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Development and Evaluation of a Passive Solar System for Poultry Egg Incubation

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Abstract **-** Design, development and evaluation of a **Passive Solar Poultry Egg Incubator** were undertaken. The incubator had two heat **collectors** and storage media **(thermal masses)** and heat exchangers. The main heat absorber was made of 80mm thick concrete incorporated with a separate heat storage media to serve as back up during sunless hours. The system was insulated with 4mm thick plywood for both internal and external surfaces, with 6mm thick foams used to fill the annular spaces. The absorber surfaces were pre-treated by painting them black for better heat collection. Digital thermocouple/multi-meters was incorporated into the chambers for temperature and relative humidity measurements. At average ambient temperature of 36.6 ^oC, the heat absorber surfaces attained a maximum temperature of 91.5 ^oC at 15:00 (GMT) and a minimum temperature of 37.1 ^oC at 6:00. The temperature maintained in the incubating chamber ranged between 30.9 – 46.6 ^oC depending on the time of the day and weather conditions. At average ambient relative humidity of 69.2 %, the incubating chamber relative humidity was averagely at 61.6 %, using activated charcoal as dehumidifying material. Heat collection and transfer efficiencies of the thermal mass were 96.4 % and 44.3 % respectively. The incubator was tested for fertility and hatchability with 125 broiler eggs obtained from a reliable commercial hatchery. The percentage fertility and hatchability recorded were 74.4 % and 73.1%, respectively, with 21 days as incubation period.

Keywords: PASSIVE, SOLAR, POULTRY, EGG, INCUBATOR, THERMAL MASS, COLLECTORS.

INTRODUCTION

The main objective of this work is to harness the abundant solar energy available in Makurdi, Benue State, North-Central Nigeria, to heat up an incubating chamber for poultry eggs. Mankind has utilized solar energy for years for domestic drying, provision of warmth and for other uses. By 1915, several engines had been run from solar-generated steam, and most of the solar collector concepts used today had been developed. They all relied on glass, either for mirrors or for transparent covers to trap heat as in a green house [1] Lunde, (1980).

The craving for alternative energy source, outside fossil fuel, has become a global phenomenon. To this effect, countries around the world are investing massively in solar energy power plants. One of such major investment in the recent times is by the USA Department of Energy which has been charged with the development and sponsoring programmes that will transform the way energy is provided in the United States. Researchers from University of Arkansas have developed high performance concrete to store thermal energy for concentrating solar power plants [2] Emerson, Hale, and Selvam, (2011).

For a thriving poultry production in developing countries such as Nigeria, where electricity supply has remained inadequate and unreliable, alternative methods of meeting the energy needs in agriculture and in the poultry industry specifically, have to be evolved. These alternative energy needs cannot be over-emphasized, for energy is required at various stages of poultry production especially during incubation processes. At this stage, heat energy is the major requirement for successful hatching of the eggs into chicks and eventual growth of the young chicks in the brooding house, and then to maturity.

However, it is expedient that such alternative energy source should be dependable, in abundant supply, and environmentally friendly. It should also be inexpensive and readily available to local farmers. Solar energy looks the best alternative energy option for this, because it is clean and is readily available all year round in the tropics and in North Central Nigeria, along Benue River Valley, Makurdi-Nigeria. A good solar system should be able to convert solar radiation into useful heat or electrical energy, store it and release it for utilization when needed.

Several methods of solar energy storage are available [3] Duffie and Beckman, (1980). These include storing as sensible and latent or concealed heats. The advantage of sensible heat storage is that materials for energy storage are locally available and inexpensive. Such materials include water, stones, masonry wall systems, gravels and local bricks walls. The technology of masonry wall system as solar energy collector and storage device in buildings has been reported [4] Nayak, Bansal, Sodha, (1983).

In Nigeria, [5] Okonkwo, Anazodo, Akubuo, Echiegu, and Iloeje (1992) reported on solar heating system. The results of the analysis showed an absorber plate temperature of up to 83 ^{o}C measured and 122 ^{o}C predicted while storage medium temperature was 45.56 ^{o}C.

Though the solar incubating and heating systems are not generally common in Nigeria, the built-in thermal storage solar water space conditioning system could serve as a good example of utilizing solar energy in Nigeria as illustrated by [6] Okonkwo, (1998).

