Asian Journal of Advances in Agricultural Research

11(3): 1-16, 2019; Article no.AJAAR.52344
ISSN: 2456-8864

Design and Construction of Thermal Control Solar Heated Poultry House

T. O. Tehinse[1*], F. R. Falayi[1] and T. O. Aduewa[1]

[1]Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author TOT designed the study, supervised the research wrote the first draft of the manuscript, carried out the experiment and provided the result. Author FRF proofread the manuscript, managed the literature searches and edited all work. Author TOA performed the statistical analysis, wrote the protocol, worked on the design calculation and managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2019/v11i330054
Editor(s):
(1) Professor, Oguz Dolgun, Department of Plant and Animal Production, Head of Department, Sultanhisar Vocational College, Adnan Menderes University, Aydın, Turkey.
Reviewers:
(1) O. O. Egbewande, Ibrahim Badamasi Babangida University, Nigeria.
(2) Subrata Kumar Mandal, CSIR-Central Mechanical Engineering Research Institute, India.
Complete Peer review History: https://sdiarticle4.com/review-history/52344

Original Research Article

Received 26 August 2019
Accepted 05 November 2019
Published 11 November 2019

ABSTRACT

Introduction: Chickens in extensive and semi-intensive poultry production systems account for more than 75% of all poultry in the Southern Nigeria.
Aims: To design, construct and test a thermal control solar heated poultry house.
Methodology: Thermally controlled solar heated poultry house was designed and constructed in the Department of Agricultural and Environmental Engineering Research Farm, Federal University of Technology, Akure, Nigeria. The poultry house consists of seven sections/rooms of which five rooms were regulated into five different temperature levels while one of the last two serve as control experiment section and the other serve as the observation section. The poultry house was tested and evaluated using developed and calibrated data logger to determine the environmental condition in the thermally controlled animal house with respect to the ambient conditions. The results obtained from the pre-stock test were analyzed graphically using Microsoft excel software version 2016
Results: The dry bulb temperature in the poultry house is 28.91±0.02ºC, 31.75±0.14ºC, 34.93 ±0.06ºC, 37.92±0.07ºC, 40.95±0.06ºC and 26.47±1.72ºC for sections with preconditioned temperature of 29ºC, 32ºC, 35ºC, 38ºC 41ºC and control respectively, dry bulb temperature in the

*Corresponding author: Email: tehinse2@gmail.com;

poultry house is 20.39±0.32ºC, 21.64±0.1ºC, 19.13±0.2ºC, 17.57±0.27ºC, 16.26±0.27ºC and 24.77 ±0.1ºC for sections with preconditioned temperature of 29ºC, 32ºC, 35ºC, 38ºC 41ºC and control respectively, the relative humidity in the poultry house is 44.69±2.37%, 41.9±1.21%, 38.43±0.38%, 33.8.

Conclusion: There was little or no temperature stability in the non-thermally controlled section of the poultry house, the temperature of the thermally controlled section of the poultry house was found in a close range with low deviation from the preset temperature in the sections.

Keywords: Poultry; house; broiler; temperature; sensor; solar panel; humidity.

1. INTRODUCTION

Chickens in extensive and semi-intensive poultry production systems account for more than 75% of all poultry in the Southern Nigeria. Owned by smallholders in rural areas, these birds provide food security and family income and play an important role in socio-cultural events. Chickens are raised all around the world under widely varying circumstances with same generally objective which is to maximum production for minimum costs and risks. Energy is one of the most important material bases for the economic growth and social development of a country or region. Scientific forecasts and analysis of energy consumption will be of great importance for the planning of energy strategies and policies [1]. Energy analysis allows the energy cost of existing process operations to be compared with that of new or modified production lines [2]. Efficient use of energy in agriculture will minimize environmental problems and prevent destruction of natural resources [3]. The enhancement of energy efficiency not only helps in improving competitiveness through cost reduction but also results in minimized greenhouse gas emissions [4].

Designing environmental control systems for agriculture requires understanding of the complex interactions between the biological systems within the space and the environment provided by that system. Environmental temperature and humidity are important variables in the design specification of livestock buildings, because of their role in thermo-regulation and hence productivity [5]. According to Lucas and Marcos [6], much information has been published on the effects of heat stress on productivity and immune response in poultry with respect to housing system. However, our knowledge of basic mechanisms associated with the reported effects, as well as related to poultry behavior and welfare under heat stress conditions is in fact scarce. Environmental stressors, such as heat stress, are particularly detrimental to animal agriculture [7,8,9].

Heat stress results in estimated total annual economic loss to the U.S. livestock production industry of $ 1.69 to $ 2.36 billion; from this total, $ 128 to $ 165 million occurs in the poultry industry [10]. Sohail et al. [11] established that broilers subjected to chronic heat stress had significantly reduced feed intake (−16.4%), lower body weight (−32.6%), and higher feed conversion ratio (+25.6%) at 42 days of age. Many additional studies have shown impaired growth performance in broilers subjected to heat stress [12,13,14,15,16]. In poultry housing, environment may affect the performance of birds as well as its well-being. Interestingly, during the summer season in Nigeria, environmental temperatures are often between 36-40ºC, which is not constant during the time. The variation in environmental factors during wet and dry season results in challenges in the health of the poultry if not well monitored. Researchers like [17,18] and [19] established that resistance can be developed, to certain extent against cold conditions by exposing the chickens to low environmental temperatures for a short time (3 h) during the early period of life.

With these facts and findings, it is important to design poultry housing with the ability to control the thermal condition in order to evaluate the effect of varying temperature and humidity level and its effect on bird's stress index. The aim of the research work is to design and construct a thermal control solar heated poultry house.

2. MATERIALS AND METHODS

2.1 Design Background

The design of poultry facilities combined with appropriate poultry housing and management are essential contributors to bird's well-being, the quality of poultry research and production, teaching or testing programs involving birds, and the health and safety of personnel. Any controlled animal housing must provide environments, housing, and management that are well suited for the species or strains of animals maintained and consider their physical, physiologic, and behavioral needs, allowing them to grow, mature, and reproduce normally while providing for their health and well-being.

An animal's environment is the totality of all external conditions that affects it [20]. Thermal environment describes the effects of air temperature, moisture, air velocity and solar radiation on the regulation and balance of animal heat, and their influence on production, growth, feed conversion and health [20]. Livestock and poultry are homoeothermic, which means they maintain a relatively constant body temperature during environmental temperature changes. Internal body temperature is controlled by a dynamic equilibrium between heats produced internally and heat gained from or lost to the environment. The animal produces heat when transforming the chemical energy of feed into work or body tissue. In its simplest form the thermal balance is: Heat production ± heat lost ± heat storage [20].

