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Article

Construction of an Electrically-Operated Egg Incubator

Umar A. B.[1*], Lawal K.[1] and Mukhtar M.[1] and M. S. Adamu[2]

[1]*Department of Physics, Kebbi State University of Science and Technology, Aliero*

[2]*Department of Physics, Bayero University Kano*

* Author to whom correspondence should be addressed; E-Mail: abdulbello2005@yahoo.com

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Abstract: The modem hatchery is an example of scientific solution used to solve a biological problem. An incubator is an apparatus, which simulates the broody bird by means of temperature, humidity and ventilation regulation, as well as turning of egg for embryo development into chick. An electrically operated incubator with the capacity of 60 eggs was constructed and tested. It was constructed using locally available materials and it is a still air incubator. Also when tested the temperature was between the range of 37°C-38°C, the relative humidity was also 55%-60% and turning of egg was done 3 times daily; however the egg did not hatch due to unavailability of a stable power supply. Thus, the power supply to the incubator can be improved using an alternative source of power supply.

Keyword: Temperature; Humidity; Ventilation, Egg Incubator.

1. Introduction

Electrical incubator is a device used for scientific incubation process in which temperature, humidity and other environmental variables can be maintained at desired temperature levels (Adichie *et al.*, 1985). For an egg-incubator, it enhances the propensity of hatching egg in mass. A great number of eggs can be hatched at a time while the layers (mother hens) can be free to lay more eggs thereby resulting into high poultry production and low reduction in expenditure. The relevance constitutes an aspect of encouraging or promoting food production and security which is very significant in our present dispensation of global economic melt-down. The complexities involved in the fabrication of incubators manufactured in the developed countries is that they are too advanced in terms of materials

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or technical expertise and are very expensive to come by for less developed countries to cope with (Alabi and Isah, 2002). Concerted efforts have been made to use the principles of physics or electronics to construct an egg incubator that is very simple to operate and use (Adewumi *et al.*, 2001).

Egg incubation is a technology that provides opportunity for farmers to produce chicks from egg without the influence of the mother hen, is also one of the ways of transforming eggs to chicks. The most important difference between natural and artificial incubation is the fact that the natural parent provides warmth by contact rather than surrounding the egg with warm air in case of artificial incubation. The developing chick in an egg is called an embryo, and a careful study of the different stages of embryonic development will uncover many interesting facts. Incubation of eggs will show you the effects of heat, air, and moisture on hatchability. Over the years, incubators have been refined and developed so they are almost completely automatic. Modern commercial incubators are heated by electricity, have automatic egg-turning devices, and are equipped with automatic controls to maintain the proper levels of heat, humidity, and air exchange. Both still-air and forced-draft incubators are used in hatcheries. However, all the new incubators are forced-draft; that is; they have fans to circulate the air. They are capable of maintaining more even temperature, humidity, and oxygen levels than still-air incubators (Resnick and Halliday, 1992). Eggs of exotic birds and common chickens require a standard measure of care in storage and incubation to ensure a successful hatch. Environmental conditions, handling, sanitation and record keeping can impact the success of incubating and hatching eggs. Most eggs are laid by mid-morning. Eggs should be collected several times a day to reduce the amount of time eggs remain in the nest. This practice decreases the number of cracked and soiled eggs and also prevents premature incubation. Embryos begin to prematurely develop at temperatures above 72°F (22.2°C) (Sani *et al*., 2000).

The size, shape, color, and texture of a bird egg are specific to each species. They contain thousands of pores through which water can evaporate and air can seep in, enabling the developing embryo to breathe. Developing embryos are extremely sensitive to the temperature of its immediate environment, it was observed that some eggs will hatch if they continuously maintained at a temperature between 35°C and 40°C**,** further suggested that the optimum temperature is between 37°C and 38°C in forced draft incubator and about 1°C higher in still air incubator, they observed the relationship between the relative humidity and temperature in forced draft incubator and inferred that as the humidity increased the temperature required decreased (Aremu and Shaiwoye, 1993).

