Comparative Cooling Efficiency of Brick Walls for Poultry House in Hot Climatic Conditions

O. M. Idowu, K.P. Daniel and U. Abdullahi

Department of Architecture, Department of Industrial Design, Department of Building, Modibbo Adama University of Technology (MAUTECH), Yola, Nigeria

The attainment of thermo-neutral condition in a poultry house is determined, to some extent, by the choice of wall materials. The extent to which bricks produce desired cooling in relation to other materials as walls for poultry houses is uncertain. This study was aimed at determining the relative cooling efficiency of brick walls over sand-crete block walls on one hand, and a combination of thatch insulation and iron-roofing sheets on the other. The quasi-experimental research design employed thermo-anemometer to determine temperatures inside five poultry houses: three made up of brick-walls; one of sand-crete block-walls; and one of insulated iron roofing sheet-walls. Analysis of variance (ANOVA) was employed to establish any significant difference in temperature in the houses (at 0.05 level of significance). The result showed that brick walls have higher cooling efficiency than the other materials, but not at a significant level. Also, thermo-neutral condition was not attained in any of the five poultry houses. It was recommended that architectural strategies that may further reduce temperature to thermo-neutral condition in poultry houses be investigated.

Keywords: Cooling efficiency; bricks; sand-crete blocks; insulated iron sheets; poultry house; hot climate; thermo-neutral condition

INTRODUCTION

The climate in poultry houses influences the wellbeing and health of the birds. Poultry houses are, hence, expected to create thermal environment within comfort zone to engender minimum stress, and optimum health and production performance of the enclosed birds. The comfort zone of birds is the range of temperature in which the birds are able to keep their body temperature constant with minimum effort (PoultryHub, 2018). Hy-Line (2016) specifies heat stress index (HSI) less than 70 as the comfort zone of birds; the index being expressed mathematically as:

\[ \text{HSI} = (0.6 \times \text{Dry bulb temperature}) + (0.4 \times \text{Wet bulb temperature}) \]

The thermo-neutral zone is the temperature range in which the birds are not using any energy to lose or gain heat (Czarik and Fairchild, 2008). This temperature zone depends on feeding level, housing conditions, age, body weight, health condition, and type of the birds. According to Czarik and Fairchild (2008) and Hy-Line (2016), the thermo-neutral zone of adult chicken is generally between 18 and 27°C at decreasing relative humidity from 100 to 15%. Within this temperature range, sensible heat loss is adequate to maintain the bird’s normal body temperature (PoultryHub, 2018). Beyond the range, heat condition may slide progressively from the alert zone (HSI, 70-75; 28°C - 32°C), the danger zone (HSI, 76-81; 34- 38°C), to the emergency zone (HSI >81; above 38°C) (Hy-Line, 2016).

*Corresponding author: O. M. Idowu, Department of Architecture, Modibbo Adama University of Technology (MAUTECH), Yola, Nigeria. E-mail: idowumosegun@gmail.com; Tel +2348061510635.
Birds generally have higher body temperature than mammals and are indeed the hottest animals because the basal rates of metabolism are higher and the conductance is lower in birds than in mammals of the same weight (McNab, 1970). The body temperature of adult birds ranges between 41°C and 42.2°C; increase of temperature to above 45°C may cause birds to enter into a state of hyperthermia or to actively dissipate heat from the body by increasing evaporative cooling, through panting and gular fluttering (Nilsson Molokwu and Olsson, 2016).

The hot dry climate is characterized by air temperature and relative humidity beyond desirable comfort zone for birds. In poultry houses or scoops, often constructed with sandcrete blocks and iron roofing sheet in this region, temperatures have been reported to rise above thermo-neutral zones for birds (Idowu, 2010). To avert this situation, poultry houses should be designed for passive cooling to thermo-neutral levels (Crown, 2005). Odim, Okonkwo and Idowu (2012) and Hy-Line (2016) revealed that this can be achieved by design strategies aimed at solar protection, heat dissipation and heat modulation. Appropriate building orientation, application of shading devices and vegetative covering around buildings to minimize heat radiation are some of the common solar protection strategies (Odim et al, 2012). Where solar protection is insufficient or ineffective, heat dissipation and modulation should be stepped up to enhance passive cooling. Heat dissipation strategies include natural ventilation and evaporative cooling, while heat modulation aimed at elongating heat conduction time (time-lag) across barriers deploys thermal mass and insulated fabrics (Odim et al, 2012; University of Minnesota (UMN), (2015). Passive cooling by heat modulation could be an effective strategy in climates characterized by wide diurnal temperature range, as obtained in Yola, the study area where range as high as 20°C has been reported (Idowu, 2012).

