DEVELOPMENT OF A DUAL POWERED POULTRY EGG INCUBATOR

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ABSTRACT

This paper entails the development of dual power poultry egg incubator. It is a 300 egg capacity incubator that was designed to be powered using two sources of energy which are solar energy and electrical energy. The materials selected were wood, mild steel and aluminum. The wood was coated inside with black paint in order to absorb heat making used of four headlight car's bulbs and four DC fan of 1.3A rating each. The temperature and egg turning mechanism were regulated electronically. The results obtained include power supply to the system through out of 21-26 days without power interruption until hatch period by making use of 12volts 200A battery, solar panel 1.5A rating, charge controller, flex solar cable wire, and battery charger(AC-DC). The incubator mechanism was programmed to display after 2 hours interval. The incubating chamber was maintained throughout the incubating period within a temperature range of 37.0˚C to 37.5˚C using a programmed temperature sensor; and relative humidity ranged from 45% to 60%. The percentage hatchability of the eggs was found to be 81%.

Keywords: Eggs; Incubator; Mechanism; Microcontroller; Solar

1.0 INTRODUCTION

Egg incubation is a technology that provides opportunity for farmers to produce chicks from egg without the consent 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. Nothing can be more interesting than the study of the chicken egg and its development from the incubated stage to the emergence of the chick from the shell. The developing chick in an egg is called an embryo, and a careful study of the different stages of embryonic development uncovers many interesting facts. Incubation of eggs shows the effects of heat, air, and moisture on hatchability. Formation of egg would be seen; what its different parts and their functions, and how a chick embryo develops. Eggs have been incubated by artificial means for thousands of years (MohdAdid, 2008).

The world's population is growing at an alarming rate and so is the demand for protein especially in the rural areas; poultry is a good source of protein and it is affordable. A broody hen (a hen that wants to set and hatch eggs and raise the chicks) is limited to hatch just about 10-12 eggs at once in 21 days, which reduces its productivity as it takes time to incubate and hatch the chicks. In contrast, some large birds, such as condors and albatross, may lay only a single egg every two years (Okonkwo 2005). For the world growing population, relying on this natural type of incubation is not enough, hence the need for artificial incubation. This way, a female bird just concentrates on laying eggs while the incubation is done for her artificially (Singh, 1990).

1.1 Aim and Objectives

The aim of this project is to develop a dual power poultry egg incubator.

The objectives to be met are:

(i) to design and construct a dual powered poultry egg incubator using locally available materials and ensuring it's economically viable.

(ii) to test hatchability of chicken eggs at different locations on the four trays of the chamber design

1.2 Background Study

Prior to this project, several studies on dual power poultry egg incubation had already been conducted. In this paper, a dual power poultry egg incubator was designed, fabricated and tested to evaluate its performance. The incubator consisted of a solar collector with a built-in thermal storage and incubating chamber of 300 eggs capacity. From the results, an average outlet collector temperature of 72.4˚C was obtained on the lowest solar radiation day and 51.8˚C was obtained on the lowest solar radiation day. The incubating chamber was maintained throughout the incubating period within a temperature range of 37˚C to 39.5˚C and relative humidity ranged from 58% to 71.5%. The percentage fertility and hatchability of the eggs was found to be 85% and 78.5% respectively.

Renema *et al.,*(2007), studied internal egg temperature in response to pre-incubation warming in Broiler, Breeder and Turkey Eggs. From the study, warming rate potentials for small broiler breeder eggs (52 to 57g), large broiler breeder eggs (64 to 69g) and turkey eggs (74 to 107g) were found to be 0.0506, 0.0488 and 0.0471 kJ/min respectively. It was also found that an increased in egg size decreased the warming rate (Bolaji, 2006). The hypothesis was true for small broiler and large broiler breeder eggs.

Okonkwo, (2008) researched on passive solar heating for poultry chick brooding in Nigeria. From the research, it was found out that solar energy application was the most attractive option for a sustainable energy supply in poultry production. It was also found that in comparison with conventional poultry brooders, solar energy brooding systems were pollution free, environmentally friendly and had low maintenance cost and energy.

1.3 Types of Incubator

1.3.1 Forced Air Incubator

This type of incubator has fans that circulate the air in the incubator and around the eggs; the effect of force air is to ensure air incubating temperature which varies from 37.36°C to 37.56°C and humidity which varies from 28.3°C to 31.1°C (wet bulb).

1.3.2 Still-Air Incubator

A still air incubator consists of a box or container with appropriate dimension (30.50cm × 30.5cm × 40.5cm). There is a 0.95cm inlet at each end between the level of the eggs and the water pan, two outlets 0.95cm in size are provided.

