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Development of solar powered poultry egg incubator

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Proceedings of the 2016 International Conference on SET: A driving force for sustainable development tagged COLENG 2016, Federal University of Agriculture, Abeokuta, March 7-11, 2016

Proceedings of the

**COLLEGE OF
ENGINEERING**

**INTERNATIONAL
CONFERENCE**

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SUSTAINABLE DEVELOPMENT

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INTERNATIONAL CONFERENCE

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Comparison between the Cooling Capacity of the Air-Conditioners installed and Results obtained during Implementation using the Case Study.

As reported earlier, one (1) Air-Conditioner Split System of 23,000 Watts was installed in the laboratory. Using the software just developed and confirmed using the manual method, the dimension of the laboratory (11.68m x 9m) was used which gives the standard Cooling Capacity to be 24,622.4 W.

Table 2 below shows the oneway descriptive analysis of the data. It gives the summary in form of mean values of the reading and the necessary statistical values were also calculated for all the three parameters in both morning and afternoon periods.

Table 2: Summary of the Mean values of the Readings

		Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Temperature	Morning	60	27.320	1.2344	.1594	27.001	27.639	24.6	29.4
	Afternoon	60	28.060	1.5609	.2015	27.657	28.463	25.1	30.3
	Total	120	27.690	1.4496	.1323	27.428	27.952	24.6	30.3
Humidity	Morning	60	40.12	3.845	.496	39.12	41.11	34	50
	Afternoon	60	30.23	7.082	.914	28.40	32.06	20	41
	Total	120	35.17	7.538	.688	33.81	36.54	20	50
No. of People	Morning	60	26.63	13.395	1.729	23.17	30.09	5	46
	Afternoon	60	34.33	8.800	1.136	32.06	36.61	18	50
	Total	120	30.48	11.929	1.089	28.33	32.64	5	50

CONCLUSION

Software developed to determine the Cooling Capacity of CAD/CAM laboratory is indeed an easy tool for any stakeholder in determining the cooling capacity of any building design of known dimension most especially for computer experts to contribute professionally at the designing stage and/or already completed building. It can also be concluded that Air-Conditioners installed (operational) in the CAD/CAM Laboratory, Federal University of Agriculture, Abeokuta (Case study) is not enough for an ideal Computer-Aided Design / Computer-Aided Manufacturing Laboratory in order to ensure optimal performance and system reliability. 23,000 W capacity of air-conditioning system was installed instead of 24,622.4 W capacity that was required. This is evident from the results obtained from the readings after the analysis.

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DEVELOPMENT OF SOLAR POWERED POULTRY EGG INCUBATOR

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ABSTRACT: Chick production from developing embryo is a profitable business in Nigeria due to the high demand of protein. The constant failure of electricity supply in Nigeria obstructs operation of incubator and reduce its performance. This study developed solar powered poultry egg incubator. The dimension of the designed incubator was 610mm×607mm×1649mm with capacity of 150eggs. From the design calculation the sizes of the solar panel, charge controller, batteries and inverters required were 480W, 40A, 400AH and 2000W respectively. The heat loss through the walls by conduction, air convection and ventilation hole were 59.77, 10.9741 and 0.0003222W respectively. The heat generated by 150eggs due to the metabolic activities was 21.9W. Out of the 146eggs loaded 64% of the eggs were fertile while the percentage of chicks that hatched, chicks with unabsorbed yolk, fully developed chicks but not hatched and banger were 44%, 40%, 13% and 3% respectively. All the embryos in the fertile egg developed to the last stage (21st day) of incubation period. The low hatchability may be as a result of the faulty hygrometer used which led to increase in the number of opening made at the last stage. The modification of the developed incubator would improve the efficiency of the incubator.

Keywords: Incubator; Temperature; Hatchability; Poultry Egg; Relative humidity; Solar system.

Introduction

Incubation of egg is a process of transforming embryo in an egg into chick under favorable environmental condition with or without the consent of mother birds.

There are two ways hatching of eggs can take place; one is by natural incubation which involves the broody bird sitting on a clutch of eggs while the other way is by artificial incubation which involves the use of incubator.