2. Material and Methods

2.1. Material Selection

The success of construction depends much on the choice of material which is one of the most important considerations. Materials are selected to provide characteristics that are essential to

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construction and also desirable. Most often, the choice of materials dictates the manufacturing processes to be used and the manufacturing cost of the product.

2.1.1. Selection of appropriate material

Successful material selection depends on the ability to satisfy the mechanical properties and operating factors of which are:

(i) Mechanical properties (i.e. strength. Durability)

(ii) Finishing and coating

(iii) Chemical composition and reaction

2.1.2. Steps of materials selection

Analysis of material required, this includes; Mechanical properties and composition, identification of alternative materials, selection for the best materials, development or construction, data collection and interpretation.

2.1.3. Factors to be considered in material selection

A good knowledge of the engineering properties of a material and the functional requirements of the proposed machine would provide a guide on appropriate choice of materials to be used. Such properties include: strength of materials, durability, resistance to corrosion, hardness, toughness, workability, ease of cleaning and appearance.

2.2. A Mathematical Model of an Incubator

A mathematical model was derived to describe heat transfer characteristics of the incubator by presenting the relationship between temperature and the incubation time.

$$Qin - Qloss = mc_v \frac{dT}{dt} \quad [1]$$

Equation 1 can be written in the form of a finite
Difference as Eq. 2 and 3:

$$\frac{T(t+\Delta t)}{\Delta t} = \left(\frac{Qin - Qloss}{mc_v}\right) \quad [2]$$

$$T(t+\Delta t) = \Delta t\left(\frac{Qin - Qloss}{mc_v}\right) + T(t) \quad [3]$$

Qloss was considered from heat lost by conduction and convection of incubator walls. Equation of Qloss was shown in Eq. 4:

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$$Qloss = (((U1A1 + U2A2 + U3A3)(T(t) - Tatm))) \quad [4]$$

Hence, from Eq. 3 and 4 the relationship between temperature and time were Eq. 5:

$$T(t + \Delta t) = \frac{\Delta t}{mc_v}(Qin - ((U1A1 + U2A2 + U3A3)(T(t) - Tatm))) + T(t) \quad [5]$$

where: Qin = Heat input to incubator (Watts), Qloss = Heat lost by conduction and convection (Watts), T = Temperature of incubator (K), t = Time (sec), m = Mass of air inside incubator (kg), Cv = Heat capacity of air (kJ $(kg/K)^{-1}$), U1 = Overall heat transfer of vertical plate (Wm^{-2}/K), U2 = Overall heat transfer of horizontal plate; hot surface facing down (Wm^{-2}/K), U3 = Overall heat transfer of horizontal plate; hot surface facing up (Wm^{-2}/K), A1 = Area of vertical wall (m^2), A2 = Area of top horizontal wall (m^2), A3 = Area of bottom horizontal wall (m^2), Tatm = Atmosphere temperature (K)

Equation 5 is a simple form of mathematical model of an electrical incubator. This model is used to examine the behavior of the constructed incubator by substituting the thermo-physical properties of selected materials in the equation. The calculation and experimental results were compared and presented in the experiments and results.

2.2.1. Temperature

Temperature was the most important factor in the incubation. The best hatch obtained by keeping the temperature at 37°C throughout the incubation period when using a forced-air incubator. Minor fluctuations (less than 0.5°C) above or below were 37°C tolerated, but did not let the temperatures vary more than a total of 1°C (Abiola, 1999).

2.2.2. Humidity

Humidity was carefully controlled to prevent unnecessary loss of egg moisture. The relative humidity in the incubator between setting and three days prior to hatching should remain at 58-60%, wet bulb. If the relative humidity inside the incubator was too low or too high, there was a hatching problem called red hocks. These chicks could possibly suffer from weak legs (Abiola, 1999).

2.2.3. Air ventilation

Ventilation played a role in cooling an overheated machine as well as making sure the oxygen; Carbon dioxide exchange was maximized. The internal fan speeds were very important and should be roughly 7200 rpm (Abiola, 1999).