Several other researchers - [7] Fagbenle (1990) and [8] Pelemo, Fasasi, Owolabi, and Shaniyi (2002) worked on estimation of daily radiation and its utilization in Nigeria using meteorological data, including but not limited to [9] Yohanna, Itodo, and Umogbai (2011), [10] Itodo (2007), [11] Adeyemo (1988). [12] Owokoya (1992) , [13] Adaramola, Amaduoboga, and Allen (2001) and [14] Odia (2006).

This study aimed at developing a passive solar system that can provide suitable conditions for incubation of poultry eggs, using solar energy and materials within the research station.

MATERIALS AND METHODS

Materials

For a material to be effective as a thermal mass, it must have a high heat capacity, a moderate conductance, a moderate density, and a high emissivity. Table 1 shows the various materials used, selected on the basis of their properties suitable for the development of the solar incubator.

Material Treatment

The exposed surfaces of the thermal masses were painted black. This was necessary to allow optimal heat collection, absorbance and transmittance. Dark surfaces have high absorptances between 0.95 – 0.99. Hence, the thermal masses made of concrete and granite stones were painted black for optimum heat absorption. Similarly, in order to improve heat quality, the heated air was dehumidified for a dry hot air into the incubating chamber. The material used was Powdered Activated Carbon (PAC), otherwise known as grinded charcoal of diameter of about 0.15 - 0.25 mm. Thus they present a large surface to volume ratio with a small diffusion distance.

Table 1: Materials and their usage

S/N	Materials	Usage
1.	Plane Glass	Cover Plate
2.	Concrete Slab	Main Thermal Mass
3.	Granite Stones	Supplementary Thermal mass
4.	Plywood	Insulating body
5.	Insulation foams	Insulation purpose
6.	PVC troughs	Heat Exchanger
7.	Activated Charcoal	Dehumidifier
8.	Testing materials	Candler, fertile eggs

Basic Design Assumptions

The design analysis of this solar incubator is based on the following assumptions;

1. The heat being absorbed by the thermal mass and air equals the theoretical heat energy that successfully passed through the transparent glass cover.
2. All manner of expansion and contraction of materials used were assumed negligibly small, hence, ignored.

Solar energy incident on the glass cover (collector)

The solar energy incident on the glass cover is given by;

$$Q_{gc} = A_{gc}.I_{gc} \tag{1}$$

Where,
A_{gc} = Glass covers surface area (m^2),
I_{gc} = Hourly Total solar irradiance on the glass cover,

Over a period of total solar hours, this becomes;

$$Q_{gc} = A_{gc}.I_{gc}.t \tag{2}$$

However, owing to the thermal conductivity of the glass cover, the total heat delivered through it is;

$$Q_{gc} = A_{gc}.I_{gc}.t.k \tag{3}$$

Where,
k = the thermal conductivity of the glass cover;
t = time (hours).

Equation (3) is the actual heat delivered through the glass cover over the solar hours.

Heat Accumulated in the Supplementary Storage

The solar energy incident on the supplementary glass cover is as obtained in Equation (2). Base on first Theoretical Assumption, the heat collected by the supplementary storage is given by;

$$Q_{gra} = A_{gc} \text{ x } I_{gc} \text{ x t x k} \tag{4}$$

Where
Q_{gra}= Heat accumulated by the granite stone
A_{gc} = Area of the glass cover
I_{gc} = solar irradiance for Makurdi
t = solar hours per day for Makurdi

Total Available Energy to be delivered into the Incubating Chamber from Main Storage Chamber

The total useful energy available for delivery into the incubating chamber from the main storage chamber was estimated by taking away the heat losses from the walls of the storage chamber from the actual energy that successfully passed through the glass cover into the storage chamber;

$$Q_{ud} = Q_{gc} - Q_{lcc} \tag{5}$$

Where;
Q_{ud} = Useful energy available to be delivered into the incubation room;
Q_{gc} = Total useful energy that successfully passed through the glass cover;
Q_{lcc} = heat loss through the walls of the storage chamber;

$$Q_{lcc} = \frac{\Delta T}{R_T} \tag{6}$$

Where $R_T = \frac{1}{A}(\frac{x_w}{k_w} + \frac{x_f}{k_f})$;

R_T = the total resistance (R-value) of wood and foam that made up the wall system;
ΔT = average temperature difference between the collector chamber and the ambient;
A = Area of the collector chamber (m^2);
x_w = thickness of the wooden wall (m);
x_f = thickness of the foam (m);
k_w = thermal conductivity of the wood (W/m-k);
k_f = thermal conductivity of the foam (W/m-k);