The most important difference between natural and artificial incubation is that the parent provides warmth and stirring of the eggs by contact rather than surrounding the egg with warm air and provision of artificial stirrer.

A broody hen can just hatch about 10-12 eggs at once in 21 days, which reduces its productivity as it takes time to incubate and hatch the chicks. More so, some large birds such as condors and albatross, may lay only a single egg every two years.

An incubator is a machine for keeping fertilized eggs warm, as the embryo transform into a chick in 21days. Incubator for egg hatching has made a great impact in the agriculture world. It increases the production of chicken, duck, turkey and their eggs to the food industry.

The high demand of chicken, fowl, turkey etc in market, hotels, guesthouses and hospital has make chick production form developing embryo to become commercialized. Constant power supply is necessary for all incubators especially when the eggs are to be hatched. If there is any breakdown in the power supply then the eggs lose their hatching value. The solar incubator on the other hand does not face this problem. The solar incubators also have the advantage of been reliable, light in weight and handy for carrying. Silent and power saving incubator is an innovative machine for rural poultry farming.

The solar system has proven to serves as a source of power for the incubator which could provide continuous power supply throughout the period of the incubation without failing. The main objective of this study is develop a solar powered poultry egg incubator.

Temperature, humidity, ventilation and turning during the incubation period markedly affect the hatchability of fertile eggs and chick quality (Benjamin, 2012). The most vital factor of incubation is the constant temperature required for the embryo development over a specific period. The humidity is also critical, and if the air is too dry the egg will lose too much water to the atmosphere, which can make hatching difficult or impossible. The minimum and maximum temperature recommended for the first 18 days were 37.7°C and 39.3°C respectively.

After 18 days of incubation, the temperature was reduced from 37.8°C to 36.0°C until the chicks were hatched. Hence for the whole period of incubation, the temperature was maintained within the range of 36°C and 39°C as recommended by previous research workers (Oluyemi and Roberts 1988). The minimum and maximum humidity values recommended within 18 days were 52% and 62% respectively. After the 18th days, the relative humidity was increased from 55% to 71% until the end of the period of incubation as recommended in pervious works (Komolafe *et al*; 1981, oluyemi and Roberts 1988). Hence for the whole period of incubation, the relative humidity was varied between 52% and 71%.

The use of solar energy has been gaining significance as a continuous supply of alternative power source, which seems to have an answer to frequent power constraints faced by farmers. Continuous supply of conventional energy in Nigeria is a mirage, due to frequent power outage Kuye el al (2008). The components of solar powered system used in the powering the solar incubator are PV solar module/cells/arrays, Charge controller, Deep cycle Battery, and Solar inverter (Zeman, 2001).

Design Analysis and Construction

The incubator design calculations were based on the conditions required for the machine to work effectively. Some of the conditions were the temperature of the incubator which was to be maintained, relative humidity and the turning mechanism which turns few seconds after every one hour.

Design of ventilation holes

According to Theraja, (2003)

Angular speed of the fan in rev/sec = $V_{fan} = 0.05$ revs/seconds

Taking the diameter of fan as 250mm

Radius of the fan= $r=(d/2)=(250/2)=0.125$ m

Speed of fan in m/s= $V_{fan} = \omega r = 0.05 \times 2 \times \pi \times 0.125 = 0.0393$ m/s....

Total cross-sectional area of the ventilation holes = A_T

Volume airflow rate through the ventilation hole= total cross-sectional area of the ventilation holes × speed of fan = $A_T \times V_{fan}$1

Volume of the incubator chamber =total volume of the air in the chamber = 0.2359 m³.

