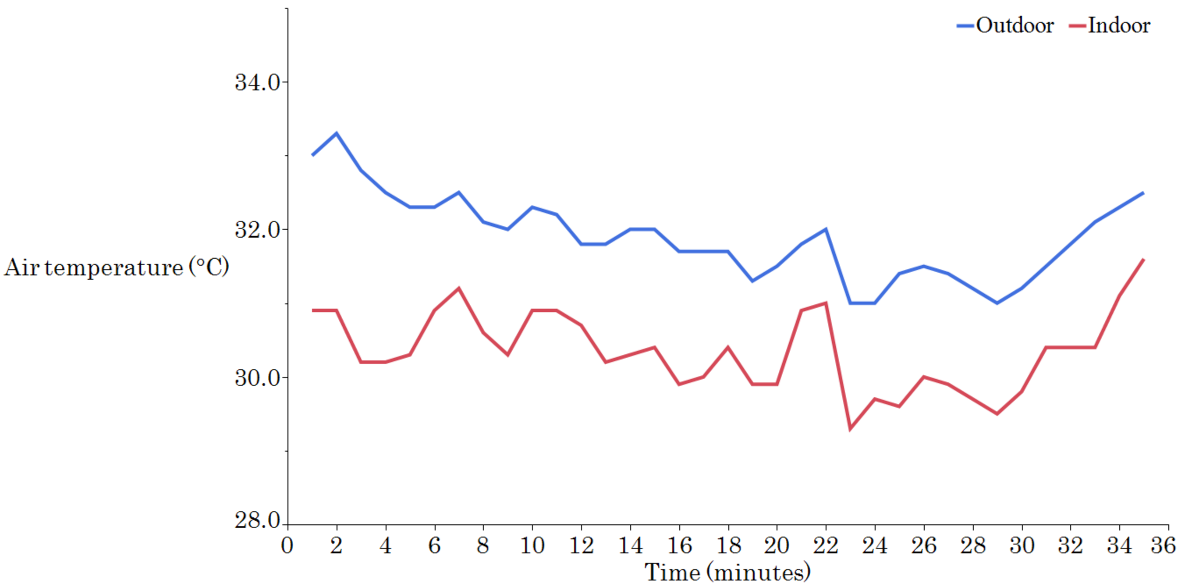

Figure 6. Air temperature variation within and outside the trailer.

The air relative humidity, within and outside the trailer, was evaluated. The results of the assessment, as shown in Figure 7, indicated that the value of the outdoor air relative humidity ranged from 56% to 64% while that of indoor varied between 61% and 69%. The mean air relative humidity, inside and outside of the trailer, was 65.3 ± 2.27%

and 59.9 ± 2.39% respectively. This indicates that the indoor relative humidity was about 5% higher than the outdoor air relative humidity compared to the air temperature which was reduced by 2°C. The t-test analysis conducted showed that there was a significant difference (p<0.0001) between the outdoor air relative humidity and the indoor air relative humidity. The increase in air relative humidity, as the air temperature increased, observed in this study, has previously been reported by Aldridge *et al.* (2019) and Jongbo (2020). The mean air relative humidity obtained for 35 minutes, that the trailer in the study, was tested is similar to that obtained by Aldridge *et al.* (2019) for 15 to 45 minutes. The hot period of the humid tropical climate is generally characterised by high air temperature and high relative humidity of about 30°C and 80% respectively (Kiki *et al.*, 2020), which could be detrimental to animals' welfare and health. Therefore, for poultry birds, raised in the humid tropical climate, subjecting them to an average air relative humidity of less than 70%, as reported in this study, might help to alleviate the negative effect of the high temperature (above 30°C) on the welfare and health of poultry birds during transportation.

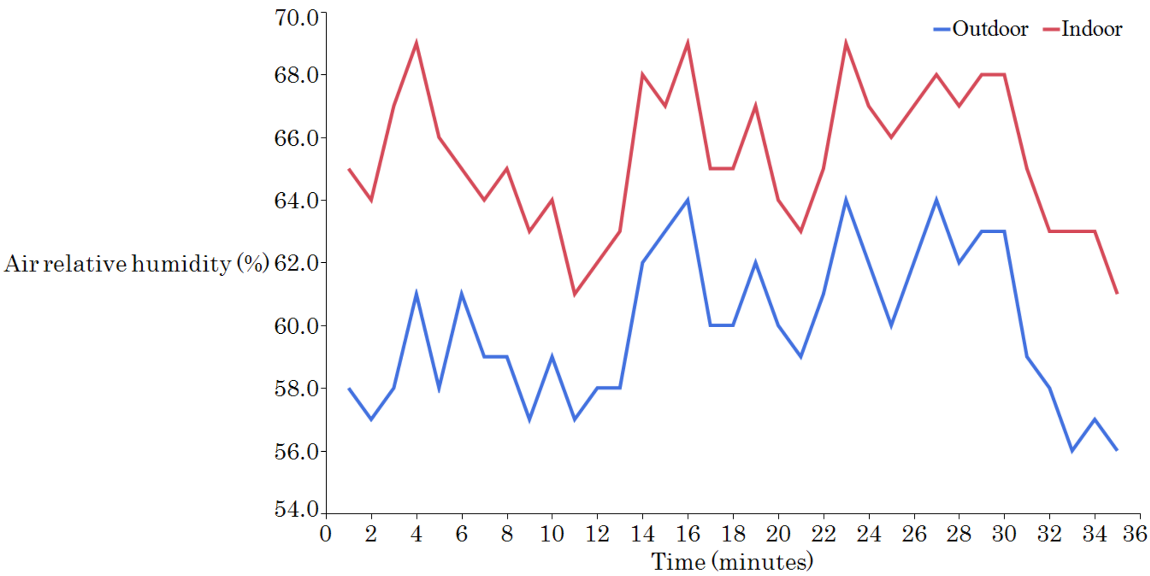

Figure 7. Air relative humidity variation within and outside the trailer.