Under high temperature conditions, birds alter their behaviour and physiological homeostasis seeking thermoregulation, thereby decreasing body temperature. In general, different types of birds react similarly to heat stress, expressing some individual variation in intensity and duration of their responses. Research by Mack et al. [21] showed that birds subjected to heat stress conditions spend less time feeding, more time drinking and panting, as well as more time with their wings elevated, less time moving or walking, and more time resting. Animals utilize multiple ways for maintaining thermoregulation and homeostasis when subjected to high environmental temperatures, including increasing radiant, convective and evaporative heat loss by vasodilatation and perspiration [22].

2.2 Design Calculations

Supplementary heat requirements when brooding was determined using a heat and humidity balance method for a naturally ventilation house with a capacity of 15 broiler birds. In the calculation of heat and humidity balance, temperature values sensible heat and moisture production of broiler were considered. In order to plan a forced ventilated poultry house with a capacity of 15 broilers and to calculate required supplementary heat, various project criteria were used to provide optimum environmental and controlled conditions.

Area of 1 × 3 m^2 per 15 broilers of 0 – 8-week-old are considered adequate, according to Arrington [23] and Turkoglu et al. [24]. Assuming a width of 0.5 m door space [25,26], the length of the tom turkey house was estimated to be 1.5 m based on an area of 1 × 3 m^2 per 8-week-old boiler. The following was also considered: minimum 0.29 m^3 of inside air volume per 8-week-old broiler [27], 2.60 m wall height [28], total windows area as 15% of the floor area and 23º gable roof angle [29]. The house was oriented east and west. Other data for structural elements is summarized in Table 1.

The following equations were used to calculate general heat balance for the broiler house [30,31,32,33,34].

Chicks were reared under a conventional temperature regimen that is, starting at 41ºC and reduced by 3ºC per experiment to 29ºC.

RH was maintained and turn 60 to 70%.

$$Q_{sup} + Q_m + Q_{additional} = Q_e + Q_v + Q_{stored} \quad (1)$$

Q_{sup} = Supplementary heat (W)
Q_m = Sensible heat dissipated by chicks (W)
$Q_{additional}$ = is the heat produced by other sources (e.g. heat production rate by equipment negligible) (W)
Q_e = net heat output through the structural elements (Roof, walls, doors, and windows) (W).
Q_v = heat output through ventilation (W)
Q_{stored} = rate of heat stored as released by building materials (W) negligible

Rearranging equation 1 and rewritten as equation 2:

$$Q_{sup} = (Q_e + Q_v) - Q_m \quad (2)$$

Equation 2 if utilized for the design and experimentation without summation may not provide heat balance required accurately in the broiler house all the time. Heat deficit will occur if Q_m is less than $Q_e + Q_v$ on the right-hand side of equation 2. Resolving this, supplementary heat is required to raise the temperature to an optimal level. Indication of excess heat is visible when Q_m is greater than $Q_e + Q_v$. For optimum efficiency and result, extra heat should be removed by ventilation.

Coefficient of total heat conductance of structural elements (U_{max}) is defined as the coefficient which is calculated from inside temperature and RH at which there is no condensation on the surface of structural elements, which may be calculated using the following equation by [31, 35,36]:

Heat loss (Q_e) through structural elements is calculated using equation 3

$$Q_e = \sum_{i=1}^{n} U_i A_i \Delta t \quad (3)$$

Where:

U is the coefficient of heat conductance of structural elements. (W/m^2°C).
A is the surface area of structural elements (m^2) in Table 1,
Δt ($t_i - t_o$) is the difference between inside (t_i) and outside (t_o) temperature of broiler house (°C) (Table 1).

Average ambient of locations (t_o) = 27°C; Max temperature for experiment (t_i) = 41°C.

Net heat output through the broiler house floor

$$Q_{e(floor)} = U_{floor} \times A_{floor} \times \Delta t \quad (4)$$
= 1.7 × 5.19 × 14 = 123.522W

Net heat output through the broiler house wall

$$Q_{e(wall)} = U_{wall} \times A_{wall} \times \Delta t \quad (5)$$
= 1.73 × 20.59 × 14 = 498.689W

Net heat output through the broiler house door

$$Q_{e(door)} = U_{door} \times A_{door} \times \Delta t \quad (6)$$
= 0.96 × 2.464 × 14 = 33.116W

Net heat output through the broiler house window

$$Q_{e(window)} = U_{window} \times A_{window} \times \Delta t \quad (7)$$
= 0.96 × 1.48 × 14 = 19.930W

Net heat output through the broiler house roof

$$Q_{e(roof)} = U_{roof} \times A_{roof} \times \Delta t \quad (8)$$
= 0.71 × 5.19 × 14 = 51.588W

Summation of net heat output through the broiler house structural element surface area is:

ΣQ_e = 726.845W

Surface coefficients of inside (f_i) and outside (f_o) heat conductance of roof 8.14 and 23.26 (W/m^2 °C)

Heat loss (Q_v) removed by ventilation was calculated using equation according to ASAE [33].

$$Q_v = 0.341 Q_{min} \Delta t \quad (9)$$

Where Δt = 14°C

$$Q_{min} = \frac{W_a}{A_i - A_o} \quad (10)$$

Where;

Q_{min} is the minimum ventilation discharge rate (m^3/h),
W_a is the released total moisture in the inside air (g/h).
A_i and A_o are absolute air moisture (g/m^3) inside and outside the house.
(Mean monthly absolute air moisture = 67.1 % RH = 0.017) outside

Table 1. Specification for the structural elements of the planned broiler housing

Structural element	Structural materials used	Area of structural element (m^2)
Floor	Hard core and 3.0 cm concrete skin 1.7 cm	5.19 m^2
Walls	Cement mortar	8.99 + 7.8 + 3.8 = 20.59 m^2
Door	Aluminum frame 3 cm glass	2.464 m^2
Window	Aluminum frame 3 cm glass	1.483 m^2
Roof	Asbestors, Fibre Glass	5.19 cm^2

Table 2. Physical properties of some materials used for W (Thermal conductivity W/m^2°C) [31]

Materials	Coefficient c_m (W/m^2 °C)	Thickness d_m (m)
Wooden cover	0.2	0.02
Asbestos	0.465	0.004
Fibre glass	0.04	0.05
Concrete	1.7	0.5

At ambient temperature of 27ºC and average relative humidity outside of 67.1% RH (Absolute Humidity)

$$A = C \cdot \frac{P_w}{T} \quad \text{(g/m}^3\text{)} \tag{11}$$

Where:

C = Constant 2.16679 gk/J
P_w = Vapour pressure in Pa
T = Temperature in K.
P_w = P_{ws}(27ºC)

P_{ws} = water vapour saturation pressure from 300.15 Pa

$$P_{ws} = A \cdot 10^{\left[\frac{M.T}{T+T_n}\right]} \tag{12}$$

Where:

T = Ambient temperature in Kelvin
T_n = Temperature rise value

$$P_{ws} = 6.116441 \times 10^{\left[\frac{0.2812}{267.726}\right]} = 6.13$$

1897.168593

$$6.13 \times \frac{67.1}{100} = 4.113$$

$$A = 2.16679 \times \left[\frac{1897.1685}{27 + 273.15}\right]$$

A = 2.16579 × 6.3207
A = 13.695 g/m^3

At maximum temperature of 41ºC and average relative humidity inside (this is based on the optional humidity required for poultry. (between 50 - 60%). At temperature of 41ºC and average relative humidity of 50%.

$$A_i = C \cdot \frac{P_{wi}}{T} \quad \text{(g/m}^3\text{)} \tag{13}$$

C = Constant = 2.16679 gk/J.
T = temperature in K
P_{wi} = P_{wsi} (41ºC)

$$P_{wsi} = \mathrm{A} \cdot 10^{\left[\frac{M.T}{T+T_n}\right]}$$

$$P_{wsi} = A \cdot 10^{\left[\frac{7.59138 \times 314.15}{314.15+240.7263}\right]}$$

$$P_{wsi} = 6.116441 \cdot 10^{\left[\frac{2384.82}{554.876}\right]}$$

$$P_{wsi} = 6.116441 \cdot 10^{4.29795}$$

P_{wsi} = 6.116441 × 19858.887

$$A_i = 2.16679 \cdot \left[\frac{121198.93}{314.15}\right]$$

2.16679 × 385.799
A_i = 837.786 g/m^3

Outside the broiler housing

$$A_o \cdot 10^{\left[\frac{7.59138.300.15}{300.15+240.7263}\right]}$$

$$A_o \cdot 10^{\left[\frac{2278.55}{540.876}\right]}$$

$$A_o \cdot 10^{[4.212]}$$

6.116441 × 16292.9 = 99654.9

$$A_o = 2.16679 \times \left[\frac{99654.9}{300.15}\right]$$

A_o = 719.4 g/m^3

Back to Equation 10

$$Q_{min} = \frac{W_a}{837.786 - 719.4}$$

W_a = 24.8g/k.

2.3 Design Consideration for the Heater

Energy required to heat quantity needed to increase the air inside the broiler housing to required temperature range will be determined using the equation according to Axtell [35]. In order to select the heating element for the broiler housing to serve as supplement and stabilizer in the drying chamber, the quantity of heat energy required for raising the drying temperature to 42ºC from ambient temperature of 28ºC is calculated using Equation 15 according to Axtell [35] as;

$$Q = MC_p\Delta T \tag{14}$$

Where;

Q = amount of heat energy (kJ/s)
M = Mass of water to be removed (0.025 g)
C_p = Specific heat capacity of water (4.182 kJ/kg/K)
ΔT = Temperature difference (42 – 28)°C
$Q = 0.025 \times 4.182 \times (42 - 28)$
Q = 0.025 × 4.182 × 14
Q = 1.46 kJ

$$Power\ rating = \frac{quantity\ of\ heat}{time} \tag{15}$$

Intended drying time = 8 hours maximum possible filament support for a broiler house 1460/(24 × 60 × 60) = 0.0169 kJ/sec= 16.9 watt Power rating for 5 rooms = 84.5 W.

2.4 Design Consideration for the Fan

According to literature, vane axial fan has the highest efficiency and it's the most applicable for heating and ventilating and also where straight flow and efficiency are required from an axial fan. The performance of a fan is defined as the amount of airflow in CFM at given static pressure. From the basics of Axial flow fans, by Hudson products Corporation (2000) vane axial fan is said to have a peak efficiency range of 78-85%. According to American Society of Mechanical Engineers (ASME), vane axial fans have higher static pressure with less dependence on the duct static pressure.

Static pressure in a poultry house is the difference in pressure that a ventilation fan creates between the inside and outside of the poultry house and is the resistance to airflow. Static pressure (SP or Ps) is very important to a mechanical ventilation system since it is the driving force for air movement in the broiler house. According to Bess Lab standards, at static pressure of 0.20 in. H_2O, the airflow is 25900 cfm which results in 12.8 cfm/watt. Applying this into all the experimental rooms (5 Nos), with two fans each, the rating result is 128 cfm/watt

2.5 Solar Panel and Battery Calculation

Total Watts per Hour (DC) = 212.5 Watts.
The heating system is expected to run for 24 hours in a day, therefore watt-hours per day = total daily usage × hours = 5100 watt-hrs/day.

2.5.1 Amp-hour calculation

Note: total watt daily requirements = 5100watt-hrs/day.
Corrected for battery losses (assume static average loss) = 5202.000 watt-hrs/day.
System voltage DC voltage only 24 v.
Amp-hours per day = Watts divided by volts 216.750 Amp-Hrs/day.

2.5.2 Battery bank calculation

Number of days' backup power required (average 24 hours' period) = 2 days
Amp-hour storage (raw capacity needed) 433.5000 Amp-Hrs.
Depth of discharge (Assume 50%) 0.5 fraction.
Required amp backup (also ensure excessive discharge is prevented = 867.0000 Amp-hrs.
Battery amps rating (20 hrs) (Battery capacity in Amps) 100 Amps.
Actual numbers of batteries wired in parallel raw number = 8.67.
Batteries wired in series related to system voltage 2.00 Amp.
Rounded number of batteries round up = 4 batteries.

2.5.3 Solar panel array calculation

Sun hours per day (Direct only) = 6 (worst situation condition).
Worst weather multiplier 1.55 default (constant).
Total sun hours per day (assumes average sun = 3.871 Amp-hr.
Panel size selection based on watt rating (watt hour rating) = 250 watts.
Nominal panel voltage Approximately solar output = 16 volts.
Amps required from solar panel watts divided by volts = 217 Amps
Number of solar panels in parallel = 3.584.
Number of panels in series (12 v) = 4.
Rounded number of solar panels = 8 panels.