Safe time require to empty all the air in the chamber= $T_{safe} = 3$ hours= 10800seconds

Volume airflow rate = $\frac{\text{Total volume of air in the chamber in m}^3}{\text{Safe time require to empty all the air in the chamber in seconds}}$ (eq. 5)

$$= \frac{V_{chamber}}{T_{safe}} = \frac{0.2359}{10800} \dots \dots \dots (eq. 6)$$

$$V_{fan} \times A_T = \frac{V_{chamber}}{T_{safe}} = 0.00002184 \text{m}^3/\text{s}$$

$$A_T = \frac{V_{chamber}}{T_{safe} \times V_{fan}} = \frac{0.00002184}{0.0393} = 0.0005557 \text{m}^2$$

Since A_T =Total cross-sectional area of the ventilation hole= πr^2

$$A_T = 0.0005557 = \pi r$$

Where, r = the radius of the ventilation hole

$$r^2 = \frac{0.0005557}{\pi} = 0.0001769 \dots \dots \dots (eq. 11)$$

$$r = 0.01330 \text{m or } 13.30 \text{mm}$$

Total Heat Loss through the Walls of the Incubator

The formula used to calculate heat loss by conduction was:

$$R = \frac{L}{AK \dots \dots \dots (eq. 13)}$$

$$Q = \frac{-\Delta T}{\sum R_{TH}} \dots \dots \dots (eq. 14)$$

$\sum R_{TH}$ = the overall conduction thermal resistance

ΔT = temperature difference (K)

A= surface area of the incubator walls (m²)

L = thickness of the incubator walls (m)

K = thermal conductivity of each wall (W/mK⁻¹)

Q = the rate of conduction heat loss through each wall

Heat Loss by Air Convection on the Outer Surface of the Walls

The formula used to calculate the heat loss by convection was:

From Mahesh (2008),

The Grashof number for fluid (air) for the wall =

$$Gr_{LT} = \frac{g\beta(T_s - T_\infty)(L_c T)^3}{\nu^2} \dots \dots \dots (eq. 15)$$

Where, g=acceleration due to gravity (m²/s)

β = inverse of the mean film temperature (K⁻¹)

ΔT =difference in temperature between the wall surface and the ambient air (K)

L_c=characteristic length of the wall (m)

ν = kinematic viscosity of air (m²/s)

From Mahesh (2008), the Rayleigh number for fluid (air) on the outer wall= Ra=Gr_L×Pr

Where, Pr=Prandtl number for fluid (air) on the outer wall

Gr =Grashof number for fluid (air) on the outer wall

Ra= Rayleigh number for fluid (air) on the outer wall

From Mahesh (2008), Nu=0.59Ra^{1/4} (eq. 16)

Where, Nu=Nusselt number for fluid (air) on the outer wall

Ra= Rayleigh number for fluid (air) on the outer wall

From Mahesh (2008), The average convective heat transfer coefficient for the wall=

$$hc = \frac{Nu k_{air}}{L_c} \dots \dots \dots (eq. 17)$$

$$Q_C = hc A (T_s - T_\infty) \dots \dots \dots (eq. 18)$$

Where, Q_C = the convective heat transfer on the wall of the incubator

hc= The average convective heat transfer coefficient for the wall

A= area of the outer wall

T_s =temperature of the wall surface,

T_∞ =air temperature

Quantity of Heat Loss by Ventilation Hole

Quantity of heat loss by ventilation hole was calculated using Q_v=ρVΔT (eq. 19)

Where, V= Ventilation rate (m³/s) = 0.00002184m³/s (eq. 20) ρ at 38.5°C was found to be 1.135kg/m³

∴ Q_v = 1.135×0.00002184×(38.5-25)=0.0003346W (eq. 21)

Heat Production by Eggs

Heat production due to the metabolic activities of the eggs was estimated using the average of Lourens et al (2005) heat production rate of 137mW for small egg and 155mW for big egg. A heat production rate of 146mW was used for the design.

Therefore the heat generated by one egg due to metabolic activities = 146mW (eq. 22)

The heat generated by 150 eggs due to the metabolic activities = W= 146mW × 150 (eq. 23)

W= 21.9W (eq. 24)

Design of the Solar System

The first step in designing a solar PV system for the egg incubator is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system which is as follows:

The electric loads in the incubator system are electric fan, electric motor and electric bulbs which are to be powered by the solar system.

Energy consumption of all loads in the egg incubator= P_BT_B+P_MT_M+P_FT_F

Where

P_B, P_M and P_F are the power rating of the bulb, electric motor and electric fan respectively.

