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SHORT COMMUNICATION

ASSESSMENT OF THERMAL COMFORT OF BROILER BIRDS IN WARM - HUMID CLIMATE

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Abstract

An experiment was conducted in a poultry house located at the Faculty of Agriculture, Alex Ekwueme Federal University, Ndufu Alike, Nigeria to assess the thermal comfort of broiler birds of 0-8 weeks old. ASHRAE standard instruments were used to measure environmental parameters within two years (May to July 2020: rainy season; Dec. to Feb. 2021: dry season and May to July 2021: rainy season; Dec. to Feb. 2022: dry season). During the survey, the birds were exposed to environmental variables such as air temperature, relative humidity, and airflow. A strong correlation was found between the ambient temperature and the mortality of the birds. The highest mortality was recorded when the ambient temperature hovered around 30°C. There was an increase in mortality rate at an indoor temperature range of 32 -34°C, while the lowest mortality was recorded at the indoor temperature of 28°C. The feed conversion ratio was low when the indoor temperatures were high. The researchers found that the first experiment was consistent with the second experiment. The study recommended good air flow and the planting of trees around broiler birds houses to enhance the thermal comfort of the birds, leading to less mortality and efficient feed conversion ratio.

Keywords: Adaptive behavior, Broiler, Feed efficiency, Heat stress, Mortality, Thermal comfort

INTRODUCTION

Poultry birds strive to be thermally comfortable inside their housing but that depends on how they interact with their immediate environment. The environmental parameters, such as air temperature, relative humidity, and air velocity and the physical parameter such as their housing come into play in determining their comfort. Thermal comfort is defined by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) as ‘that condition of the mind which expresses satisfaction with the thermal environment’ (ASHRAE 2017). For humans, it is a subjective assessment in the form of the psychological condition of the mind. In either of the two status (too hot or too cold), the individual feels thermally neutral which is an indication of the acceptability of the indoor thermal conditions. In the case of animals, this thermal neutrality or thermal comfort is difficult to assess subjectively. Humans can also be objectively assessed by allowing them to respond to questions posed to them about how they feel the impact of the environmental parameters. But assessing animals objectively is also difficult. However, the behavioural traits of birds can give insight of how they feel the impact of heat stress. For example, when poultry chicks feel hot, they often display some behavioral tendencies such as wing -raising, panting, prostrating, drinking more water, and staying in a cooler environment (if available). In the same way, people resort to behavioral adaptations, such as clothing change, posture adjustment, drinking more water, and looking for a cooler environment (when they feel hot). These adaptive behaviors help the chickens and human beings combat the effect of heat stress. Also, birds can be objectively assessed by using environmental

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variables as indicators to determine their correlation with feed efficiency and mortality.

Heat stress on poultry birds is the major complaint by poultry farmers and this impacts heavily on their thermal comfort. Heat stress caused by high ambient temperature occurs when the level of heat produced by animals surpasses their capacity to dissipate the additional heat to the surrounding environment. Indeed, heat stress was found to affect poultry production, particularly, within the tropical regions (Renaudeau *et al*. 2012; Vandana *et al.* 2020). The death rate in broiler birds, caused by excess heat inside their housing, is often substantial and this may impact the capacity to meet the food needs of the teeming population. Heat stress results in annual economic losses of $128 to $168 million in the poultry industry alone (Nwab *et al*. 2018). This situation was further compounded by the continuous increase in global temperature which has risen beyond the 1.5°C that was projected by the International Panel on Climate Change (Masson-Delmotte 2018). It has been projected that the temperatures in Africa are likely to rise faster compared to the other parts of the world (Tofu *et al.* 2022) . Hazardous climatic environments limit efficient food production in tropical and subtropical areas, and the broiler feed intake is reduced when the ambient temperature rises to a high level. A poultry house is expected to have an indoor environment that has a moderate temperature and adequate air circulation to enable the birds to suffer less from heat stress.