1.4 Theory of Incubation

Incubation is the process by which birds hatch their eggs, and to the development of the embryo within the egg. The most vital factor of incubation is the constant temperature required for its development over a specific period.

Especially in domestic fowl, the act of sitting on eggs to incubate them is called brooding, and most egg laying breeds of chicken have had this behaviour selectively bred out of them to increase production. In most species, body heat from the brooding parent provides the constant temperature. 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. As incubation proceeds, an egg will normally become lighter, and the air space within the egg will normally become larger, owing to evaporation from the egg.

1.5 Factors to Be Considered In Incubation Process

Some of the factors to be considered in the incubation process are: Length of incubation; Temperature; Humidity; Ventilation; Turning of Eggs; Fertile egg quality; Storing fertile egg; Cleaning and culling; Storage time; Embryonic development.

2.0 MATERIALS AND METHODS

Over the course of this project, the dual power system was completed and the control system was incorporated. The dual power system consists of AC-DC battery charger, solar battery, micro controller, DC fans and car headlight bulbs. The LCD display was stable due to the programming incorporation. The incubator consists of a solar PV panel, electricity using charge over switch with built-in thermal storage and incubating chamber of 300 eggs capacity. It also has air ducts for regulating heat flow from the solar collector to the incubating unit.

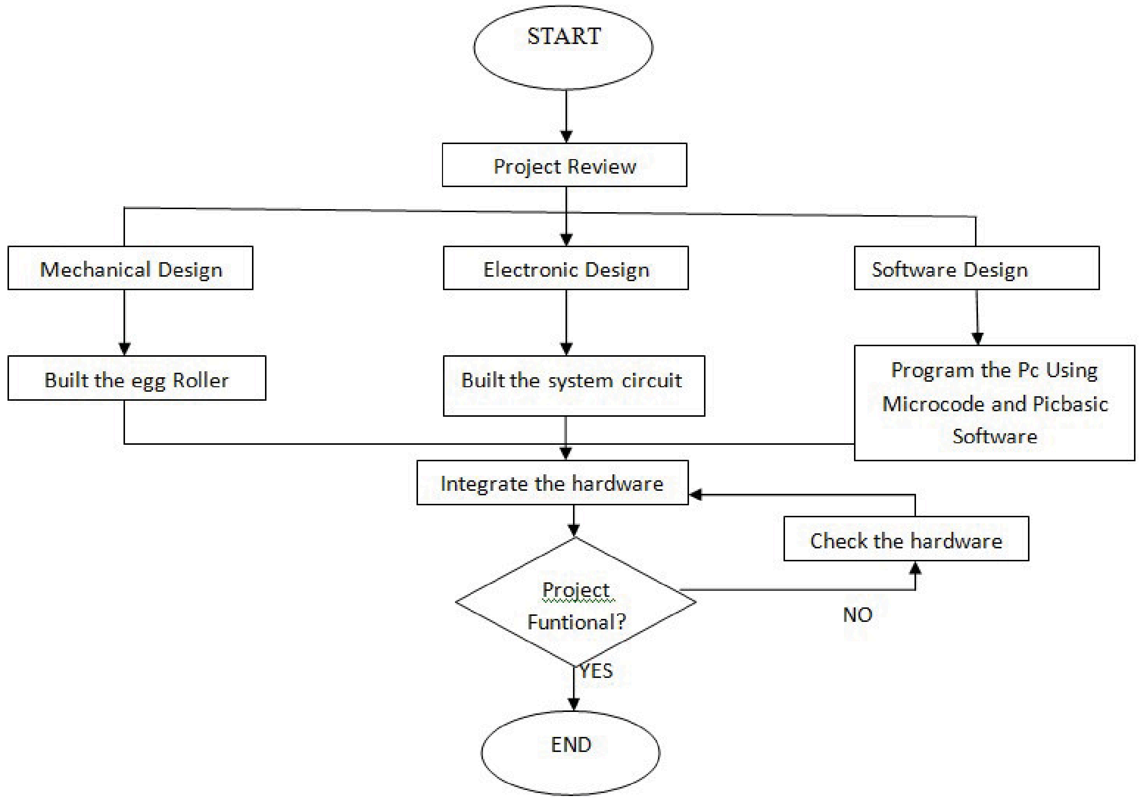

Figure 1: Flowchart of the Project Development

2.1 Assumptions

The design analysis of the solar collector in this project was based on the following assumptions:

- Collector Performance is based on steady state conditions;
- The temperature drop between the top and bottom of the absorber plate and glazing is negligible;
- Heat flow is one dimensional through the cover as well as through the back insulation;
- Thermo physical properties of the materials are independent of temperature;
- Heat losses from the top and bottom of the collector are to the same ambient temperature.