P_B, P_M and P_F are taking as 100W, 1hp(750W) and 20W respectively.

Considering the starting torque of the electric motor where the starting electric current is two times the operating electric current. The electric power of the electric motor was calculated as:

P_M=1hp×2 or (750 ×2 watts)=2hp or (1500watts)

While T_B, T_M and T_F are the time of usage of the bulb, electric motor, and the fan per day respectively.

Since the loads (electric bulb and electric fan) are required to be working for the whole day while the electric motor is to be rocking 2seconds after every one hour throughout the whole day.

T_B=24hours=86400seconds,

$T_M = 2 \times 24 = 48$ seconds,

$T_F = 24$ hours = 86400 seconds,

Energy consumption of all loads in the egg incubator = $100 \times 86400 + 1500 \times 48 + 20 \times 86400$
 = 10440000 Joules (eq. 26)

Sizing of the PV Modules (Solar Panel or Cell)

Size of solar modules in watts = $\frac{\text{total daily energy requirement in joules}}{\text{total seconds of sunlight during the day in seconds}}$ (eq. 27)

Taking the hours of sunshine as 7 hours or 25200 seconds we have

Size of solar modules in watts = $10440000 / 25200 = 414.29$ Watts or 414.85 J/s
 480 Watts power rating of solar panel would be needed

Size of Batteries

To determine the size of the battery (total capacity) the equation below is used:

The size of battery in AmpHours = $\frac{\text{total energy requirement for period without sunshine}}{\text{Nominal battery voltage}}$

Taking the nominal battery voltage as 12 Volts.

Since the sunshine hours is taking as 7 hours, the battery is required to store charge based on the remaining hour without light which is 17 hours.

Let total energy required for the whole day = E_{day}

Time which energy is required in the incubator per day = $T_{day} = 24$ hours = 86400 seconds

Time without sunshine = $T_{wo} = 17$ hours = 61200 seconds

The total energy required by the incubator for the period without sunshine is calculated as:

The total energy required by the incubator for the period without sunshine

= $\frac{E_{day} \times T_{wo}}{T_{day}} = \frac{10440000 \text{ Joules} \times 61200 \text{ seconds}}{86400 \text{ seconds}} = 7395000$ Joules

The size of battery = $(7395000 / 12) = 6165250$ Ampsecond

Since battery is size in AmpHours, therefore the size of the battery is:

Size of the battery = $6165250 \text{ Amp} [1/3600 \text{ hours}] = 171.8$ AmpHours

For long life span of solar battery the battery should not be discharged below 50% of its capacity. Therefore the size of the solar battery is multiplied by 2.

The size of the battery = 171.8×2

The size of the battery = 342.36 AmpHours

Therefore, the size of the battery that would be needed is 400AH.

Sizing of the Solar Charge Controller

To figure out what size of solar charge controller needed the following procedure was used:

Size of Solar Charge Controller in Amps = (solar panel wattage) / (nominal battery voltage)

The nominal battery voltage is taking as 12V

Size of Solar Charge Controller in Amps = $\frac{\text{solar panel wattage}}{\text{nominal battery voltage}} = \frac{480}{12}$
 = 40 Amps (eq. 31)

The size of the solar charge controller that would be needed is 40Amps

Sizing of the Solar Inverter

For safety, the power rating of solar inverter should be equal or more than the total loads (electric fan (20W), electric motor 1hp (750W) and electric bulb (100W)) in the incubator in watt at any instant.

Considering the starting torque of the electric motor where the starting electric current is two times the operating electric current. The electric power of the electric motor is calculated as:

$P_M = \text{power of electric motor} = 1 \text{ hp} \times 2$ or $(750 \times 2 \text{ watts}) = 2 \text{ hp}$ or (1500 watts)

The total power of loads in the solar incubator = $P_T = 100 + 20 + 1500$

The total power of loads in the solar incubator = 1620 watts

Since the total power of load needed by the egg incubator is 1620W, therefore, a solar inverter that has at least 1620 watts continuous power rated would be selected.