Heat stress in chickens occurs when the temperature experienced by the birds is higher than their core body temperature. When this occurs, the feeding appetite of the animal reduces (Elijah and Adedapo 2006), resulting in weight loss. The discomfort zone causes heat stress, and the birds spend less time feeding, moving, walking, drinking, elevating wings, and resting; thus, affecting the general performance of the birds. Furthermore, exposing broiler birds to the environmental temperature outside its thermo-neutral zone may adversely affect their immune functions. Heat stress caused by a rise in temperature might cause viruses and bacteria to grow in chickens. Heat stress results in various harmful influences on the physiological and performance traits of poultry birds (El-Khorty *et al*. 2017). Kim *et al*. (2017) further posited that heat stress causes minerals, and vitamins to be excreted from the body of broilers resulting in mineral and vitamin deficiency. Heat can be minimized by adopting simple and basic rules of designing animal facilities that consider the shape, orientation, ventilation, etc (Renandea *et al*. 2012).

Air temperature, air movement, humidity, and metabolism are factors that influence heat absorption in animals. Some research works were definite in mentioning the range of temperatures the birds are more impacted. At a temperature of 30.0°C, the appetite of the animals (livestock) is suppressed, and they can eventually reduce their feed intake by three to five percent for every added degree of temperature (Igbal 2022). Ahaotu *et al*. (2019) added that as the ambient temperature increases to 34.0°C, the mortality due to heat will be higher in broiler by 8.4%. Also, seasonal temperature variation interferes with the broiler's comfort and suppresses production efficiency, growth rate, feed conversion, and live weight gain (Okonkwo *et al*. 2019). High temperature affects the physiological functions of poultry production and chronic heat stress in broilers negatively, affects fat metabolism, and muscle growth, and reduces meat quality (Damir *et al.* 2018). Even during the transportation of the birds, high ambient temperature has been associated with higher mortality (Vecerek *et al*. 2016).

Adaptation has always been adopted by humans and animals to be comfortable. People like animals, have been adapted too, and where fuel was scarce and warmth needed, they largely controlled their comfort behaviorally – adaptively (Humphreys *et al.* 2015). The proponents of the adaptive comfort model believe that people and animals tend to adapt naturally to the changing surrounding environment. There is a linear relationship between neutral temperature (comfort temperature) and indoor temperature, on one hand, and the relationship between adaptation and indoor comfort temperature as expounded by the adaptive comfort model. Climates in each locality may influence different perceptions of thermal comfort. This may have been the reason why local birds grown in tropics and subtropics are better adapted to high temperatures, whereas new animals that have been introduced to the tropics are more likely to be affected by heat stress (King *et al.* 2006), because of differences in climate. The adaptive comfort model also recognizes that the difference between outdoor and indoor air temperature and airflow can also affect the perception of comfort (Du, Bokel *et al.* 2019). Air temperature above the core body temperature of birds can trigger heat stress which may be detrimental to the welfare and productivity of broiler chickens. When the daily temperatures reach their extremes, especially during the summer months, it becomes critical for the birds to dissipate body heat to the surrounding environment. Poultry birds do not sweat and therefore must dissipate heat in other ways to maintain their body temperature at approximately 105°F (40^{o}C). However, their body temperature is regulated mainly by the loss of heat to the surrounding environment through conduction, convection, radiation and evaporation. Birds expend energy when panting and during the process, their body heat is dissipated by the evaporative process. Panting removes heat by the evaporation of water from the moist lining of the tract. The evaporative cooling can be hindered by high humidity and low airflow. For the birds to maintain thermal neutrality, about 60% of heat is dissipated through evaporation (Daghir 2008). Also, high feed intake by the birds can cause heat gain in chickens from high metabolism. This high ambient temperature affects broiler's feed conversion ratio and mortality rate. It is against this background that the researchers assessed the thermal comfort of broiler birds in warm and humid climate.