2.2.4. Positioning and turning

Egg is positioning in the incubator and turning ensured that the embryo was fully developed and in position to hatch. Common practice in the chicken was to set the eggs vertically with the air cell

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at the top of the egg. Any eggs that were positioned on their sides should be turned on their long axis. This means the eggs were set at a 45° angle, after a 90° turn; they face 45° in the other direction (Abiola, 1999).

2.3. Methods

An Incubator for chicken egg was constructed in order to test, determine and evaluate its performance. The Incubator box gross dimension was 100cm long, 80cm width and 50cm height, it made from plywood of 18mm thick. The heat source was two lamps of 100 Watts tungsten lamps, The Incubator box had a dimmer switches to adjust the temperature at the middle of the Incubation to 37^{o}C, One little fan was also installed to ventilate air inside the incubator, Water tray was placed on the bottom floor of the cabinet to increase and recover humidity in the incubator during the experimental period. Two thermometers used to measure the dry-bulb and wet-bulb temperature inside the incubator, one thermometer used to measure the egg surface temperature at the top.

Regarding the information listed above, which is the important factors for artificial incubation, an electrical incubator was then constructed. This machine has a capacity of 60 eggs spread in two trays.

2.4. Mechanical Design

The project construction began with the mechanical components which consist of the incubator Frame, casing and the egg turning trays.

2.4.1. Incubator casing

The construction of the incubator began with the hard wood using 20mm square to construct the main body of incubator as shown in figure 1.

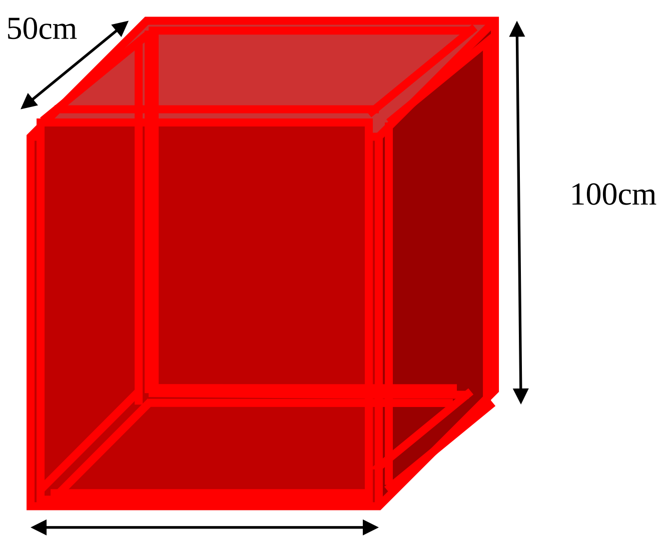

Figure 1: Structural framework

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Good quality plywood was used to create the side boards to give the aesthetic carved out shape. The plywood was chosen due to its insulation properties, ease in construction, flexibility, durability and availability.

2.4.2. Egg turning trays

The egg turning trays is very important in order to change the position of eggs. The egg must be turned at least one times daily. The two egg turning trays were made of flexible wire net of 6mm thickness and soft wood for frame work. Each holding 30 eggs and a total egg holding capacity of 60 eggs. The eggs turning trays as shown in figure 2.

Figure 2: The Egg Turning Trays

2.4.3. Thermometer

A thermometer is a device that measures temperature or a temperature gradient. A thermometer has two important elements: the temperature sensor (e.g. the bulb on a mercury-in-glass thermometer) in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (e.g. the visible scale on a mercury-in-glass thermometer) (Benedict, 1984).

2.4.4. Fan

A mechanical fan is a machine used to create flow within a fluid, typically a gas such as air. The fan consists of a rotating arrangement of vanes or blades which act on the fluid. The rotating assembly of blades and hub is known as an impeller, a rotor, or a runner. The major function of fan in an incubator is to cool or circulate heat in the system (Steve, 2010).