The size of the solar inverter that would be needed is 2000Watts

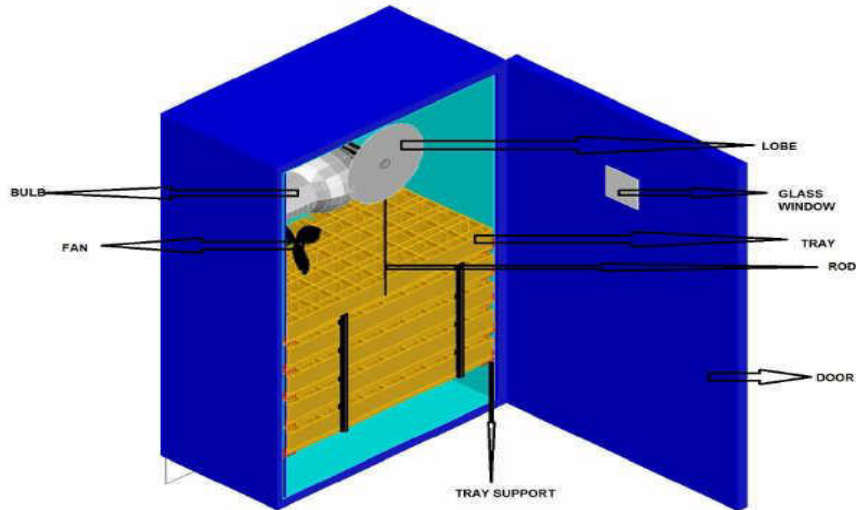


Figure 1: Isometric drawing of the designed solar powered egg incubator



Figure 2: View of the Egg Incubator during Construction



Figure 3: View of the Synchronization of the Constructed Egg Incubator and the Installed Solar System in Operation and View of the Solar Panels during Installation.

Automatic Control System

Automation was used to reduce the need for human involvement in the production of chicks using control system and information technologies. It was introduced in the egg incubator to save labor, energy, improve quality, accuracy and precision of the incubator system with minimal or reduced human intervention.

However, the parameters of the incubation process that required automation are humidity, temperature, turning and ventilation. Automatic control units were provided for temperature and turning to minimize human intervention in area of turning and provide accuracy and correct precision in area of temperature control.

Automatic control units (Automation) for the turning system

For automatic control of the turning system the following control devices were used:

1. On delay timer (Controller)
2. Off delay timer (Controller)
3. Contactor (electric control switch or electromechanical device)
4. electric motor (actuator)
5. Switch
6. Capacitor

Automatic Control Units (Automation) for the temperature control

For automatic control of the turning system the following control devices were used:

1. Thermostat (Controller)
2. Contactor (electric control switch or electromechanical device)
3. Sensor (Probe)
4. heater (Electric bulb)
5. Dimmer (Variable Resistor) for heater
6. Fan (For uniform distribution of heat)
7. Dimmer (Rheostat) for fan. The control of humidity was achieved with Hygro-thermometer clock and. Sensor (Probe)

Results and Discussion

The developed egg incubator and the solar system were installed in Agricultural and Bio Resource Engineering laboratory of Agricultural Engineering department located in AMREC Building at Federal University of Agriculture, Abeokuta.

To have successful hatchability of the fertile eggs tests and performance evaluation were carried out on the installed incubator and the solar system.

Effect of Ambient Temperature on the Interior Temperature of the Incubator

The ambient temperature has great influence on the interior temperature of the incubator which made the interior of the incubator not having a constant temperature throughout the period of incubation but the interior temperature of the incubator was still maintain within the recommended range of 36°C to 39°C with the help of the thermostat. This same observation was reported by Adewumi (2006).

The thermostat was set to 39°C. The effect of ambient temperature on the interior temperature of the egg incubator is shown in table 1.