MATERIALS AND METHODS

The experiment was conducted in a farm house located at the Faculty of Agriculture in Alex Ekwueme Federal University, Ndufu Alike, Ebonyi State, Nigeria. Nigeria is located at latitude 10^0 00'N and Longitude 8^0 00'E of Greenwich meridian. Hence, it experiences a tropical climate that is characterized by hot and wet conditions associated with the movement of the inter-tropical convergence zone both North and South of the equator. The mean monthly temperature during the hottest months is (29.0^{o}C) while the mean monthly temperature during the coldest months is (26.0^{o}C). The mean annual precipitation is between 1700-2100 mm.

The experiments have three replicates. The first experiment took place from May 2020 to July 2020 and from Dec 2020 to Feb 2021 representing the rainy season and dry season, respectively. While the second experiment took place May 2021 to July 2021 and from Dec 2021 to Feb 2022, representing the rainy season and the dry season, respectively.

The pen used for the experiment measured 15 meters wide x 40 meters long, with floor to ceiling height of approximately 2.4 meters. The floor of the poultry house was covered with cast-in-situ concrete and finished with a weak cement screed. Covering the cement screed is 0.7 cm thick wooden shaves. The front view of the poultry house is oriented towards the Southwest with approximately 90% of its surface covered with wire mesh. The rear side is oriented towards the North East (A) and is covered with block work (B). The right side is oriented in the Southeast (C), partly covered with wire mesh with shrubs planted beside it.

Data Collection and Analysis

During the fieldwork, both observational and empirical field data were collected. The observational study involved the recording of the bird's behavior and mortality while the empirical fieldwork involved measuring the environmental parameters such as the indoor air temperature, indoor globe temperature, indoor relative humidity, outdoor temperature, and indoor air velocity. For the first experiment, 4600 birds from the same parent stock were reared, while 3400 birds were used during the second experiment. Tiny tag Ultra 2, Tiny Tag Plus 2, and Kestrel were used to measure the indoor air temperature and indoor relative humidity, the outdoor temperature and airspeed, respectively. The instruments used for meas-

Table 1: Technical characteristics of the measuring instruments

Instrument and make	Measured Parameter	Range	Resolution	Accuracy
Tiny tag Ultra 2	Indoor air temperature Indoor air humidity	-25 to +85°C 0% to 100%	±0.01°C\ ±0.3%	±0.01 -
Tiny tag Plus 2	Globe temperature Outdoor temperature	- -25 to +85°C	- ±0.01°C	-
Kestrel 3000 Pocket Wind meter	Air velocity	0.30 to 40.0m/s	-	±1.66%

Table 2: Number of birds housed, density and mortality

Season	Survey period	Number of Birds	Bird's density (birds/m^2)	Mortality
Rainy	May 2020 – July 2020	4,600	8	250 (5.4%)
	May 2021 – July 2021	3,400	10	195 (5.7%)
Dry	Dec 2020 – Feb 2021	4,600	8	360 (7.8%)
	Dec 2021 – Feb 2022	3,400	10	240 (7.1 %)

uring the environmental parameters met the prescriptions of the ASHRAE standard. Data collected from the field experiments were presented in a spreadsheet and analyzed using both descriptive (mean, standard deviation, coefficient of variation) and inferential statistical techniques.

RESULTS AND DISCUSSION

Measurement of Thermal Variables

A graphical representation of operative temperature in the poultry house is shown in figure 1, while Table 3 shows the statistical summary of the measured thermal variables characterized according to minimum, maximum, mean and standard deviation values according to season, for the two periods the survey were conducted. The first survey was used for the analysis while the second survey was used to determine the validation of the first result. There was no significant difference between the air temperature and the ambient temperature. The first experiment indicates that the indoor air temperature of the broiler house ranged from 22.4°C to 35.4°C and from 22.6°C to 36.8°C during the rainy season and dry season, respectively. The mean indoor temperature during the rainy season was 28.4°C (SD=1.4), while the mean indoor temperature was 29.7°C (SD=1.9) during the dry