2.6 Structural Design Calculation

Structural analysis of the animal housing was carried out in order to determine the effects of loads on physical structures and the components of the animal house. Structures subject to this type of analysis include all that must withstand the building component loads. To perform an accurate analysis for the poultry house, the following information such as structural loads, geometry, support conditions, and material properties were critically analyzed. The timber tie beam was designed, considering the tie beam (beam breadth of 50 mm and beam depth of 100 mm with timber strength class of C40), span details (Number of span = 1, length of bearing is 75 mm and effective length of span according to the plan was 3575 mm) and section properties. Loading details according to analysis was determined and the results are as follows:

$$Joist\ self\ weight = F_{swt} = 0.02\ kN/m$$
$$Dead\ load = F_{dead} = 1.10\ kN/m^2$$
$$Imposed\ UDL\ (medium\ term) = F_{dead\ udl} = 0.25\ kN/m^2$$

The medium-term load was also designed. Load duration factor K_3 was designed as 1.25. Maximum bending moment (M) was 0.249 kNm. Maximum shear force (V) value was designed as 0.278 kN. The maximum support reaction (R) for the animal housing was 0.278 kN and the maximum deflection was 7.307 mm. From calculation, the bending stress analysis was designed at a value of 13.000 N/mm^2 while the permissible bending stress is $M_{adm} = 20.172\ N/mm^2$ and the applied bending stress is $M_{max} = 2.983\,N/mm^2$

For the shear stress, the value derived from calculation was M = 13.000 N/mm^2 and the permissible bending shear stress is $adm = 1.925\ N/mm^2$. The bearing stress for the animal housing designed was also investigated having compression perpendicular to grain (no wane) value of $C_{p1} = 3.00\ N/mm^2$, permissible bearing stress is $C_{adm} = 4.125\ N/mm^2$ while the applied bearing stress is $C_{max} = 0.074\ N/mm^2$

2.7 Design of Column, Base Plate and Holding Down Bolts

a) Loadings

$Dead\ load\ (gk) = 1.1\,kN/m^2$
$live\ load\ (qk) = 0.6\,kN/m^2$
$Designed\ load\ (n) = 1.4(1.1) + 1.6(0.6)$
$= 2.5\,kN/m^2$
Span of supporting beam (from structural layout) L= 3.575 m

$$Load\ of\ supporting\ beam\ (wall\ plate) = n\frac{L}{2}$$

$= 2.5 \times \frac{3.575}{2}$ = 4.47 kN/m^2.

Maximum load on column = 10.21 + 14.15 = 24.36 kN

b) Column

(1) Design Load Estimation
$F_c = 24.36\ kN\ (from\ analysis\ result)$
Section properties for 114.3 × 5 CHS S275
Ag = 1720 mm^2, D = 114.3 mm, t = 5 mm, r = 3.87, D/t = 22.9
Design Strength
$P_y = 275\,N/mm^2$
€ = 1.0

(2) Section Classification
Axial compression
Using No-sway mode
The column is held in position by the base plate LE = 1.0 L = 1.0 × 3000 = 3000
λ = LE/r = 3000/3.87 = 775.2
P_y = 275 N/mm^2
P_c = 162N/mm^2
P_c = Ag Pc
$1720 \times \frac{16}{10^3}$
= 27.52 kN
$P_C > F_C$

Therefore, the section is adequate; adopt 114.3 × 5 CHS S275
Base Plate
Using 114.3 × 5 CHS S275
Section properties
Surface area = 0.359 m^2 / meter length
Perimeter = 359 mm
Ag = 1720 mm^2, D = 114.3 mm, t = 5 mm

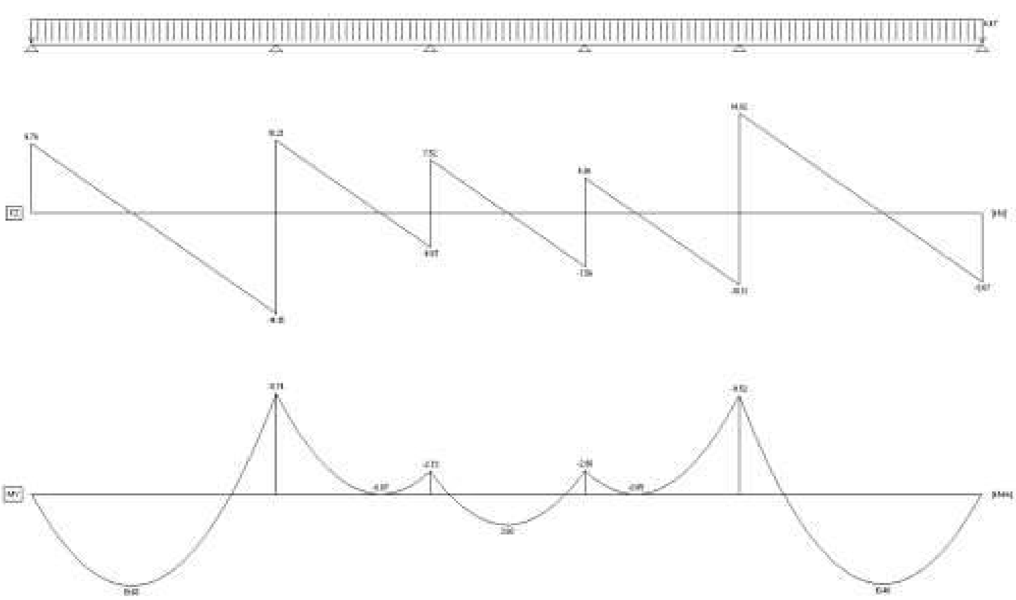


Fig. 1. Analysis result showing shear force and bending moment diagrams (Using Beamax analysis software)

Assume base plate is ≤ 16 mm thick
Py = 275 N/mm^2 € = 1.0

Self-weight of column (114.3 × 5 CHS S275)
=13.5 kg/m

$$\frac{(13.5 \times 3 \times 10)}{1000}$$
=0.41 kN

Design load for base plate = Load on column + Self weight of column Design load = 24.38 + 0.41 = 24.77 kN

$$\text{Effective area required} = \frac{24.77 \times 103}{0.6 \times 20} = 2064\, mm^2$$

Effective area = Ag + 4C^2 + Perimeter × C
C = 0.95 mm
D – 2t – 2C = 114.3 -2(5) – 2 (0.95)
= 102.4 mm
D + 2C = 114.3 + 2(0.95)
= 116.2 mm

$$t_p = C\left(\frac{3w}{P_{yp}}\right)0.5 = 0.95\left(\frac{3 \times 0.6 \times 20}{275}\right)0.5$$
= 0.34mm ≤ 16mm

Adopt a base plate of 200 × 200 × 5 mm thick.

c) Holding down bolts

Assume M12 for light construction.