Table 1: The effect of ambient temperature on the interior temperature of the egg

Time	Temperature, °C (Incubator)	Temperature, °C (Ambient)	Electric Bulb (time on), seconds	Electric Bulb (time off), seconds
7:00am	36	24.7	20	5
7:30am	36	24.6	20	5
8:00am	36	24.5	17	5
8:30am	36	24.6	16	6
9:00am	36	24.4	14	7
9:30am	36	24.9	14	7
10:00am	36	25.2	12	8
10:30am	36	25.8	12	8
11:00am	36	26.8	11	9
11:30am	37	27.1	10	10
12:00noon	37	27.3	10	10
12:30pm	37	27.6	9	12
1:00pm	37	28.3	9	13
1:30pm	38	29.0	8	14
2:00pm	38	29.9	8	15
2:30pm	38	30.3	8	15
3:00pm	38	30.1	8	16
3:30pm	38	30.2	8	17
4:00pm	38	33.2	7	20
4:30pm	39	33.7	7	24
5:00pm	39	32.2	7	28
5:30pm	39	32.7	7	26
6:00pm	38	31.6	7	20
6:30pm	38	30.1	8	12

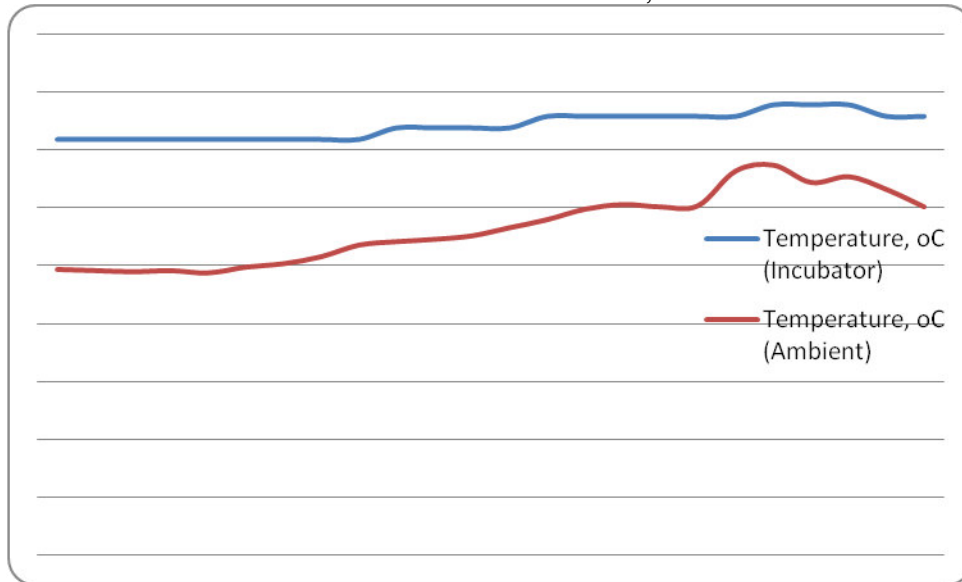


Figure 4: Temperature of incubator and ambient temperature against time

Daily Average Interior Temperature throughout the Incubation Period

The daily interior temperature of the egg incubator and its average for each day were taken throughout the incubation period.

Table 2: Table showing the average daily temperature of the incubator with day of incubation

Day of Incubation	Average daily temperature of the Incubator, °C
1	37.6
2	37.6
3	37.5
4	36.9
5	37.8
6	37.8
7	37.1
8	37.2
9	37.5
10	37.4
11	37.9
12	37.7
13	37.3
14	37.8
15	37.2
16	37.8
17	38.0
18	37.8
19	37.0
20	37.2
21	37.0

Throughout the period of incubation the temperature was maintained within the recommended range of 36°C to 39°C. This was achieved by setting the thermostat to temperature of 39°C for the first 18th day of incubation and 38°C for the last three days of incubation.