2.4.5. Humidity measurement

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Humidity is the amount of water vapor (water that has turned from a liquid to an invisible gas) in the air. The humidity is measure by placing two (2) thermometers inside the incubator, one of the thermometers (the wet bulb) has a wet wick around it, and the wet-bulb thermometer reads a lower temperature than the normal (dry-bulb) thermometer. The difference in the temperature readings given by the dry-bulb and the wet-bulb thermometers is a direct measure of the relative humidity.

The absolute temperature of the wet thermometer can be used to calculate the relative humidity of the air.

$$p_w = p_s - AP(T_D - T_W)$$

where:

P_W is the experimental Partial vapor pressure of water, $\boldsymbol{P_S}$ is the saturation vapor pressure at temperature T_W, **A** is the psychrometer constant (typically values of A, for T_W above 0°C, are around 5×10^{-4} to 10^{-3}), **P** is the experimental pressure, $\boldsymbol{T_D}$ is the dry bulb temperature, $\boldsymbol{T_w}$ is the wet bulb temperature.

The figure 3 below show the humidity measurement

Figure 3: The Humidity Measurement

2.5. Electrical Design

The circuit consists of alternative current (AC) power supply. The incubator has junction box (Figure 4) to connect the electric fan and bulbs with the dimmer control switch (DCS) to adjust the mean temperature inside the incubator at 37°C manually.

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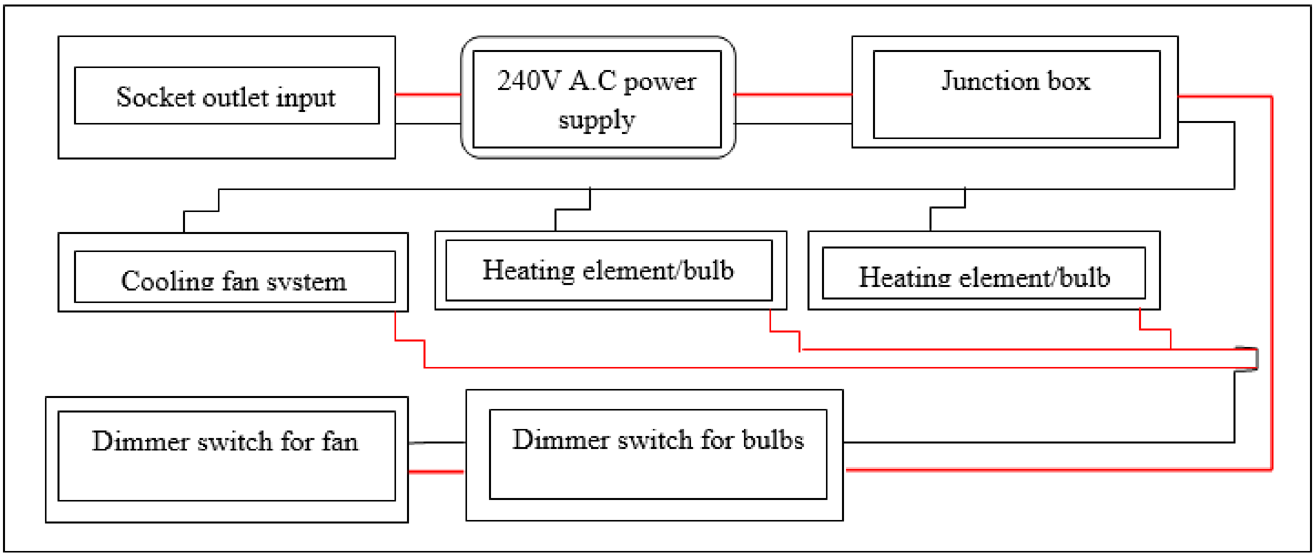

Figure 4: Block diagram of the electrical design

2.5.1. The electric bulb

An incandescent light bulb, incandescent lamp or incandescent light globe is an electric light which produces light with a wire filament heated to a high temperature by an electric current passing through it, until it glows. The hot filament is protected from oxidation with a glass or quartz bulb that is filled with inert gas or evacuated. Incandescent bulbs convert less than 5% of the energy they use into visible light with the remaining energy being converted into heat. The major function of incandescent lamp in an incubator it served as source of heat to the system (Roy, 2006). The figure below show electric bulb