Useful Energy Delivered into the Incubating Chamber

$$Q_{ui} = Q_{tm} + Q_a \tag{7}$$

$$Q_{tm} = (h_{ic}.A_{tm}(T_{itm} - T_{ic})) \tag{8}$$

Where,
Q_{ui} = Useful energy delivered into the incubating chamber;
Q_{tm} = Direct heat dissipation from the thermal mass (concrete);
h_{ic}= Radiation heat transfer coefficient from the inner surface of the thermal mass into the incubating chamber;
A_{tm}= Area of the thermal mass;
T_{itm}= Inner surface temperature of the thermal mass;
T_{ic}= Incubating chamber temperature.

$$Q_a = 2\acute{m}_a\acute{m}C_{pa}(T_{hac} - T_{ic}) \tag{9}$$

Where,
Q_a = heat transferred by the hot flowing air into the incubating chamber via the heat exchanger (PVC)
$\acute{m}_a$ = mass flow rate (Kg/hr),

C_{pa}= specific heat capacity of air (KJ/Kg.^{o}C);

But,

$$\acute{m}_a = \rho_a . A_{pvc} . F_r \sqrt{g} . D_v \frac{(T_{hac} - T_{ic})}{T_{hac} + T_{ic}} \quad (10)$$

Note: Equation (9 and 10) are as provided by [15] Bansal and Gour (1996) and [16] Zriken and Bilgen (1987) respectively.

Where,
ρ_a = Density of air, Kg m^{-3}
A_{pvc}= cross sectional area of the PVC trough, m^2;
F_r= Froude Number
D_v= Vertical distance of the PVC troughs from storage chamber (which serve as inlet opening) to exit into the incubating chamber).
F_r is the collector heat removal factor which relates the actual useful energy gained by the collector to the useful energy gained by the air.

$$F_r = \frac{\acute{m}_a . C_{pa}(T_c - T_a)}{A_c[\alpha . \tau . I_t - U_l(T_c - T_a)} \quad (11)$$

Where,
$\acute{m}_a$= mass flow rate of air
C_{pa}= Specific heat capacity of air
T_c= Collector temperature
T_a= Ambient temperature
A_c= Area of collector
α = Absorptance of solar collector
τ= Transmittance of solar collector
I_t= Solar irradiance
U_l= Overall heat loss coefficient

Heat Transmission via the Supplementary Heat Exchanger

Heat transfer from the supplementary storage is by convection only, estimated using equation (9), which for a single PVC trough opening becomes $Q_a = \acute{m}_a C_{pa}(T_{hac} - T_{ic})$.

Actual Heat Requirement of the Incubating Chamber

The total heat requirement of the incubator (Q_T) is the summation of the heat energy required to raise the temperature of air (Q_a) and egg (Q_e) from 30 ^{o}C to 38.5 ^{o}C; the heat loss through the wall of the structure (Q_s) and the heat loss by ventilation (Q_v) (Bukola, 2008).

$$Q_T = Q_a + Q_e + Q_s + Q_v \quad (12)$$

Heat Requirement of Air within the incubator

The heat absorbed by the air within the incubator to ascend from ambient temperature of 31.8 ^{o}C as measured, to the incubating temperature of 39 ^{o}C was estimated as follows;

$$Q_a = \dot{m} \, x C_a x \Delta T \quad - 13$$

Where,

Q_a= Heat requirement of air

m= mass flow rate (Kg/hr)

C_a== specific heat capacity of air KJ/Kg.^oC

ΔT= Average temperature difference, ^oC.

Heat Requirement of Eggs

$$Q_e = M_e * C_e * \Delta T \quad - \quad 14$$

Q_a= Heat required to raise the egg temperature, KJ
m= mass of egg (Kg/hr)

C_a== specific heat capacity of egg KJ/Kg.^oC

ΔT= Average temperature difference, ^oC.