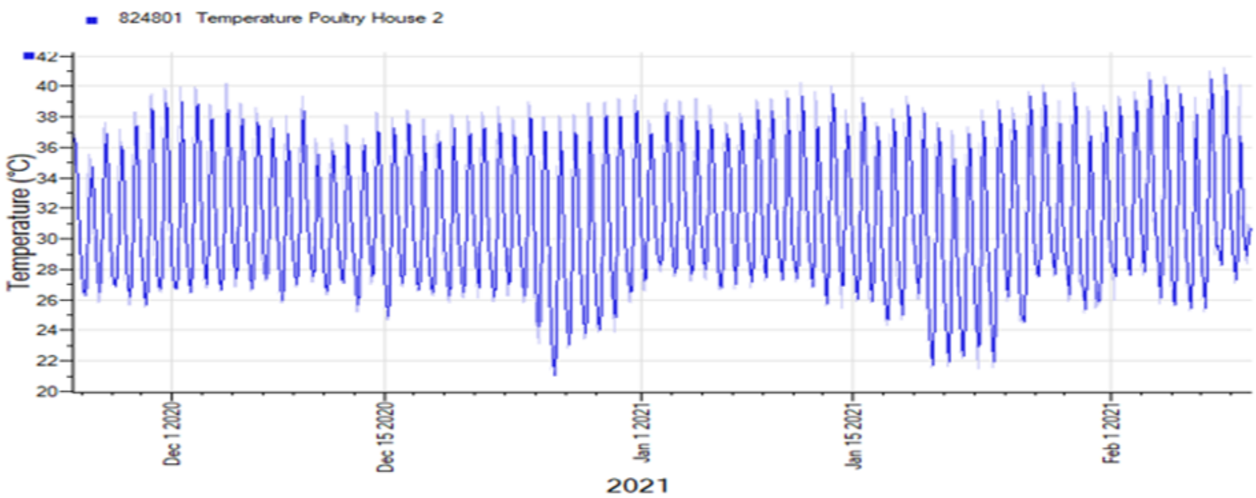

Figure 1: Temperature measurement in the poultry house

Table 3: Distribution of thermal variables

Parameter	Rainy Season		Dry Season	
	1st study	2nd study	1st study	2nd study
Air Temperature (°C)				
Mean	28.4	28.9	29.7	29.8
SD	1.4	1.3	1.9	1.7
Min	22.4	22.1	22.6	22.7
Max	35.4	36.1	36.8	36.9
Globe temperature (° C)				
Mean	28.5	28.7	29.6	29.4
Outdoor Temperature (°C)	29.6	29.3	30.6	30.7
Mean	1.6	1.6	1.4	1.4
SD	22.3	22.1	22.4	22.3
Min	37.4	37.2	37.6	37.7
Max				
Indoor RH (%)				
Mean	71.8	70.9	69.6	69.9
SD	1.6	1.5	1.5	1.6
Min	23.6	23.7	23.8	23.4
Max	94.2	94.3	92.4	92.8
Air velocity (m/s)				
Mean	0.28	0.30	0.19	0.22
SD	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-

1st experiment: May 2020 – July 2020 and Dec 2020 – Feb 2021
2nd experiment: May 2021 – July 2021 and Dec 2021 – Feb 2022

season. The result shows that the mean indoor temperature during the dry season was significantly higher than the mean indoor temperature during the rainy season (by 1.3°C). This implies that the birds were exposed to warmer temperatures during the dry season compared to the rainy season. The result of the coefficient of variation indicates that there was higher variability in indoor ambient temperature during the dry season (5.5%) compared to the variability during the rainy season. Furthermore, the outdoor temperature ranged from 22.3-37.4°C during the rainy season, while during the dry season the range was from 22.4-37.6°C. The outdoor temperature had mean values of 29.6°C and 30.6°C during the rainy season and dry season, respectively. The implication is that the indoors of the broiler house were cooler than the outdoor in both seasons the surveys were carried out.