To understand the thermal zone (safe, alert and dangerous) within the trailer, the apparent equivalent temperature (AET), of the empty trailer was evaluated as shown in Figure 8. The result of the study shows that the AET varied from 29.39°C to 31.70°C with a mean of 30.45 ± 0.54°C. According to Mitchell (2006), AET of 40 to 45°C could cause moderate thermal stress for broiler while severe and high mortality could occur as the AET reaches 65°C and above. In this study, it is clear that even at high outdoor temperatures during the summer period, the AET within the trailer could be maintained at a safe zone since the estimated AET was 30.45 ± 0.54°C compared to the AET of 80.5°C obtained by Aldridge *et al.* (2019) which was severe and detrimental. The high AET obtained by Aldridge *et al.* (2019) could have occurred as a result of high relative humidity within the trailer. Exposure of broiler to high air temperature and high relative humidity is highly detrimental to the birds' welfare, health, production and economic growth of farmers (Jongbo, 2018).

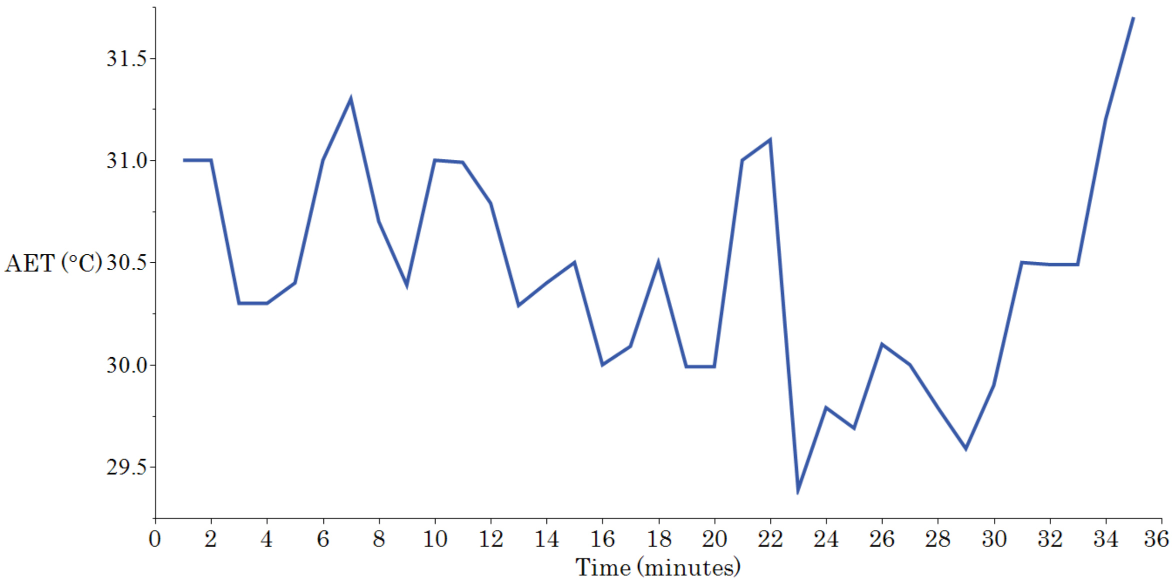

Figure 8. The apparent equivalent temperature of the trailer.

CONCLUSION

A motorbike powered trailer suitable for small scale farmers for the transportation of poultry birds was developed. The empty trailer was tested to understand the thermal conditions within it when operated on the typical Nigeria road which is almost like off-road tracks. The results of the tests have shown that the air temperature and air relative humidity of the trailer were 2°C and 5% respectively lesser than the outdoor thermal condition during the summer periods. The thermal zone within the trailer indicated that the trailer could provide a safe zone for poultry birds, most especially the broiler chickens, in the tropical humid climate which is generally above the thermal comfort zone (24°C) of broiler chickens. Since the trailer has not been evaluated when occupied with broiler chickens, it is difficult to appropriately quantify the AET, the effect of motorbike speed on both poultry birds and the environmental parameters, the behavioural and physiological responses of broiler chickens, the performance of broiler chickens and the effect of broiler chickens on the thermal conditions of the trailer. Therefore, further study would involve evaluating the effect of motorbike speed on the indoor thermal conditions, surface temperatures of broiler chickens, sensible heat transfer of broiler chickens, the live body weight of broiler chickens and the AET of broiler chickens when subjected to different road terrace and motorbike speeds.

DECLARATION OF COMPETING INTEREST

The authors would like to declare that there is no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors would like to declare their contributions to the manuscript as follow:
Ayoola Olawole Jongbo: Investigation, methodology, conceptualization, formal analysis, data collection, writing- original draft, review and editing.

Timothy Oluwatimilehin Adelaja: Investigation, methodology, data collection writing-original draft.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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