Heat Loss through the Walls of the Incubating Chamber

Fourier's law of heat conduction for steady state and one directional flow was adopted and mathematically expressed as,

$$Qs = KA\Delta T / x = \Delta T / R_T \quad - 15$$

$$R_T = 1/A\ (1/h_1 + x_1/k_1 + 1/h_0) \quad - 16$$

Q_s= Heat loss through the walls of the structure

k_1 = thermal conductivity of wood (W/m.K)
k_2 = thermal conductivity of foam (W/m.K)
h_i = convective heat transfer coefficient from inner fluid (heated air) to solids (the walls)

h_o = heat transfer coefficient from solid (the walls) to the outer fluid (outside air)

x_1 = thickness of wood (mm)

x_2= thickness of foam (mm)

Heat loss through ventilation openings

The rate at which heat is removed by ventilation air is given as;

$Q_v = M_a.C_{pa}.(T_o - T_1) = \rho \cdot V\ C_a.\ \Delta T$

M_a = amount of ventilating air in Kg/hr

Q_v = heat loss via the openings in KJ
C_{pa} = Specific heat capacity of air in KJ/Kg.K

ΔT= = difference in temperature between incubating chamber and the ambient

V= ventilation rate, m^3/s

ρ = density of air Kg/m^3

Efficiency of the system

The efficiency of the system was estimated using the following relationships;

Collector efficiency=

$$= \frac{\text{the energy transferred to the thermal mass}}{\text{total energy that falls on the collector}} \text{ x } 100\% \qquad (17)$$

Incubator efficiency

$$= \frac{\text{the useful energy transferred to the incubating chamber}}{\text{total energy delivered into the storage chamber}} \text{x} 100\% \qquad (18)$$

Performance Evaluation of the system

$$\%\, \boldsymbol{Fertility} = \frac{\textit{Number of fertile eggs}}{\textit{Number of eggs loaded}} \text{ x } 100\% \qquad (19)$$

$$\%\, \boldsymbol{Hactchability} = \frac{\textit{Number of eggs hatched}}{\textit{Number of fertile eggs}} \text{ x } 100\% \qquad (20)$$

DESCRIPTION OF COMPONENTS OF THE EGG INCUBATOR

The solar egg incubator consists of six main components as shown in Figure 1. The photograph of the incubator developed is as shown in Figure 2.

The transparent plane glass cover) – A: The plane glass has been used as a solar collector for ages, owning to its unique properties. The plane glass has high solar transmittance of 0.84 to 0.91, long wave transmittance of 0.03; Neat appearance; Cleans easily; Abrasion resistance; High heat tolerance (up to 204^{o}C); Excellent weathering resistance and Low flammability (Lunde, 1980). Its job is to allow the passage of shortwave solar radiation into the heat storage chamber and prevent the escape of long wave energy being accumulated within the storage chamber.

The absorber/thermal mass (concrete slab) – B: The concrete is a mixture of cement, sand, gravel and water. The water stirs the reaction between the cement, sand and gravel, hence binding them together into what is known as concrete slab. The property of concrete that makes it ideal for heat storage include its high heat capacity of 1000 J/Kg ^{o}C, heavy density of 2000 Kg/m^3 and good thermal conductivity of 0.18 KJ/Kg.K. It absorbs heat and gets heated up at slow rate but also radiates heat to the ambient slowly; thereby retain heat for a longer time for use during cold hours.

The supplementary heating system granite stones – C: The granite stones serves as the supplementary storage with the useful properties such as; Heat Capacity of 790 J/Kg^{o}C, Thermal conductivity of 2.8 W/m.K and Density of 2403.4 kg/m^3.

The incubating chamber – D: The incubating chamber is made of ply woods, lined at the surface with insulation foam. These two materials helps to keep the heat energy delivered into the incubating chamber from escaping into the atmosphere. The desirable properties for this purpose are; Very low thermal conductivity of 0.045 W/m-K which increases the insulation provided by plywood.

Insulating casing (ply wood) – E: The ply wood is the overall casing of the incubator, covering all the chambers. It forms the wall of the incubating and the heat storage chambers, with desirable properties being very low thermal conductivity of 0.13 W/m-K.