Experts have also recommended some expedient heat stress reduction measures, in order to avoid poultry climatic conditions aggravating beyond the comfort zone. These measures include raising ventilation in closed houses and employing evaporative cooling based on relative humidity (Hy-Line, 2016). The University of Minnesota (UMN), (2015) posits that poultry houses or scoop must provide protection from inclement weather, and keep heat stress index within comfort zone by insulation and adequate ventilation. Wind speeds ranging from 0.7m/s (for low stocking density) to 3.0m/s (for high stocking density) is required and recommended around birds (Crown, 2005). In a similar vein, Poultry Hub (2018) indicates that air velocities higher than 0.2m/s will have a positive effect and help to cool the animals, when poultry indoor temperatures are higher than 30°C. Adequate ventilation can be achieved by providing window areas at 10 per cent of poultry house floor area, and open roof ridge depending on climate (Counting My chickens, 2015; Hy-Line, 2016).

**Thermal properties of brick and other wall materials**

Brick is described as a small block of burnt clay of such size that can be conveniently held in one hand and is slightly longer than twice its width. It is usually of 215mm long, 102.5mm wide and 65mm high (Barry, 1980). Brick is believed to possess heat modulation values, and of thermal cooling advantage over the conventional building materials like sand-crete blocks and iron roofing sheets. Barry (1980) indicated that brick wall is a moderately good insulator against heat transference. Double skin cavity brick walls are known to be of better insulation value, which increases with overall thickness of the wall (Fisher, 1979). Although, mud brick is not considered to be a very good thermal insulator since it possesses a high unit-mass and very low porosity, its high thermal capacity is conducive to storing the absorbed heat for a longer period of time and releasing it back into the surrounding space more slowly than the other materials in common use in Nigeria (Elias-Ozkan Summers, Summers and Yannas, 2006).

In Nigeria and other third world countries, majority of the houses in rural areas are built with laterite, a type of soil with high clay content. According to Ganiyu (2012), clay walls have excellent thermal mass property, and play an important role in stabilizing temperature by delaying the passage of external heat through the walls, thereby keeping the internal temperature of the building cooler over a long period. To corroborate this claim, Hamman (2012) also reported higher thermal comfort levels of occupants in lecture theatres of brick wall compared to those of sand-crete block wall. Brick as a ceramic product has also been reported to exhibit high water resistance and chemical stability qualities (Ibrahim, 2005). Clay, the raw material for brick production, is abundant and can be fired manually with available bio-fuel in the study area. Its use in building walls is therefore economical, environment friendly, and resource-sustainable.

Another material often used for walls of back-yard poultry houses is corrugated iron roofing sheets, especially those dismounted from leaking or old roofs. Iron roofing sheets have high thermal conductivity (and low thermal resistance) which make them not suitable as wall materials for passive cooling without insulation. When employed as wall or roof material, it is necessary to incorporate a layer of some insulating materials with iron sheets (Barry, 1980; Owen, 1985). The University of Kentucky (UKY), (2014) cited natural plant materials as among those that can be employed for insulation, and these include cellulose insulation, cork, hemp, cotton and straw (UKY, 2014). The high thermal insulation property of straw bale, which is locally available, has also been cited by Elias-Ozkan et al (2006).
The reported studies on thermal properties of brick in the study area are largely qualitative, based only on human user perception. Quantitative studies on thermal performance of brick in poultry houses or any animal-farm building have not been reported in the study area. It is expected that this study will provide quantitative data on the cooling efficiency of brick, and possibly promote its use in poultry houses, rather than the other popular materials in the study area.