Seasonal Comparison of Indoor Temperature and Outdoor Temperature

The result of the Paired sampled test between the indoor air temperature and the outdoor temperature produced correlations of 0.79 and 0.88 in the rainy season and dry season, respectively with both statistically significant at 0.01 ($p<0.05$). The result suggests that an increase in outdoor temperature in both seasons resulted in a corresponding increase in indoor temperature. However, the indoor temperature correlated higher with the outdoor temperature during the dry season compared to the rainy season. This can also be explained by the fact that the mean indoor temperature experienced during the dry season (29.7°C) is very close to the mean outdoor temperature recorded during the same season (30.6°C). A comparison of the relationship between the indoor temperature and the outdoor temperature between the two seasons shows that during the rainy season, 64% of the variation in indoor air temperature could be explained in terms of the outdoor temperature while during the dry season 81% of the variation in indoor air temperature could be explained in terms of the outdoor temperature. Furthermore, the lower air velocity recorded during the dry season (0.19 m/s) compared to that recorded during the rainy season (0.28 m/s) may not have helped in flushing out the pockets of heat that accumulated inside the poultry house, hence the recorded high indoor temperature during the dry season. This implies that at high indoor temperature the broilers experience discomfort and stress which results to weight loss and reduces efficiency of production. This finding agrees with (Mishra *et al*. 2013; Zhai *et al*. 2017; Boerstra *et al*. 2015), that high airflow enhances indoor comfort by reducing air temperature.

Further breakdown of the variability of indoor temperature according to time of day shows that the indoor ambient temperature was higher than the outdoor temperature in the morning hours as shown in Figures 2 and 3. The reverse is the case in the afternoon hours where the outdoor temperatures were higher.

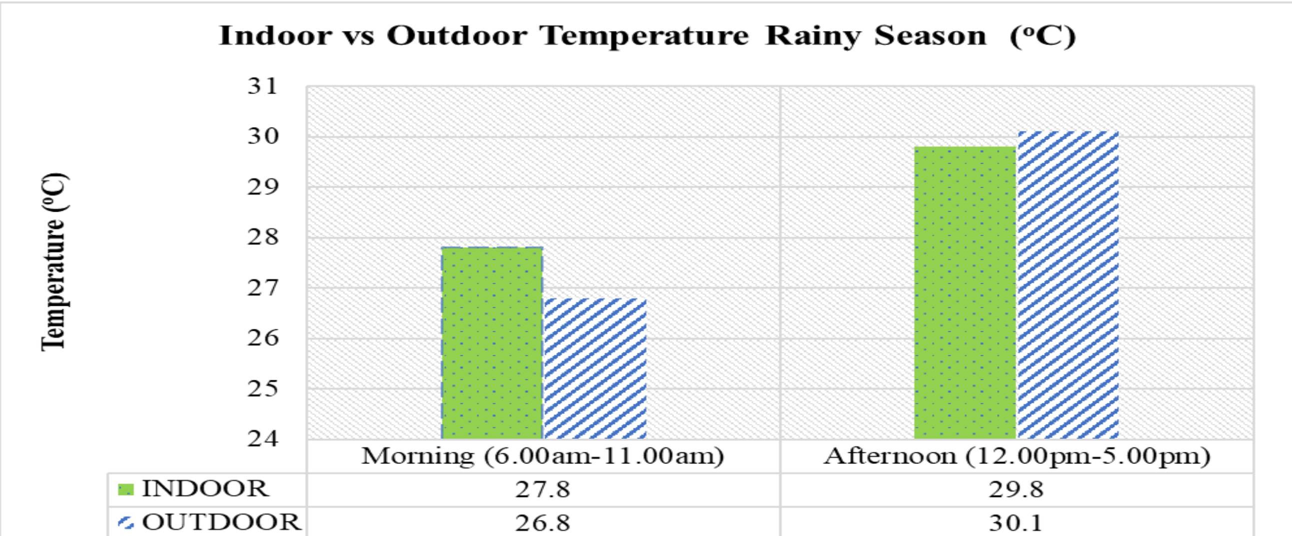

Figure 2: Comparison of indoor temperature and outdoor temperature (Rainy Season)