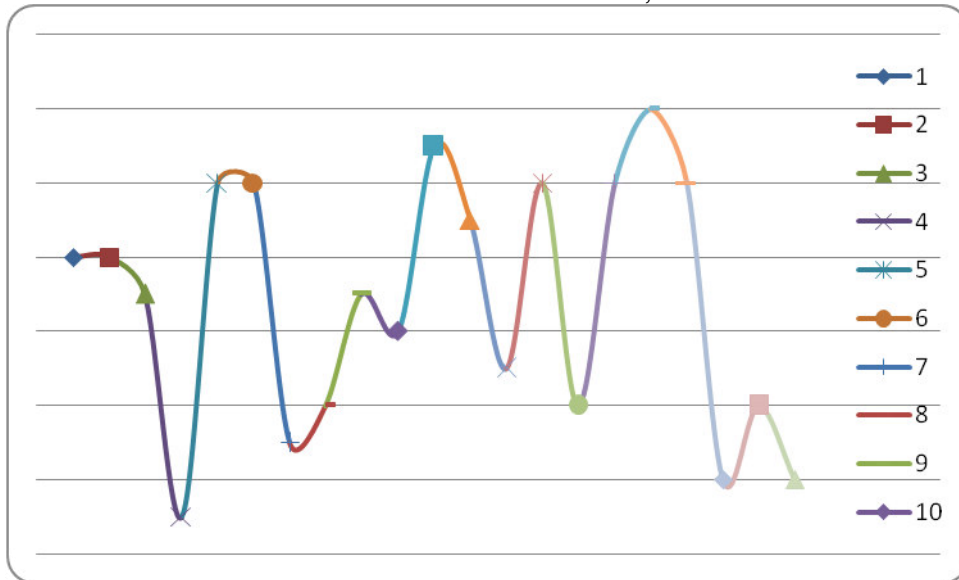


Figure 5: Graph showing the average daily temperature of the incubator with day of incubation

PERFORMANCE TEST ON THE EGG INCUBATOR

S/N	STATUS	TRAY 1	TRAY 2	TRAY 3	TRAY 4	TRAY 5	TOTAL
1	H	06	14	07	10	04	41
2	I	17	07	08	10	11	53
3	U	02	07	13	07	08	37
4	F	04	01	02	01	04	12
5	B	01	01	-	-	01	3
6	G	-	-	-	-	-	-
7	BRT	-	-	-	-	03	03
8	BRV	-	-	-	01	-	01
TOTAL		030	030	030	030	030	150

Table 3: The table below shows the results for the status of egg loaded in each crate after 21 days of incubation:

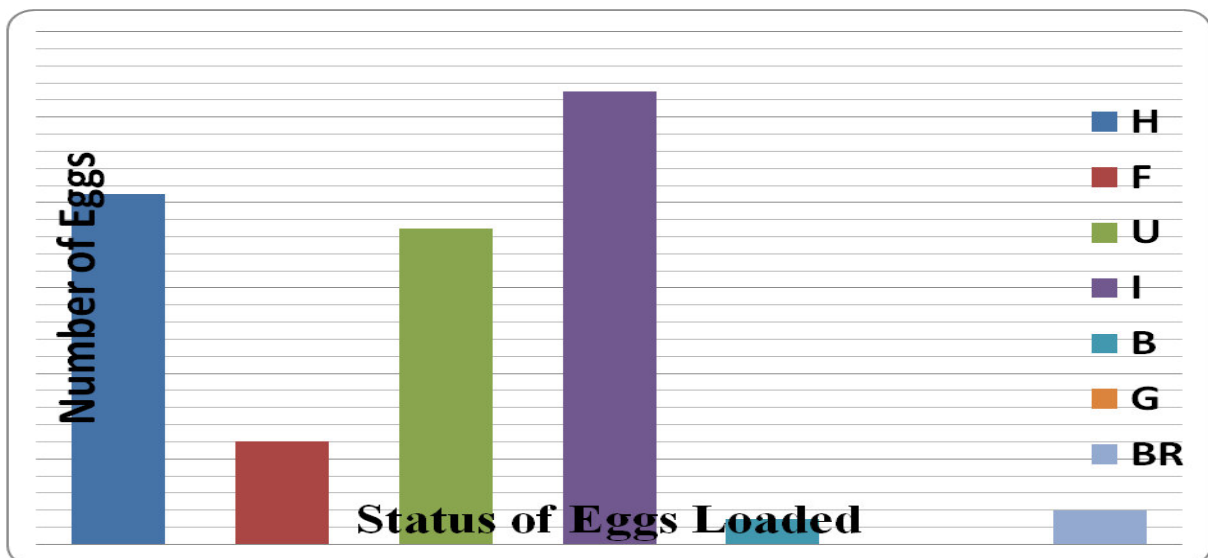


Figure 6: Bar Chat for the Status of Egg Loaded in each Crate after 24th day of Incubation