From the analysis and calculation, the specifications used for the hold down bolts are stated.
6 mm fillet welds
M12 mm H.D. bolts
330 mm long with 112 mm threaded length

Fig. 2 shows the exploded view of the designed poultry house. The controlled poultry house consists of 7 rooms/sections with 6 of the rooms been experimental rooms and the last was designed for the purpose of observation and control of experimental process

2.8 Evaluation and Testing of the Poultry House

The poultry house was tested and evaluated using developed and calibrated data logger (Fig. 3) to determine the environmental condition in the thermally controlled animal house with respect to the ambient conditions. Three temperature sensors were installed vertically at equidistance of 30 cm interval and above the ground and the relative humidity sensor and a wet & dry bulb temperature sensor were position in the five thermally controlled rooms and same set up was placed in the control experiment room. These sensors were all positioned in same level in the whole room in order to ascertain the temperature and relative humidity level in the rooms at different temperature range. The results obtained were analyzed graphically using Microsoft excel software version 2016.

PART LIST

S/N	DESCRIPTION	QTY	S/N	DESCRIPTION	QTY
1	PV SOLAR PANEL	-	10	DEHUMIDIFIER	5
2	ROOFING	1	11	CENTRIFUAGAL BLOWER	5
3	BOARD	1	12	PVC PIPE	-
4	PARTITIONING NET	5	13	HEAT EXCHANGER	1
5	BATTERY	-	14	BUFFER TANK	1
6	INVERTER	1	15	SOLAR COLLECTOR	1
7	CONTROL UNIT	1	16	CONTROL EXPERIMENT ROOM	1
8	DOOR	6	17	EXPERIMENT ROOM	5
9	WINDOW	7	18	ROOFING SUPPORT	7
			19	OPERATOR'S ROOM	5

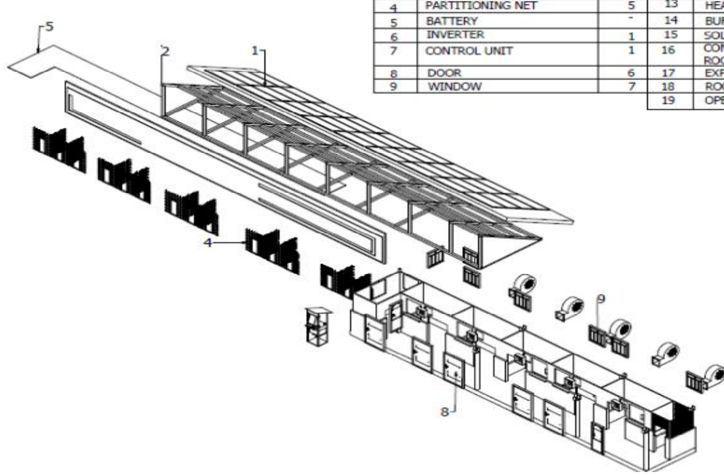


Fig. 2. Exploded view of the designed poultry house

Fig. 3. Picture of data logger for the poultry house

3. RESULTS AND DISCUSSION

3.1 Description of the Poultry House

Each of the experimental room spacing was 3 m by 1.5 m. Five of the six rooms are experimental rooms while the last is the controlled experiment room. The rooms consist of a blower with heating element attached for blowing hot air into the room and likewise a suction fan (dehumidifier) is positioned at the top of each room to aid the easy passage of air out of the room, serving as the only source of ventilation. Each of the six rooms are further divided into three compartments of 1 m by 1 m each to serve as replicate using wire mesh. The experimental rooms except the control experiment room is completely seal up with no allowance for heat loss in order not to expend more energy in attaining the desired temperature and humidity level. Each compartment has a drinking and feeding trough for the broilers. The fans and heater with lightening is powered by the solar system which has 4 batteries of 200 Ah, 24 volt each positioned inside the observatory room and 8 panels of 150 watt each placed on the roof of the housing directed to the southern azimuth for trapping maximum solar insolation. The solar panels are linked to a charge controller to ensure overcharging does not occur. A data logger was designed to collate environmental data from each of the rooms and was placed inside the observatory room to disallow interference of human inside the experimental room every hour. The pictorial representation of the animal housing is shown in Figs. 4 and 5.

The controlled poultry housing operates under two basic principles which are temperature and humidity regulation. The aims of these two basic principles are to remove excess heat, remove excess moisture and limit the build-up of harmful gases and provide enough oxygen for respiration. For this purpose of the testing of the developed poultry house, the 5 experimental rooms are programed to 5 different temperature levels (41, 38, 35, 32 and 29ºC). with the fans programmed to produce air speed of 1.5 m/s.

Fig. 4. Front view of the developed poultry house

Fig. 5. Back view of the develop poultry house

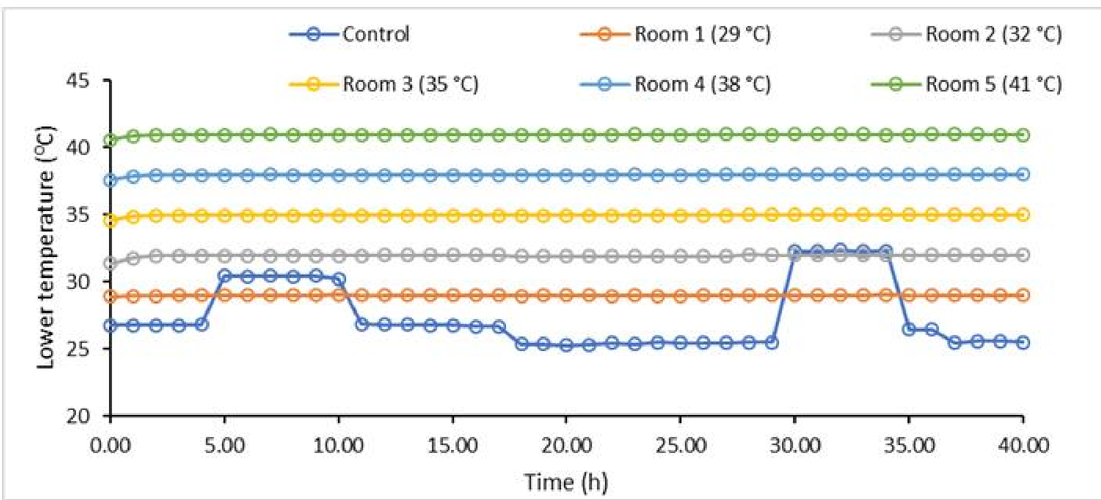
Table 3. The descriptive statistics of temperature in the poultry house