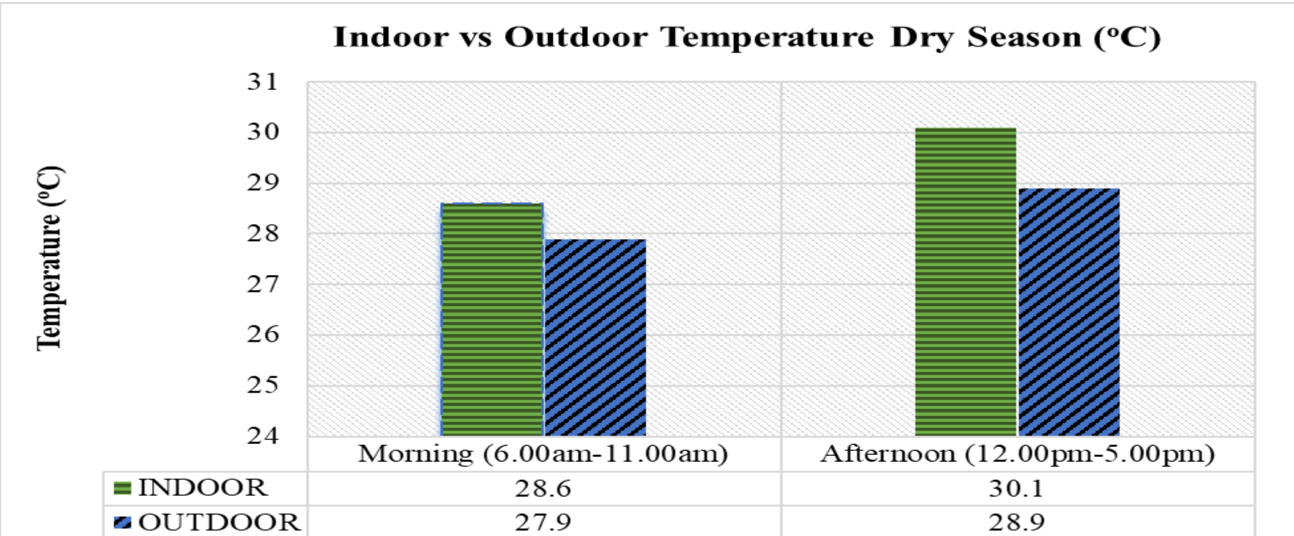

Figure 3: Comparison of indoor temperature and outdoor temperature (Dry Season)

Relating the Broiler's Performance to Indoor Ambient Temperature

Result of the field work, presented in Table 4, shows that the broiler birds generally had higher feed efficiency during the rainy season compared to the dry season. Furthermore, the mean feed efficiency was higher during the rainy season compared to the dry season. One may infer that the generally higher indoor ambient temperature recorded during the dry season had an influence on the low food intake of the birds during the dry season. Birds are known to eat less when under heat stress caused by high temperature or cold stress caused by low temperature. At high temperatures, the birds burn off energy through panting to stay cool. In this case, the feed efficiency deteriorates resulting in weight loss. The findings agree with (Sanou *et al.* 2022; Abiola *et al.* 2020: Renaudean *et al*. 2012) that high ambient temperature has a negative effect on the performance of the broiler birds. In colder conditions, more energy is used to maintain body heat and so less feed would be converted into flesh. In both cases, none of the two scenarios promote feed efficiency in broiler birds' production. Furthermore, as shown in Table 4, irrespective of the season the food efficiency of the birds was on the increase as the birds got older. This implies that older broiler birds use more quantities of feed to maintain their body weight. At 7th week, a ratio of 1:92 was recorded, showing a high feed efficiency. As the broiler bird eats 1kg feed, 0.92 fresh was added. From the result, the average feed efficiency recorded was high in the raining season. This might be due to better airflow during the season.