The Study Area

Yola is located on the north eastern part of Nigeria between latitude 7° and 11° North of the equator, and longitude 11° and 14° of the Greenwich meridian. Based on analysis of climatic data of temperature, rainfall and relative humidity, Yola has been classified, as espoused in Idowu (2012), as a hot-dry zone. It is characterized by mean daily maximum dry bulb temperature during the dry season not less than 35°C, daily diurnal temperature ranges up to 20°C, relative humidity not exceeding 40%, and the mean yearly rainfall below 1000mm. The dry season lasts about five months from November to March when there is usually no rain, with maximum temperature up to 45°C, and relative humidity as low as 15%. Wind speeds during this period range from 0.16 to 1.36m/s (Idowu, 2012; Abdurrahman, 2015). Incidence of temperature rise beyond the thermo-neutral zone of birds, resulting in heat stress and high mortality rate have been reported in poultry houses in hot dry climate of the study area (Idowu, 2010).

MATERIALS AND METHODS

Clay from River Benue shore below the Jimeta bridge was molded, dried and manually fired on site by two artisans producing over 2000 bricks, each of 110mm thickness. Other materials procured for the construction of the poultry sheds include the following: Sand-crete blocks, trips of sand, bags of cement, water, bundles of corrugated iron roofing sheets, sheets of locally woven thatch, pieces of hardwood, and other carpentry wares. Six units of Hot-wire thermo-anemometer were also procured for observing wind speeds and temperature.

Design and construction of the sheds

The procured materials were deployed to erect five sheds at the selected site behind the University’s old administrative buildings (figure 1). The site was considered to be of fairly flat terrain with minimal obstruction to wind flow. The sheds were spaced over 10m apart and arranged to take advantage of prevailing wind with minimal incidence of solar heat radiation. The buildings/sheds’ fenestrations are manipulated to study their effects on ventilation and temperature within five poultry sheds, each of which has floor area 2.4m x 3.6m considered adequate for 150 birds. The sheds were constructed as follows (Table 1):

**Shed 1**: Had fenestrated wall of bricks; un-fenestrated roof and un-insulated iron roofing sheets (see plate 1); **Shed 2**: Had fenestrated wall of bricks; fenestrated roof of corrugated iron insulated with double layers of woven thatch (plate 2); **Shed 3**: With fenestrated wall with bricks; unfenestrated roof of corrugated iron insulated with double layers of woven thatch (plate 3); **Shed 4**: Made of fenestrated sand-crete block wall; un-fenestrated roof and un-insulated iron roofing sheets (plate 4) and **Shed 5**: Composed of fenestrated wall and roof of corrugated iron insulated with double layers of woven thatch (as in plate 5).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Shed 1</th>
<th>Shed 2</th>
<th>Shed 3</th>
<th>Shed 4</th>
<th>Shed 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Area</td>
<td>8.64m²</td>
<td>8.64m²</td>
<td>8.64m²</td>
<td>8.64m²</td>
<td>8.64m²</td>
</tr>
<tr>
<td>Wall Material</td>
<td>Bricks</td>
<td>Bricks</td>
<td>Bricks</td>
<td>Sandcrete</td>
<td>Ins/Iron</td>
</tr>
<tr>
<td>Wall Fenestration</td>
<td>1.62 m²</td>
<td>1.62 m²</td>
<td>1.62 m²</td>
<td>1.62 m²</td>
<td>1.62 m²</td>
</tr>
<tr>
<td>Roof Material</td>
<td>Iron</td>
<td>Ins/Iron</td>
<td>Ins/Iron</td>
<td>Iron</td>
<td>Ins/Iron</td>
</tr>
<tr>
<td>Roof Fenestration</td>
<td>None</td>
<td>0.36m²</td>
<td>None</td>
<td>None</td>
<td>0.36m²</td>
</tr>
</tbody>
</table>

Data collection

The designed and constructed sheds were subjected (exposed to external) climatic conditions, and the wind speeds and temperatures were observed within and outside the five sheds.