2.5.2. The dimmer switch

The Incubator box had a dimmer switch Fig. 3.5.2 to adjust the temperature at the middle of the Incubating to 37°C, The dimmer switch made from a plastic of rubber inside is a copper connected with an electric cut off which used in house, behind it iron spring to touch one side of electric cut off, and to touch the other side of it and close the electric circuit manually by rotating the dimmer switch to a certain level in order to increase the temperature of the incubator when the temperature inside the incubator was less than 37°C. But when the mean temperature inside the incubator is greater than 37°C, we also use the dimmer switch to decrease the temperature inside the incubator (Bellman, 2001).

2.6. Principle Operation of Incubator

The temperature of incubator is maintained between the ranges of 37-38°C. The thermometer used to measure the temperature at a level or slightly above where the center of the egg. Overheating the embryo is much more damaging than is under heating it, overheating speeds up embryo development, lowers the percentage of hatchability, and causes abnormal embryos. Although a short

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cooling period may not be harmful, longer periods of low temperatures will reduce the rate of embryonic development. Excessively low temperatures will kill the embryos. If the temperature remains beyond either extreme for several days, hatchability may be severely reduced.

Humidity; the moisture level in the incubator should be about 50 to 55 percent with an increase to about 65 percent for the last 3 days of incubation. Moisture is provided by a pan of water under the egg tray. The water surface should be at least half as large as the surface of the egg tray. Add warm water to the pan as necessary. If more humidity is needed, increase the size of the pan or add a wet sponge. Humidity adjustment can also be made by increasing or decreasing ventilation. Figure 5 shows the normal size of an egg's air cell at 7, 14, and 18 days of incubation.

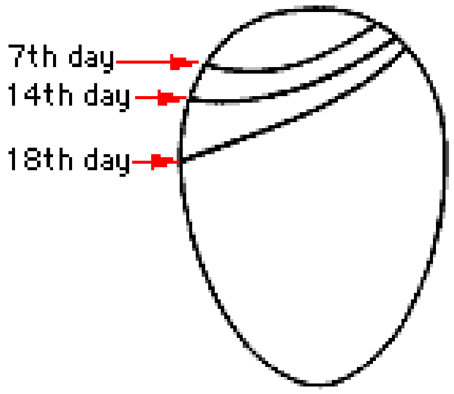

Figure 5: Size of the air cell in the egg on the 7th, 14th, and 18th day of incubation (Demuth, 2001)

The Ventilation of incubator is adjusted by increasing or decreasing openings in the sides or top of the incubator. Normal air exchange is needed during embryo development and should be increased as the chicks begin to hatch. The embryo needs oxygen and produces carbon dioxide. However, the correct relative humidity must be maintained until most of the chicks are out of their shells (Demuth, 2001).

The Turning of the eggs should be placed into the incubator on their sides. Turn them at least three times a day, Turn the eggs an odd number of times so the position that is up the longest (at night) will be changed from day to day. Mark the date on each egg so you can tell if the eggs have been turned. When you turn the eggs, move them to a different part of the tray to minimize the effects of temperature variation in the incubator. If the eggs are not placed on their sides, they should be placed at an angle so the small ends are in the downward position (Kaufmann and Bennett, 1989).

As temperature changes, so does the oxygen consumption of the embryo and, hence, its heat production, H_{emb}. Avian embryos for the majority of the incubation time are poikilothermic and therefore do not increase their metabolic heat output to maintain T_{emb} when T_{inc} declines. Indeed, the opposite occurs and as T_{inc} decreases so does oxygen consumption (Tazawa *et al.*, 1989) showed that

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at about 18 days of incubation the chick embryo could maintain oxygen consumption when temperature fall from 37 to 35^{o}C but as temperature decreased further, oxygen consumption then declined. After piping, an increase in oxygen consumption in response to a decrease in T_{inc} has been observed in both chickens (Tazawa *et al.*, 1989) but full thermoregulatory response in Galliformes only develops after hatching. The temperature experienced by the developing embryo is dependent on the incubator temperature, the metabolic heat production of the embryo, and the thermal conductance of the egg and surrounding air. Studies investigating the effects of temperature on the development and hatchability of poultry embryos have concentrated mainly on the effects of incubator temperature and have ignored the other two factors (French, 1997).