Regression Analysis on Effect of Temperature on Mortality

Figure 4 shows the regression analysis of the bird's mortality (dependent variable) upon the mean indoor operative temperature (independent variable). It was observed that at a temperature range of 32.0 — 34.0^{o}C, there were sharp rises in mortality of the birds in both seasons. However, the rise was more during the dry season. A further check on the figures indicates that irrespective of the season, lower mortality was recorded at the mean indoor temperature of about 28.0^{o}C. This mean indoor temperature (28.0^{o}C) is close to the mean indoor temperatures of 28.9^{o}C and 29.7^{o}C for the rainy season and dry season, respectively (Table 3). Human beings are known to adapt (find comfortable) at the temperature they experience more, and this finding may be extended to poultry birds. Also observed is the higher mortality during the rainy season compared to the dry season at the same mean indoor temperature (26^{o}C). At this mean temperature the birds were exposed to cold weather during the rainy season.

Adaptive Actions

The birds were generally observed to be panting fast with their beak open when the indoor temperature was high. At high temperature there was also rapid up-and-down movement of their throat, and their feathers were raised. These were signs of their attempts to adapt to high indoor temperature, and these adaptive behaviors prevailing more during the dry season. The birds were also observed to move closer to the North-West side of the building when the indoor temperature was rising. The outdoor of the North-West side of the poultry house has some vegetation which helped to reduce the impact of ambient temperature on that side of the poultry house. Higher frequency of water drinking was observed in the afternoon hours when the indoor temperature was at its peak.

Validation Test of the 1st and the 2nd Experiment

The results of the correlation analysis of the environmental variables of the first and the second experiment were 0.98, 0.85 and 0.94

Table 4: Feed Efficiency Ratio at different stages of broiler production

Week	1st	2nd	3rd	4th	5th	6th	7th	8th	Flock Average
Rainy Season	1.80	1.85	1.85	1.85	1.92	1.88	1.92	1.91	1.90
Dry Season	1.86	1.87	1.86	1.85	1.88	1.80	1.86	1.80	1.80