2.2 Preliminary Design

2.2.1 Capacity of the Incubator

This is needed to calculate the total power consumption needed by the system composed by the incubator and any other element added to the system like fans, temperature and humidity meters.

Hence this incubator will have a capacity of 300 eggs.

2.2.2 The Incubator Components

- Frame/Chamber: mild steel, aluminum, wood and fiber glass
- Heating System: car headlight Bulb
- Ventilation: DC Fan
- Control System: Micro-Controller and Digital Thermometer
- Turning System: windscreen wiper motor, and

When it comes to the design of an incubator, heat required and transferred are critical factors and are of major importance. Temperature and relative humidity in the incubator are dependent on the heat supplied and level of ventilation. Adequate heat supply and ventilation enhance air circulation and heat transfer.

2.3 Determination of Humidity

The humidity required for the incubation of poultry egg is the mass of water vapour per unit volume over unit volume of air. It keeps the egg from losing too much or too little moisture during the incubation process. However, humidity depends on mass flow of air, temperature and speed of the fan, therefore the equation to determine humidity is:

$$H = \frac{m_v}{V} \quad (1)$$

$$€ V = m_v R_v T \quad (2)$$

$$H = \frac{V}{R_v T} \quad (3)$$

where;

H= humidity

m_v= molar mass of water

€ = Energy density or heat density

R_v = Gas constant

T = temperature

V = volume

2.4 Determination of Heat Generation

Heat generated Q, is determine as MCΔT. Therefore heat required to raise the temperature of the incubator will be the heat required to raise the temperature of the air, eggs, glass, egg tray, water and wooden wall. Hence, these heats are determined below; for heat generated in the incubator;

$$Q_I = M_I C_I \Delta T \quad (4)$$

Therefore, heat required to raise the temperature are listed below

Air

$$QA = m_A \, CA\Delta T \quad (5)$$

Eggs

$$QE = m_e \, Ce\Delta T \quad (6)$$

Water

$QW = m_w\ CW\Delta T$ (7)

Rosewood

$QP = m_r\ CR\Delta T$ (8)

where; Q = heat

C is specific heat capacity

ΔT is change in temperature

m is molar mass

Therefore, total heat required to raise the temperature of the incubator will be the summation of all the heat of the parameters listed above, given as;

QI= QA + QE+ QT + QW + QR+ Qg (9)

2.4.1 Selection of Windscreen Wiper Motor

Torque generated by wiper motor

Tm = Power Angular velocity

That is, $T_m = \mathbf{60\ x\frac{Power}{2\pi N}}$ (10)

Where;

N = Speed in rpm

Power = $\boldsymbol{\omega}$T (11)

$\boldsymbol{\omega}$ = 2π N

P = 2πNT (12)

N = rev per min.

T = Torque

2.5 Total Heat Requirement

The average mass of one egg was weighed and found to be 60g and the specific heat capacity of the egg was taken to be 3.18 kJ/kgk^{-1} $Qe =$ 60 x10^{-3} x 3.18x10^{3} x (27.5-21.5)

Qe =1144.8 J

The heat energy required for 300 eggs will be:

Qe =300x1144.8 = 343440 J

This is the total heat required to raise the temperature of the eggs from 27.5 to 31.5. But this heat was provided for gradually to avoid cooking the eggs. Usually a warming rate for incubation is taken to be 0.0488 kJ/min. So the time taken to raise the temperature of the eggs from 27.5 to 31.5 was found to be: 0.0488 kJ/min = 48.8 J/min

48.8 J = 1min

343440 J = ?

Time taken = 7037.70 minutes

= 117.295 hours

= 4.8 days

Qe= $\frac{48.8J}{60}$ = 0.8133 W

2.6 Energy Gained by Dual Power Poultry Egg Incubator

To obtain the energy gained by the solar collector, the overall heat loss coefficient for the collector was determined using the analysis below:

The overall heat transfer coefficient U_L was the result of convection and radiation between the absorber plate and the glass cover (view provided at the door)

$U_L = \frac{1}{R}$;