Deploying six units of the hot-wire- thermo-anemometer, five rounds of wind speeds and temperatures were observed and recorded in and outside each of the sheds in the afternoon hours (between 2.30 and 3.30pm) at five minutes intervals. Each round of observation was made for 30 readings of equipment at five seconds intervals. The observation process was repeated daily for 16 days starting from 5th and ending on 26th of April 2013 when heat was expected to peak ... observation of wind speeds and temperatures within and outside the five sheds.
Figure 1: Sketches of study objects: (a) Site plan; (b) Typical shed floor plan; (c) Typical closed- and opened-roof shed sections.
Plate 1: Side views of Shed 1

Plate 2: Side views of Shed 2

Plate 3: Side views of Shed 3

Plate 4: Side views of Shed 4

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RESULTS

The design variables of the sheds under study are indicated in Table 1, while Table 2 shows the summary of observed daily mean temperatures in the afternoon in and outside the sheds for the 16 days of observations. The corresponding summary of daily mean wind speeds within the same observation period is indicated in Table 3. Summaries of the Analysis of Variance (ANOVA) of these means (of temperature and wind speeds) are shown in Table 3.
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Table 4: Analysis of Variance Summary of Mean Temperature

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Sum of squares</th>
<th>d.f.</th>
<th>Mean square</th>
<th>F_cal</th>
<th>Sig.</th>
<th>F_crit</th>
<th>Remark: Difference in mean</th>
</tr>
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<tbody>
<tr>
<td>Between groups</td>
<td>1.149</td>
<td>4</td>
<td>0.287</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>206.377</td>
<td>75</td>
<td>2.752</td>
<td>0.104</td>
<td>0.981</td>
<td>2.45</td>
<td>Not significant</td>
</tr>
<tr>
<td>Total</td>
<td>207.526</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ analysis (2015)

Table 5: Analysis of Variance Summary of Mean Wind Speed

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Sum of squares</th>
<th>d.f.</th>
<th>Mean square</th>
<th>F_cal</th>
<th>Sig.</th>
<th>F_crit</th>
<th>Remark: Difference in mean</th>
</tr>
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<tbody>
<tr>
<td>Between groups</td>
<td>0.017</td>
<td>4</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>0.836</td>
<td>75</td>
<td>0.011</td>
<td>0.378</td>
<td>0.824</td>
<td>2.45</td>
<td>Not significant</td>
</tr>
<tr>
<td>Total</td>
<td>0.853</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ analysis (2015)

Figure 2: Study sheds daily indoor mean temperature

Tables 4 and 5 respectively. Figure 2 is a graphical presentation of the variation of daily indoor mean temperature in the sheds.

Sheds 2 and 5 have roof fenestration area of 0.36m² each, while sheds 1, 3 and 4 are without any roof opening. Outside the sheds, daily mean temperature ranged from 36.74 °C to 51.00 °C, while the grand mean temperature for the period of study was 44.00 °C (with standard deviation, SD of 4.27). Daily mean temperatures in the sheds ranged from a minimum value of 34.60 °C to a maximum of 41.30 °C, both obtained in shed 5. Grand mean temperature in the sheds in the 16 days ranged from 38.75 °C (with SD of 1.56) in shed 3 to 39.09 °C (SD of 1.79) in shed 5. The lowest daily mean indoor temperature was recorded five times (days) in shed 3, four times in shed 4, three times in shed 5 and twice each in sheds 2 and 4. Daily outdoor mean temperatures above 45°C were recorded six times, when the maximum cooling of 10.06°C was observed in shed 3, followed by cooling of 9.96°C and 9.4°C observed in sheds 1 and 3 respectively. A maximum mean temperature reduction (cooling) between outside and shed interiors of 5.25 °C was obtained also from shed 3 (Table 2). The lowest daily indoor mean temperatures are mostly found in shed 3, and the highest in shed 5, as revealed in Figure 2. The difference in cooling in the sheds is not significant as shown in the ANOVA summary (Table 4): the calculated value of f-ratio being lower than the critical (tabulated) value.

External daily mean wind speeds (Table 3) ranged from 0.24m/s to 1.32m/s, with the grand mean wind speed in the observation period of 0.50m/s (SD of 0.28). Within the sheds, daily mean wind speeds ranged from 0.09m/s to 0.65m/s while the grand mean wind speeds varied from 0.21m/s (SD of 0.08) to 0.25m/s (SD of 0.12).