The Sanitation of incubator taking off after the hatching, broken egg shells and membranes are usually left in the egg chamber. At times, unhitched eggs may be left in the incubator and all these left over materials needs proper clearing and disinfection after each hatch (Lourens *et al.*, 2005). The figure 6 below show the principle operation of incubator:

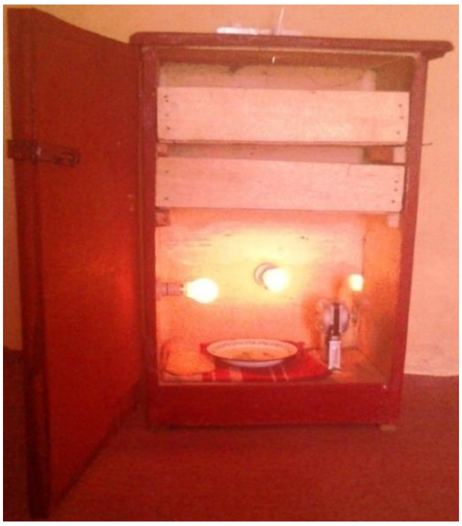

Figure 6: The incubator

2.7. Theory of Heat Exchange

The thermal energy of incubation has been modeled by (Kashkin, 1961), (Kendeigh, 1963), (Sotherland *et al.*, 1987), (Meijerhof and Beek, 1993). A simple form of the model can be given as:

$$T_{egg} = \frac{T_{inc} + (T_{emb} - T_{waterloss})}{K}$$

where:

T_{egg} = temperature of the egg (Celsius), T_{inc} = temperature of incubator (Celsius), H_{emb} = heat production of embryo at a given moment of incubation (watts), $H_{water\ loss}$ = heat loss from evaporative

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cooling (watts), and K = thermal conductance of egg and surrounding boundary of air around the egg (watts per degree Celsius). The heat balance of an animal is described by (Schmidt-Nielsen, 1975) as follows:

$$H_{emb} = H_{water\ loss} + H_{rad} + H_{conv}$$

Or can be written as,

$$H_{emb} - H_{water\ loss} = H_{rad} + H_{conv}$$

where H_{rad} and H_{conv} are the heat lost or gained by radiation and convection (watts) respectively.

Equation (1) uses the terms $H_{emb} – H_{water}$ loss to describe the heat loss or gain from an egg because they are easier to measure than either H_{rad} or H_{conv}. Heat transfer through radiation is assumed to be small because all the surfaces within the machine will be at temperatures close to (within approximately 1 to 2°C) of the surface temperature of the egg. (Kashkin, 1961) estimated that 40 to 45% of the total heat loss from a duck's eggs was by radiation, however, this estimate has assumed that the total egg surface would be able to radiate heat to the surface of the incubator. Equation 1 contains the term $H_{water\ loss}$ because eggs continually lose water through incubation, typically amounting to 12% of the fresh egg weight between the onset of incubation and the start of pipping (Ar and Rahn, 1980). The phase change from liquid water to water vapor requires heat and at incubation temperature this equates to approximately 580cal/g of water lost (Schmidt- Nielsen, 1975). For example, a 60g chicken egg loses approximately 0.4g of water/d, which equates to a heat loss of 232cal/d or 11.2mw. Embryo heat production can be measured directly, but (Romijin and Lokhurst, 1960) showed that it can be estimated by measuring O_2 consumption. Every liter of O_2 consumed by the embryo is equivalent to the production of 4.69 kcal of heat (Vleck *et al.*, 1980). Typical O_2 consumption of a chicken egg just before piping is 570mL/d equivalent to heat production of 2.67kcal/d or 130mw. At the onset of incubation, H_{emb} is negligible and therefore $T_{egg} < T_{inc}$ because $H_{emb} < H_{water\ loss}$. The thermal conductivity term, K, used in Equation 1 combines the thermal conductivity of the egg (K_{egg}) and the boundary layer of air around the egg (K_{air}). (Sotherland *et al.*, 1987) determined values for K_{egg} and K_{air} and showed that the air boundary layer around the egg was approximately 100 greater a barrier to heat loss than the egg itself. These also showed that the value of K_{air} is dependent on the air speed over the eggs and the relationship could be estimated as follows:

K = (0.97 V0.6) M0.53

where V = air speed (centimeters per second), and M = egg mass (grams).