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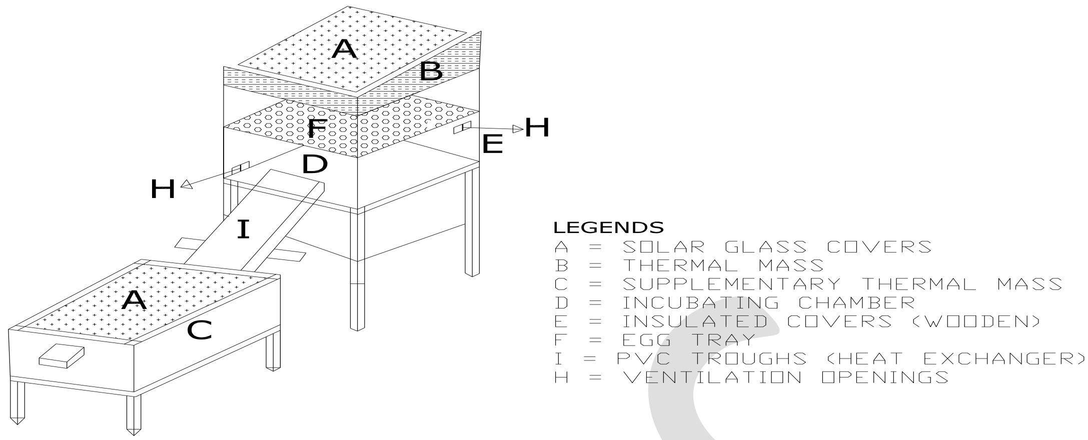

Fig. 1: The Poultry Egg Incubator

The egg tray (ply wood) F: The egg tray was made from plywood, perforated to allow an average egg to hang through without falling through the perforation.

Ventilation: The air circulation through the incubator was by natural ventilation. The ambient (fresh) air enters through the inlet openings (located down the windward side of the incubator) into the system where it is heated up by the accumulated solar energy. This brings a temperature difference between the air at the lower and upper ends of the collector. The difference in temperature results in pressure difference and density variation, hence resulting in buoyancy force which in turn causes the heated air to flow through the incubating chamber and pass through the outlet openings located above the egg tray on the leeward side of the incubator. Small inlet openings were provided to induce natural ventilation or air exchange into the incubator. Normal air exchange is needed during embryo development and usually increases as the chicks begin to hatch. The embryo takes in oxygen and produces carbon dioxide as by-product. Ventilation is needed to remove unpleasant smells and excessive moisture, and to prevent stagnation of the interior air.

Orientation of the solar collector: The collector is always tilted and oriented in such a way that it receives maximum solar radiation during the period of use. The solar collector in this work was oriented facing south and tilted at 45^{o} to the horizontal. This inclination allows average solar collection all day and also allows easy run off of water. It also enhances heat movement into the incubating chamber.

Candler: A wooden Candler was constructed which was an integral part of the incubator for testing the fertility of eggs. Candling process was done on the 7th, 14th and 18th day of incubation

Fig. 2: Picture of the developed Solar Incubator

PERFORMANCE EVALUATION

The solar incubator was constructed and assembled as shown in Figure 1. The measuring instruments used such as temperature sensors and hygrometer were positioned such that the inner condition of the system and ambient conditions of temperature and relative humidity were taken simultaneously. The solar system was monitored for one week (7 days) by taking measurements of the temperature and relative humidity in the system within the period. The readings were taken for 24 hours each day and at a regular interval of 3 hours; (i.e. at 0:00, 3:00, 6:00, 9:00, 12:00, 15:00, 18:00, and 21:00) GMT.

The activated charcoal (dehumidifier) and evaporative cooling pan were provided in the heat collector chambers and incubating chambers, respectively, to control relative humidity throughout this study. This is to prevent condensation within the collector chambers, so as to deliver clean and dry heated air into the incubating chamber. After the seven days monitoring of the system to establish the environmental parameters that can be maintained, the incubator was loaded with fertile eggs obtained from a reliable hatchery. Candling process was used to check the fertility of eggs on the 7th and 14th day of incubation.

Table 2 shows the average temperatures and relative humidity pooled together for the 7 days monitoring of both ambient and incubating system at different time of the day (i.e. 0:00, 3:00, 6:00, 9:00, 12:00, 15:00, 18:00, and 21:00) GMT. Table 3 shows the average temperature of the 7 days data collection within the incubating chamber at specific distances away from the thermal mass.