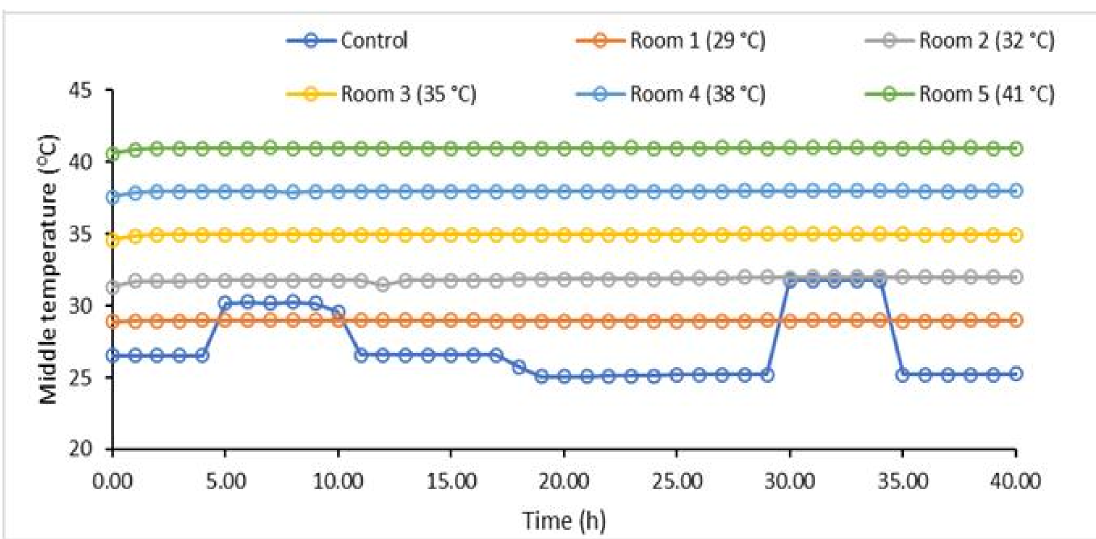
Temperature (°C)	Statistics	Control	Room 1 (29 °C)	Room 2 (32 °C)	Room 3 (35 °C)	Room 4 (38 °C)	Room 5 (41 °C)
Lower temp	Mean	27.395	28.981	31.936	34.963	37.961	40.966
	Standard Error	0.377	0.003	0.016	0.010	0.010	0.010
	Standard Deviation	2.444	0.021	0.106	0.065	0.065	0.063
	Sample Variance	5.974	0.000	0.011	0.004	0.004	0.004
	Kurtosis	-0.379	2.556	23.284	31.033	30.119	32.252
	Skewness	1.085	-0.868	-4.389	-5.324	-5.213	-5.472
	Minimum	25.250	28.910	31.350	34.580	37.580	40.590
	Maximum	32.370	29.020	32.020	35.000	38.000	41.000
	Confidence Level(95.0%)	0.762	0.006	0.033	0.020	0.020	0.020
Middle temp	Mean	27.058	28.956	31.832	34.943	37.941	40.946
	Standard Error	0.370	0.003	0.022	0.010	0.010	0.010
	Standard Deviation	2.397	0.022	0.142	0.065	0.065	0.063
	Sample Variance	5.744	0.000	0.020	0.004	0.004	0.004
	Kurtosis	-0.503	1.097	4.060	31.033	30.119	32.252
	Skewness	1.044	-0.475	-1.573	-5.324	-5.213	-5.472
	Minimum	25.060	28.890	31.310	34.560	37.560	40.570
	Maximum	31.750	29.000	31.990	34.980	37.980	40.980
	Confidence Level(95.0%)	0.747	0.007	0.044	0.020	0.020	0.020
Top temp	Mean	26.694	28.508	31.327	34.527	37.425	40.376
	Standard Error	0.392	0.003	0.017	0.010	0.010	0.010
	Standard Deviation	2.538	0.020	0.109	0.063	0.063	0.063
	Sample Variance	6.442	0.000	0.012	0.004	0.004	0.004
	Kurtosis	-0.458	-0.333	13.931	32.412	31.721	32.252
	Skewness	1.087	0.340	-3.124	-5.487	-5.402	-5.472
	Minimum	24.620	28.470	30.790	34.150	37.050	40.000
	Maximum	31.680	28.550	31.420	34.560	37.460	40.410
	Confidence Level(95.0%)	0.791	0.006	0.034	0.020	0.020	0.020

3.2 Temperature

Table 3 shows the descriptive statistic of the temperature in the poultry house on a vertical scale at 30 cm interval from the ground level. As deduced from the table, the temperature at 30 cm (lower temperature) from the ground level ranges between 25.25 and 32.37ºC with standard deviation of 2.444 for the non-thermally controlled room and the temperature ranges from

28.91-29.02ºC, 31.35-32.02ºC, 34.58-35.00ºC, 37.58-38.00ºC, and 40.59-41.00ºC with standard deviation of 0.021, 0.106, 0.065, 0.065 and 0.063 in the poultry house which were thermally controlled to 29ºC, 32ºC, 35ºC, 38ºC and 41ºC respectively, the temperature at 60 cm (middle temperature) position from the ground level ranges between 25.06 and 31.75ºC with standard deviation of 2.397 for the non-thermally controlled room and the temperature ranges from, 28.89-29, 31.31-31.99, 34.56-34.98, 37.56-37.98, 40.57-40.98 with standard deviation of 0.022, 0.142, 0.065, 0.065 and 0.063 in the rooms which were thermally controlled to 29ºC, 32ºC, 35ºC, 38ºC and 41ºC respectively whilst, the temperature at 90 cm (Top temperature) position from the ground level ranges between 24.62-31.68ºC with standard deviation of 2.538 for the non-thermally controlled room and the ranges from, 28.47 - 28.55, 30.79 -31.42, 34.15 - 34.56, 37.05-37.46, 40-40.41 with standard deviation of, 0.02, 0.109, 0.063, 0.063, 0.063 in the rooms which were thermally controlled to 29ºC, 32ºC, 35ºC, 38ºC and 41ºC respectively. This result shows that there is no temperature stability in the non-thermally controlled section of the poultry house and the recorded temperature of the thermally controlled section of the poultry house was found in a close range with low deviation from the preset temperature in the sections. Fig. 6 show the graphical representation of the hourly recorded temperature level recorded by each sensors in the various room of the building.