The effect of changing air speed from 0 to 100 or 400m/s increased thermal conductance by approximately 2.5 and 6, respectively. A similar relationship was found by (Meijerhof and Beek, 1993). An important consequence of the relationship between K_{air} and air speed is that the differential

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between T_{egg} and T_{inc} during the second half of incubation will become greater at slower air speeds. (Meijerhof and Beek, 1993) estimated the increase in T_{egg} over T_{inc} for eggs of different weights and H_{emb} at two air speeds, 0.5 and 2 m/s. Similarly, it is possible to use the values of K derived by (Sotherland *et al*., 1987) for air speeds of 0, 1, and 4 m/s in Equation 1 to estimate $T_{egg} – T_{inc}$

3. Testing and Results

3.1. Testing

At the end of construction of the incubator, performance test was done to determine its efficiency. Chicken egg which require 21 days of incubation were used in carrying out the test on the incubator. A total of 23 days were spent for the testing of the incubator. The first two (2) days were used for sanitation, fumigation and running of the incubator to allow for the detection and possible rectification of defects before eggs were set.

A total of 6 eggs were set on two levels of trays each containing three eggs respectively. The incubation process started immediately. On the seventh day of incubation, the eggs were candled to find out the fertiled eggs. This process of exposing the egg to a beam of candle light is done to see if the eggs are shrimp, which connotes fertility. On the other hand if the egg is infertile, it will not show any shrimp. It was discovered that 2 eggs each both the top and the bottom tray were fertile, thus a total of 4 fertile eggs. The infertile eggs were removed.

Figure 7: An infertile egg

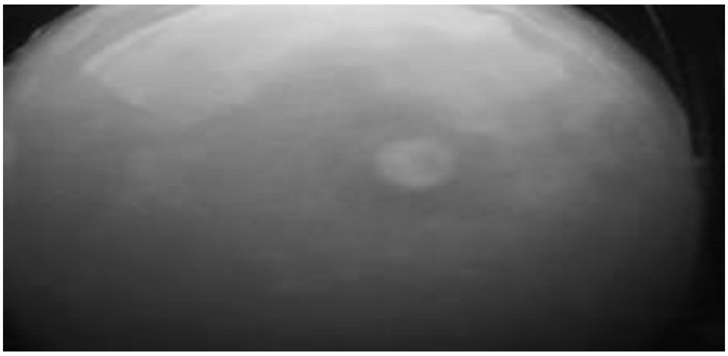

Figure 8: A fertile, un-incubated egg

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Figure 9: A 3-day-old chicken embryo

On the 12th day one egg each were picked from the top and bottom trays respectively and were broken to determine the level of the embryonic development. It was discovered that the embryo has developed features like, eyes, beak, feathers, wings, legs etc. The level of the embryonic development at this stage were clearly noted or established. One egg from the top tray was broken and noted that there no sign of embryonic development, this shows that it is infertile.

Figure 10: A 12-day-old crane embryo

On the 18th day of incubation one fertile and one infertile egg from the bottom tray were broken to observe the level of embryonic development. There were pronounced embryonic development in the fertile egg and no development in infertile egg. On the 21st day, which was the expected day for incubation of chicken eggs, no eggs were hatched and no development on the remaining infertile egg due to power outage for some days.