The results of Table 2 show that the average ambient temperature was lower in the morning and increased to the highest value of 36.6^{o}C at 3: PM (15:00) and start decreasing to attain the lowest value, 28.3℃ at 3: AM (3:00). The ambient relative humidity was observed to be highest at 6: AM (6:00) and was decreasing to attain the lowest value at 6: PM (18:00) and then increased slightly towards night time. The temperature of the thermal mass was lowest at 6: AM (6:00) and increased to the highest value of 91.5^{o}C at 3: PM (15:00), with the decreasing trend towards midnight and morning hours. The relative humidity range of 56.1% to 64.2% was maintained in the incubating room from 6: 00 to 6:00 the next day throughout the monitoring period. This result values fall within the required range provided in literatures [17] Adewumi and Oduniyi, (1999); [18] Hamre, (2011), [19] Bukola, (2008).

The results of Table 2 show that the temperature of the incubating room varied significantly at different time of the day. The mean temperature, 42.4℃ recorded at 12noon was significantly higher (P≥0.05) than the temperature values obtained at any other time of the day.

Table 2: Effect of time period on the Temperature and Relative humidity of the incubating chamber

Environmental Parameters	Time of the day, h								
	0	3	6	9	12	15	18	21	$FLSD_{0.05}$
T_{inc}, ℃	33.6^{b}	37.1^{c}	41.0^{a}	42.0^{d}	42.4^{e}	41.1^{a}	38.0^{f}	36.2^{g}	0.7717
RH_{inc}, %	56.1^{d}	59.7^{ac}	64.2^{a}	64^{a}	62.7^{ab}	62.6^{ab}	62.5^{ab}	61.3^{bc}	2.5396

Means of the different superscript letters indicate significant difference (P≥0.05)
T_{inc} = incubating room temperature, RH_{inc} = incubating room Relative humidity

Table 3 shows the average temperatures of the incubating chamber at various distances from the thermal mass. The Table indicates that minimum temperature of 30.5℃ was obtained at 6: AM (6:00) and at a distance of 100 cm away from the thermal mass. The highest value of 46.6℃ was attained at 3: PM (15:00) and at a distance of 20 cm away from the thermal mass. Table 3 also indicates increasing trend pattern in temperature values from 6: AM (6:00) in the morning to highest values between 12 noon to 6: PM (12:00 to 18:00) in the evening. This may be as a result of heat dissipation from the thermal mass and this finding agrees with the finding by [20] Nwakonobi *et al* (2013).

The graphical presentations shown in Figure 3 indicate the trend pattern of the average temperature variation with time of day for both ambient and thermal mass (absorber) outer and inner surfaces while Figure 4 shows the variation of the incubating room temperature at specific distances of the egg tray from the thermal mass. Figure 5 shows the relative humidity variation with time of day for ambient and incubating chamber. Table 2 The comparisons of the environmental parameters of incubating room carried out for different time of the day indicate that the mean temperature of the incubating room was significantly higher ($P \leq 0.05$) with value of 42.4℃ at 6: PM (18:00) and is statistically different from the mean temperature values of the other times of the day. The lowest temperature value is at 6: AM (6:00) with the value of 33.61℃ and is statistically different ($P \leq 0.05$) from the other times of the day. The mean temperature obtained at 12 noon and 9: PM (18:00) was statistically indifferent.

Figure 3 shows that the heat absorbing surface (outer) of the thermal mass was consistently at higher temperature level than inner side thereby inducing gradient for heat flow towards the incubating chamber.

The temperature value, 38.0℃ at 12 midnight was higher than that recorded at 3 AM (3:00), 6 AM (6:00) and 9 AM (9:00) and differences are statistically significant ($P \geq 0.05$).

It was observed from Table 2 that between the hours of 12 midnights to 9:00, incubation temperature range of 36.2℃ - 38.0℃ was obtained which was within the acceptable range of 37℃ - 39℃ (Oluyemi and Roberts, 1979).

The relative humidity (RH) of the incubating room which is another important parameter to assess the suitability of the system for poultry egg incubation was also affected significantly by the diurnal variation at different time of the day. The relative humidity value, 64.2 % attained at 12 noon though differ significantly with that obtained at 3:00, 6:00 and 9:00 but the differences with rest of the time of the day were statistically the same ($P \geq 0.05$). The lowest value, 56.1 % of RH was recorded at 6:00 in the morning which differs significantly with the rest of others. The RH, 61.3% recorded at 3:00 differs significantly and was higher than that obtained at 6:00 and 9:00.