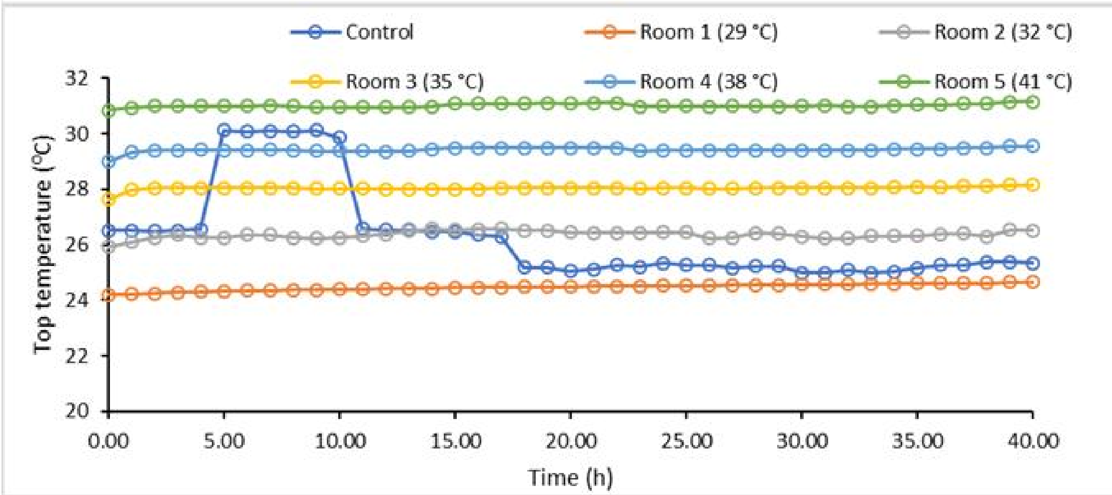


Fig. 6. Temperature profile of the poultry house

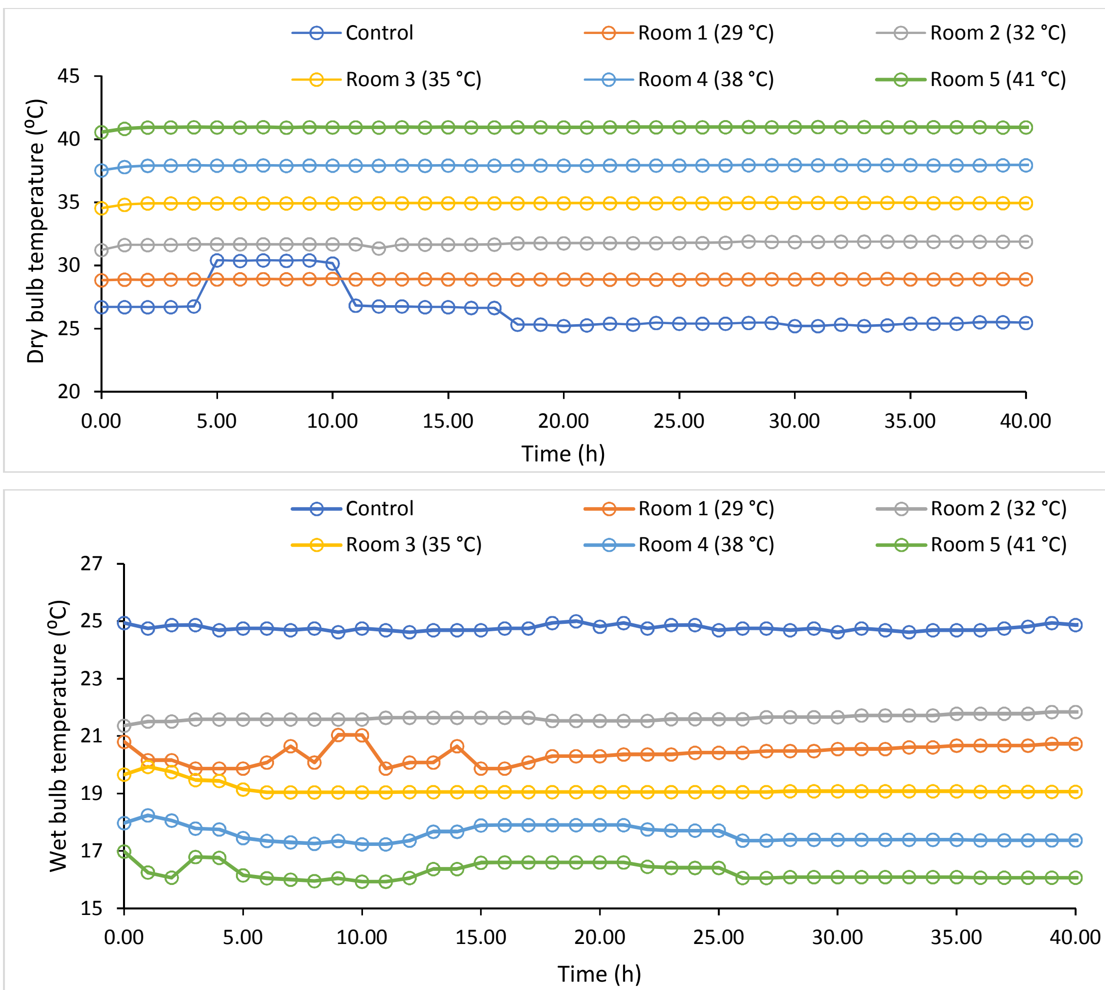


Fig. 7. Wet and dry bulb temperature of the poultry house over time

3.3 Wet and Dry Temperature

Table 4 shows the descriptive statistic of the wet bulb and the dry bulb temperature in the poultry house. As deduced from the table, the dry bulb temperature and wet bulb temperature ranges between 25.21-30.42ºC with standard deviation of 1.717 for the non-thermally controlled room and the dry bulb temperature ranges from, 28.84 -28.95ºC, 31.23-31.91ºC, 34.55 -34.97ºC, 37.54 - 37.96ºC, 40.57-40.98ºC with standard deviation of, 0.021, 0.142, 0.065, 0.065 and 0.063 in the poultry house which were thermally controlled to 29ºC, 32ºC, 35ºC, 38ºC and 41ºC respectively. While, the wet bulb temperature ranges between 24.62-25ºC with standard deviation of 0.101 for the non-thermally controlled room and the wet bulb temperature ranges from, 19.87 -21.04ºC, 21.36-21.84ºC, 19.04-19.93ºC, 17.23-18.24ºC and 15.93-16.98ºC with standard deviation of 0.321, 0.103, 0.205, 0.268 and 0.273 in the poultry house which were thermally controlled to 29ºC, 32ºC, 35ºC, 38ºC and 41ºC respectively. Fig. 7 show the graphical representation of the hourly dry bulb and wet bulb temperature level recorded by each sensors in all the sections of the poultry house.