Figure 11: A 23-day-old crane embryo

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Observations were made from 1st day to the 23rd day and various developmental progresses were noted. Other observations were on the regulation of temperature. It takes the incubator one hour to get to the maximum temperature of 40ºC and three hours to strike minimum temperature of 35ºC regulated by the dimmer switches. The two, most common word used by poultry are 'fertility and hatchability and to arrive at the mathematical percentages, we have:

Percentage of fertility which is the percentage of the fertile eggs at the egg produced.

$$\text{Fertility} = \frac{\text{Nunmber of fertile egg}}{\text{Number of total egg set for production}} \times 100$$

From the test carried out we have:

$$\text{Fertility} = \frac{3}{6} \times \frac{100}{1} = 50\%$$

It is imperative that the fertility and hatchability percentage must be kept high to avoid considerable financial losses most especially when the incubator is run. It is as a commercial venture serving the open market at a targeted production level to maximize profit. For optimal performance of the incubator it is advised that there must be a maintenance schedule.

To enhance profit various does and don't s should be observed visa-vis the cleanliness of the incubator, and selection of eggs, temperature of storage should be 12ºC – 15ºC and 70 – 75% humidity. Eggs should never be stored for more than 14 days as hatchability probability begins to decline significantly after 14 days. It is important that before setting of eggs the eggs must be allowed to attend room temperature of (20ºC - 26ºC). The incubator should be situated at a place where ventilation is free and air circulation is adequate.

3.2. Result and Discussion

The result indicates that the incubator construction was successful as it has given an optimum climatic environment for incubation similar to naturally required conditions. It is cheap, easy to operate and portable. It can be produced in mass and can be operated by non-skilled personnel. The result is displayed in the tables below

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Table 1: Evaluation result of different days

	Time (hrs)	Temperature °C	Relative Humidity %	Turning (° at every 4hrs) Clockwise(+) and Anti-clockwise(-)
DAY ONE	7:00AM	37	45	
	8:00AM	37	45	
	9:00AM	38	45	
	10:00AM	37	45	47
	11:00AM	38	55	
	12:00PM	36	55	
	1:00PM	38	55	
	2:00PM	37	55	- 48
	3:00PM	37	55	
	4:00PM	36	55	
	5:00PM	38	60	
	6:00PM	37	60	46
	7:00PM	37	55	
	8:00PM	36	55	
	9:00PM	37	55	
	10:00PM	37	55	- 45
	11:00PM	38	60	
	12:00PM	36	55	
	1:00AM	38	60	46
	2:00AM	37	60	
DAY TWO	7:00AM	36	60	
	8:00AM	36	60	
	9:00AM	37	60	
	10:00AM	36	60	- 47
	11:00AM	37	60	
	12:00PM	37	60	
	1:00PM	38	55	
	2:00PM	36	60	48
	3:00PM	38	55	

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	4:00PM	36	60	
	5:00PM	36	55	
	6:00PM	37	55	- 46
	7:00PM	37	55	
	8:00PM	36	55	
	9:00PM	37	55	
	10:00PM	37	55	45
	11:00PM	38	60	
	12:00PM	36	55	
	1:00AM	38	60	
	2:00AM	37	60	- 47
DAY THREE	7:00AM	36	55	
	8:00AM	36	55	
	9:00AM	37	60	
	10:00AM	36	55	48
	11:00AM	37	60	
	12:00PM	37	60	
	1:00PM	38	55	
	2:00PM	36	60	- 46
	3:00PM	38	55	
	4:00PM	36	60	
	5:00PM	36	55	
	6:00PM	37	55	45
	7:00PM	37	60	
	8:00PM	36	55	
	9:00PM	37	55	
	10:00PM	37	55	- 46
	11:00PM	38	60	
	12:00PM	36	55	
	1:00AM	38	60	
	2:00AM	37	55	45

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4. Conclusion

The egg incubator has been constructed to be simple in construction and handling. This portable incubator machine attempted to replicate the conditions of natural incubation. It was successful to an extent as to natural incubation. Therefore it can be used to breed or hatch the chicken species as rapidly as possible. The portability, sensitivity, reliability and simplicity of operation of the device proved the instrument to be a dependable tool to farmers in poultry production. Its workability is about 50% efficient.

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