Table 3: Incubating chamber average temperature (^{o}C) at various distances from thermal mass

	Temperature (^{o} C)		
Time of the day	20 cm	60 cm	100 cm
6 am	36.9	33.4	30.5
9 am	37.7	37.1	36.6
12 noon	42.9	41.5	38.9

3 pm	46.6	40.8	38.5
6 pm	46.1	42.7	38.5
9 pm	43.8	40.6	38.9
12 midnight	39.2	38.3	36.6
3 am	38.5	35.9	34.3

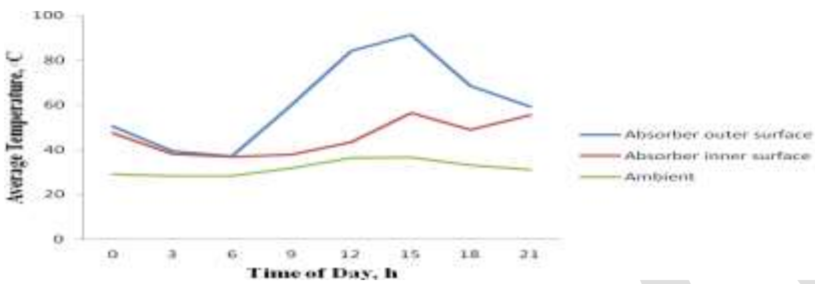

Fig. 3: Temperature variation of concrete solar absorber surfaces with time of day

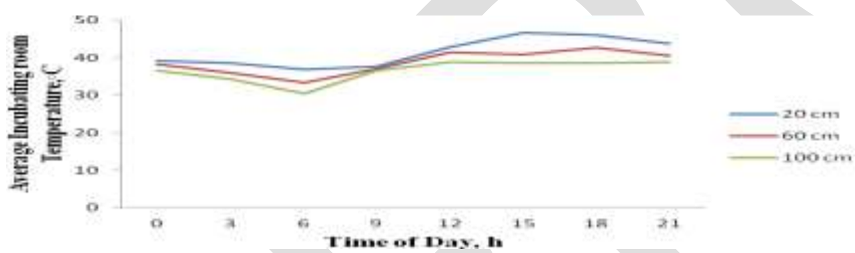

Fig. 4: Average incubating room temperature versus time of day at distances from thermal mass

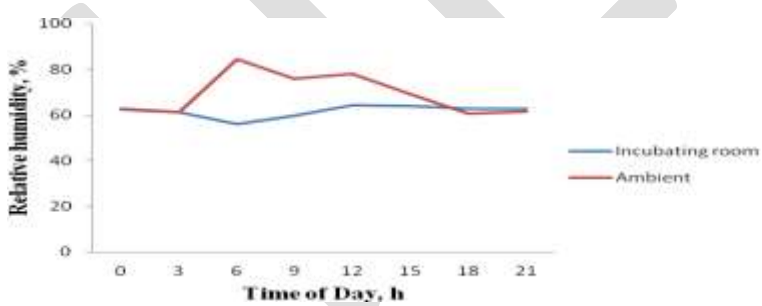

Fig. 5: Relative humidity variation with time of day

It was observed from Figure 4 that between the hours of 12 midnights to 9:00, incubation temperature range of 36.9℃ - 39.2℃ was obtained within 20 cm distance from the thermal mass which was within the acceptable range of 37℃ - 39℃ (Oluyemi and Roberts, 1979). Also, between the hours of 12 noon to 21:00 GMT, incubation temperature range of 38.5℃ - 38.9℃ was maintained at a distance of 100 cm away from the thermal mass. Similarly, from 9: 21:00 to 12 midnight and at 9: 00, the temperature was ideal at around 60 cm away from the thermal mass.

Figure 5 indicate that the relative humidity of the incubating room were consistently lower than that of ambient values except in the midnight hours. This may be due to condensation occurring leading to drop in the ambient relative humidity.

Biological performance

Out of 125 eggs that were stocked into the incubating chamber, 74.4 percentage fertility and 73.1percentage hatchability were recorded at 21 days incubation period. Figure 6 shows the newly hatched chicks. The fertility loss incurred may be as a result of possible damage to some eggs during transportation from hatchery to experimental site.

Fig. 6**:** Young Hatched Chicks few hours after hatching

CONCLUSION

The design of solar powered poultry egg incubator using local materials was found to be capable to effectively incubate poultry eggs. The results of the internal environment of the incubator established were close to that required by natural egg incubation. The utilization of the system in the poultry industry will solve the problem of power availability. However, a lot still remain to be done to improve the efficiency particularly the system insulation.

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