Table 4. The descriptive statistics of dry and we temperature in the poultry house

Temperature (°C)	Statistics	Control	Room 1 (29°C)	Room 2 (32°C)	Room 3 (35°C)	Room 4 (38°C)	Room 5 (41°C)
Dry bulb	Mean	26.474	28.911	31.752	34.933	37.921	40.946
	Standard Error	0.265	0.003	0.022	0.010	0.010	0.010
	Standard Deviation	1.717	0.021	0.142	0.065	0.065	0.063
	Sample Variance	2.946	0.000	0.020	0.004	0.004	0.004
	Kurtosis	1.366	2.556	4.060	31.033	30.119	32.252
	Skewness	1.626	-0.868	-1.573	-5.324	-5.213	-5.472
	Minimum	25.210	28.840	31.230	34.550	37.540	40.570
	Maximum	30.420	28.950	31.910	34.970	37.960	40.980
	Confidence Level(95.0%)	0.535	0.006	0.044	0.020	0.020	0.020
Wet bulb	Mean	24.766	20.394	21.635	19.129	17.569	16.258
	Standard Error	0.016	0.050	0.016	0.032	0.041	0.042
	Standard Deviation	0.101	0.321	0.103	0.205	0.268	0.273
	Sample Variance	0.010	0.103	0.011	0.042	0.072	0.075
	Kurtosis	-0.468	-0.719	0.308	7.433	-0.790	-0.339
	Skewness	0.661	-0.141	0.196	2.857	0.661	0.884
	Minimum	24.620	19.870	21.360	19.040	17.230	15.930
	Maximum	25.000	21.040	21.840	19.930	18.240	16.980
	Confidence Level(95.0%)	0.032	0.100	0.032	0.064	0.083	0.085

Table 5. The descriptive statistics of relative humidity in the poultry house

Statistics	Control	Room 1 (29°C)	Room 2 (32°C)	Room 3 (35°C)	Room 4 (38°C)	Room 5 (41°C)
Mean	58.18429	44.69071	41.9031	38.43262	33.79571	31.6419
Standard Error	1.261094	0.365314	0.187186	0.058777	0.068808	0.062256
Standard Deviation	8.172825	2.367505	1.213104	0.380917	0.445925	0.403468
Sample Variance	66.79506	5.60508	1.471622	0.145098	0.198849	0.162787
Kurtosis	-0.64216	-0.27395	-1.38867	5.030347	1.939567	-0.88796
Skewness	-0.30262	-0.37601	0.192931	0.09189	-0.4243	0.612952
Minimum	36.89	40.09	40.12	37.07	32.28	31.12
Maximum	68.22	48.84	43.9	39.43	34.64	32.52
Confidence Level(95.0%)	2.546831	0.737766	0.37803	0.118702	0.13896	0.12573

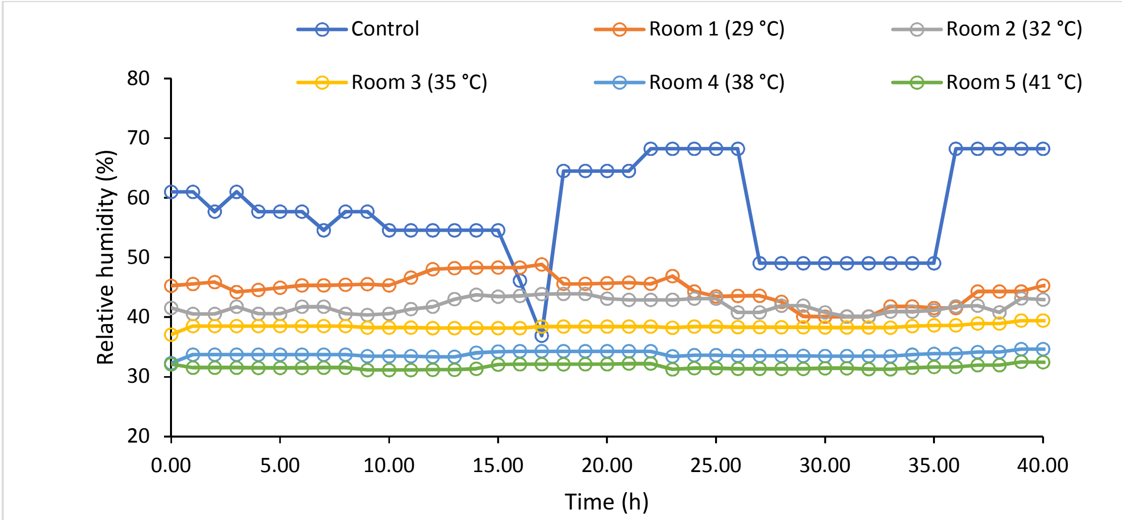


Fig. 8. Relative humidity of the poultry house over time

3.4 Wet and Dry Temperature

Table 4 shows the descriptive statistic of the relative humidity in the poultry house. As deduced from the table, relative humidity ranges between 36.89-68.22% with standard deviation of 8.173 for the non-thermally controlled room and the relative humidity ranges from 40.09-48.84%, 40.12-43.9%, 37.07-39.43%, 32.28-34.64% and 31.12-32.52% with standard deviation of, 2.368, 1.213, 0.381, 0.446 and 0.403 in the poultry house which were thermally conditioned to 29ºC, 32ºC, 35ºC, 38ºC and 41ºC respectively.

4. CONCLUSIONS

The following conclusion were drawn on the design and construction of thermal control solar heated poultry house:

i. There was little or no temperature stability in the non-thermally controlled section of the poultry house.
ii. The temperature of the thermally controlled section of the poultry house was found in a close range with low deviation from the preset temperature in the sections.
iii. The dry bulb temperature in the poultry house is 28.91 ± 0.02ºC, 31.75 ± 0.14ºC, 34.93 ± 0.06ºC, 37.92 ± 0.07ºC, 40.95 ± 0.06ºC and 26.47 ± 1.72ºC for sections with preconditioned temperature of 29ºC, 32ºC, 35ºC, 38ºC 41ºC and control respectively.
iv. The dry bulb temperature in the poultry house is 20.39±0.32ºC, 21.64±0.1ºC, 19.13±0.2ºC, 17.57±0.27ºC, 16.26± 0.27ºC and 24.77±0.1ºC for sections with preconditioned temperature of 29ºC, 32ºC, 35ºC, 38ºC 41ºC and control respectively.
v. The relative humidity in the poultry house is 44.69±2.37%, 41.9±1.21%, 38.43 ± 0.38%, 33.8±0.45%, 31.64±0.4% and 58.18±8.17% for sections with preconditioned temperature of 29ºC, 32ºC, 35ºC, 38ºC, 41ºC and control respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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