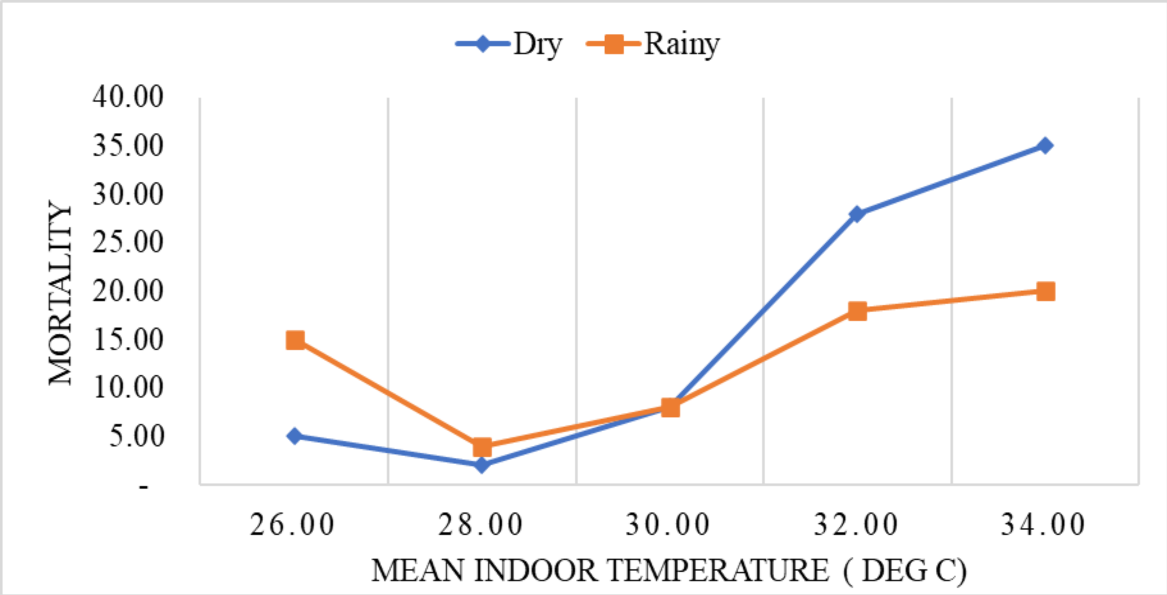

Figure 4: Linear regression analysis of mortality upon mean indoor operative temperature

for the air temperature, outdoor temperature, and relative humidity, respectively ($p<0.05$). Furthermore, there were no significant difference in mean values of indoor air temperature between the two experiments in rainy season and dry season. These results suggest that the birds used in both experiments were exposed to similar environmental variables.

The difference in food efficiency between the first and the second experiment in both seasons were insignificant. In rainy season, the difference was 0.02 while in dry season the difference was 0.01. There was consistency in the feed efficiency ratio where in both experiments there was an indication that the rainy season reported higher feed efficiency compared to the dry season.

Though unequal number of birds were reared in the first and second experiment, however the number of deaths recorded were proportionate to the number reared. Thus, while 4600 birds were reared during the first experiment, rainy season recorded 259 mortality, representing 5.4% mortality, during the same season of the second experiment 3400 broiler birds were reared with 195 mortality, representing 5.7% mortality. A similar result was obtained during the dry season survey, where 4,600 broiler birds were reared during the first survey with 360 mortalities representing 7.8% mortality, while in the same season in second survey 3,400 broiler birds were reared with 240 mortality representing 7.1% mortality. Thus, the result of the second experiment is a true reflection of the result of the first experiment.

Table 5: Mean values of environmental variables, mortality and Feed efficiency of Exp 1 and Exp 2

Survey time	Season	Air temp (°C)	Outdoor temp (°C)	Humidity (%)	Air Velocity (m/s)	% Mortality	Survey period (Week)	Feed conversion efficiency average
1st Exp	Rainy	28.4	29.6	71.8	0.28	5.4	8	1.90
2nd Exp	Rainy	28.9	29.3	70.9	0.30	5.7	8	1.92
1st Exp	Dry	29.7	29.7	69.6	0.19	7.8	8	1.80
2nd Exp	Dry	29.8	29.8	69.9	0.22	7.1	8	1.79

Table 6: Correlation of variables between Exp 1 and Exp 2

Season	Air temp	Outdoor temp	Humidity	Mortality	Feed conversion efficiency average
Rainy	98.2	93.6	89.5	98.4	90.4
Dry	91.4	98.5	91.0	93.2	89.5

CONCLUSIONS

This study examined the thermal conditions of birds in a poultry house located in the warm and humid climate in view of the global climate change which possess serious threat to poultry production. The following are concluded from the study.

1) The effect of climate change caused the overheated indoor spaces of surveyed poultry house.

2) Heat stress contributes significantly to high mortality in the surveyed poultry house

3) Heat stress impacted on the feed conversion efficiency of the poultry birds

4) A properly designed poultry house can help to minimize the rising indoor temperature

5)The study found a significant increase in indoor temperature as the outdoor temperature increased (correlation of 0.78 and 0.88 for rainy and dry season respectively). The study recommends that the planting of more trees around the poultry house should help to reduce the influence of the outdoor temperature on the indoor temperature.

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