DISCUSSION

The different mean temperatures obtained in the sheds may be indicative of the difference in either the thermal properties of the fabrics of walls and roofs or the fenestration (openings) of the sheds, since they have same size and orientation. A paired comparison of sheds with similar fenestration may indicate the thermal effect of the different fabrics. Shed 5 (made of insulated iron sheets) with indoor grand mean temperature of 39.09 °C has similar fenestration with shed 2 (of brick wall and insulated iron roof) with indoor grand mean temperature of 38.96 °C. In the same vein, shed 4 (with 150mm sandcrete block wall) and shed 1 (with 110mm brick wall) have similar fenestration but produced different indoor mean temperatures of 38.84 °C and 38.83 °C respectively. Both paired comparisons suggest that the brick has higher cooling capacity than iron sheet and sandcrete block. In addition, it is instructive to note that sheds 1 and 3 produced the two highest occurrences of lowest daily indoor mean temperature, Sheds 1 and 3 also recorded three out of the six of these occurrences of lowest daily indoor mean temperatures when the outdoor mean temperatures were above 45°C, and the three highest cooling occurrences (10.06°C and 9.4°C in shed 3; 9.96°C in shed 1). Not only do the data suggest that the cooling efficiency of the bricks is higher than those of the insulated iron and sandcrete blocks, they also seem to reveal higher efficiency of the bricks at critically high outdoor temperatures. Shed 3 which appears more efficient in cooling than sheds 1 and 2, has an insulated roof only distinguishing it from shed 1, and a closed roof only
distinguishing it from shed 2. This suggests that thatch insulated roof enhances passive cooling, but roof opening during the day negates passive cooling in this case. However, the difference in cooling efficiency of the materials is apparently weak, since it is not significant, according to the statistics.

The apparently weak difference may be attributed to the smaller brick thickness (110mm thick bricks as against 150mm sand-crete block), and the use of sand-crete mortar in the walls. Bricks of the same thickness as (150mm) sand-crete blocks is of higher thermal storage capacity (thermal mass), and expected to have higher time-lag or heat modulation effect as posited in Fisher (1979). The presence of sand-crete mortar in brick wall has also apparently contaminated the purity of the brick wall, and this might have also reduced the thermal storage capacity of the walls in question.

By and large, the cooling advantage of bricks over the other wall materials has been reinforced, albeit weakly in this study. It has reinforced the findings from earlier studies by Elias-Ozkan et al (2006), Haman (2012) and Ganiyu (2012). It is not clear if the maximum mean wind speed of 0.25m/s, when matched with the corresponding mean temperature of 38.83°C (in shed 1) would produce desired thermo-neutral conditions as espoused in Crown (2005). Even though the mean temperature is lower than 40°C, the mean wind speed is lower than 0.7m/s suggested in Crown (op cit). It is obvious that the daily indoor mean temperature ranging from 34.60°C to 41.30°C is higher than 27°C, the upper limit of the thermoneutral zone for adult birds, cited in Czarik and Fairchild (2008) and Hy-Line (2016). The temperature has reached the emergency zone, and urgent and drastic cooling strategies and actions would be required to avert deterioration in health and productivity, or even death of birds.

CONCLUSION

The main objective of the study was to ascertain whether or not poultry houses constructed with brick walls were more efficient for passive cooling in hot climatic conditions than those constructed with sand-crete block or insulated iron roofing sheet walls. Five sheds of the same size but different composition of the materials and other architectural features were constructed, and air temperatures in and around them were observed during hot climatic conditions in the study area. Ambient temperatures were found to be above the thermoneutral zone of adult birds in all the poultry houses (sheds) under study. Even though not at any significant level, brick was found to have cooling capacity higher than the other materials of the studied sheds. It was also found that thatch insulated, but closed roof enhanced day time passive cooling in the brick sheds under study. Use of brick for walls and thatch insulated roofs are therefore recommended for backyard poultry house constructions in the study area. Further studies and deployment of more passive cooling strategies for attainment of thermoneutral conditions in poultry houses in the study area are also recommended. Such strategies may include use of double- brick walls as thermal mass, indoor evaporative cooling devices and solar protection with plants around the poultry houses.

REFERENCES


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