Table 4: Performance Evaluation of Loaded Eggs on Each Tray

TRAY	Number of hatched	Number of fertile eggs	Total number of eggs	Fertility of the eggs (%)	Hatchability of the fertile eggs (%)
AM1	06	13	30	43.3	46.2
AM2	14	23	30	73.3	60.9
AM3	07	22	30	73.3	31.8
AM4	10	18	29	62.1	55.6
AM5	04	17	27	62.0	23.5
Total	41	93	146		

Fertility of Egg

Fertility of eggs = (number of fertile eggs)/(total number of eggs)

The total number of the infertile egg and Total number of eggs are 53 and 146 respectively.

Number of fertile eggs =total number of eggs-number of infertile eggs = 146 - 53 = 93

Fertility of eggs = 93/146 =63.7% =64%

Hatchability of the Fertile Eggs

Hatchability of the fertile egg in the chamber=(number of hatched eggs)/(total number of fertile eggs)×100%

Total number of chick that hatched was 41 while total number of fertile eggs was 93.

Hatchability of the fertile egg in the chamber=41/93×100%

Hatchability of the fertile egg in the chamber =44.09% =44%

Chick with Unabsorbed Yolk

Percentage of chicks with unabsorbed yolk = (number of chicks with unabsorbed yolk)/(total number of fertile eggs)×100%

The total number of chicks with unabsorbed yolk was 37 while the total number of fertile eggs was 93. The chick with unabsorbed yolk was as a result of slow development at the last stage of incubation.

% of chicks with unabsorbed yolk =(37)/93×100%=39.8% = 40%

Dead in germ (early dead of embryo) was not recorded in any of the tray. All the embryos in the fertile eggs developed to the last stage (21st day). Some hatched; some fully developed but could not hatch while some with unabsorbed yolk.

It is generally accepted that hatched eggs, late hatching, unhatched eggs and dead chicks can be used to evaluate the incubation process, to help determine where improvements can be made.

No dead in germ of the developing embryo was achieved due to uninterrupted power supply provided by the solar power throughout the period of the incubation.

After the 18th day of incubation there was challenge. The hygrometer used could not sense the relative humidity of the interior chamber except that of the ambient relative humidity due to faulty probe (sense).

The rate of evaporation of water in the container used for humidifier increased which lead to increase in the number of opening made. The increase in rate of evaporation was as a result of large number of developed embryo in the chamber which absorbed more of the evaporated water.

Although the temperature was maintained within the recommended range but there was significant quantity of heat loss during the process which led to temperature fluctuation.

It was observed that relative humidity is the most critical factor of incubation during the point of hatching. Correct relative humidity is needed for successful emerge of the chick from the shell. If the relative humidity is low the shell would be so hard for the chick to pipe and to break the shell would also be difficult.



Figure 7: The Chamber on the 18th day and after 18th day of the Incubation period respectively



Figure 8: View of the hatched normal chicks that are healthy and the hatched chicks with broken leg respectively



Figure 9: View of the chick with unabsorbed yolk and chick that were fully developed but not hatched respectively

Conclusion

Production of chicks from a developing embryo is a very sensitive task which required proper monitoring. Any little failure in any of the parameters of production during the period of incubation would lower the hatchability of the fertile eggs especially temperature which is the most critical parameter.

At the last stage of incubation humidity is another most critical factor that must be taking into consideration for successful hatching of the chick that were able to survival to the last stage of incubation.

To have the best result of hatchability of the fertile eggs the incubator system should be designed in such a way that there would be minimal opening of the incubation system.

For automated system, turning of the egg crate should be done at a low speed and few seconds after every one hour to prevent cracking or breaking of the egg due to vibration or collusion of the eggs with the components of the incubator such as crate support, connectors, linkages etc.

The modification of the developed incubator would improve the efficiency of the incubator.

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