Where, $R = \frac{1}{h_1+h_r}$

Furthermore: $h_r = \sigma \frac{(T\ plate + T\ glass)(T^2plate + T^2glass)}{\frac{1}{£_{plate}} + \frac{1}{£_{plate}} - 1}$

where; h_r = radiation heat transfer coefficient (W/m^2k^{-1})

σ = Stefan Boltzmann constant = $5.6697 x 10^{-8}\ W/m^2k^{-4}$

T_{plate}= 343 K $£_{plate}$ = 0.3

T_{glass}= 296.25 K $£_{glass}$ = 0.94

$h_r = 5.6697x10^{-8} \frac{(343 + 296.25)(343^2 + 296.25^2)}{\frac{1}{0.3} + \frac{1}{0.94} - 1}$

h_r = 2.19 W/m^2k^{-1}

2.7 Design of Ventilation Holes

Assume number of holes = 1 hole

Assume diameter of holes = 30 mm

Volume flow rate of through one hole is given as;

Volume flow rate = cross section area × velocity from equation

Volume of Hole (V_H) = $\frac{\pi d^2}{4}$

$V_H = 3.124\ x \frac{302}{4}$ = 706.95 mm^2

V_H =0.0070695 m^3

According to Theraja, (2003),

Windscreen wiper Motor feed = speed of fan = 0.25 rev/sec

Volume flow rate = speed of fan x volume

Volume flow rate = 0.25 × 0.0070695 m^3

Volume flow rate = 0.001767375 m^3/s

2.8 Determination of Aluminum Strength to Support the Weight of Eggs

Taking into consideration of the loading due to the weight of the eggs; since they are uniformly distributed on the wood, therefore; Length of Aluminum = 0.4 m, as shown in Figure 2.

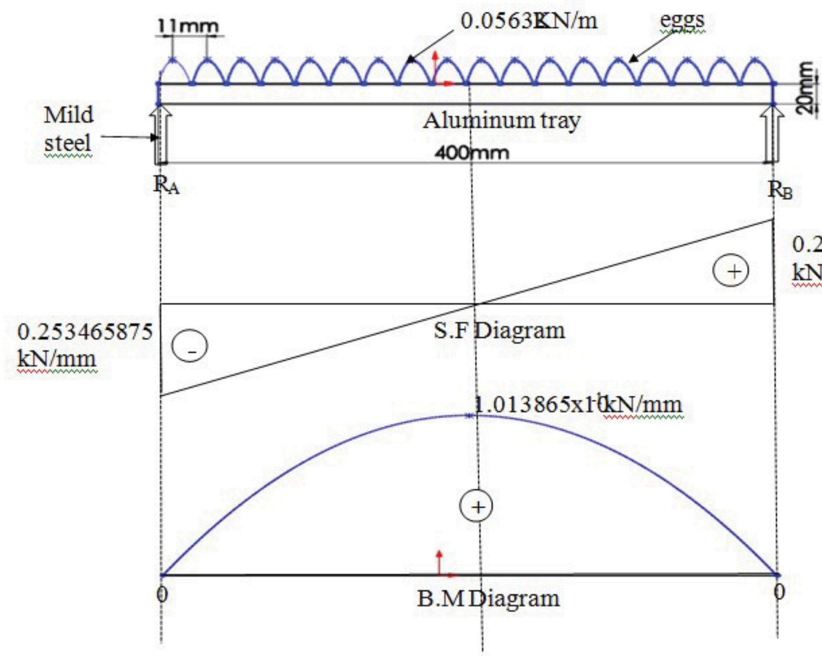

Figure 2: Bending Moment and Shear Force Diagram of the Load/Eggs on the Tray

Mass of Aluminum m_A = 2.40714 kg

Mass of an egg = 0.0689 kg

So the mass or weight of 300 eggs will be

W_e = 0.0689 x 300 = 20.67 kg

W_e = 20.6 kg

Since the weight of the eggs is 20.6 kg, then the (Uniformly Distributed Load) UDL will be the weight of the egg divided by the total span of the aluminum tray:

UDL = $\frac{We}{L}$ = $\mathbf{20.67\ x\ \frac{9.81}{0.4}}$ = 51.675 x 9.81 = 0.50693175 kN/mm

For a UDL: RA = RB = wl/2 = 0.50693175/2 = 0.253465875 kN/mm

So the bending moment at mid-point will be MC= $wl^2/8$ = 0.50693175 x$0.4^2/8$

= $1.013865\text{x}10^{-1}$ kN/mm

Mc = $1.013865\text{x}10^{-1}$ kN/mm

Where at end of the Aluminum;

B.M at B i.e will be $M_B = 0$

B.M at A i.e will be $M_A = 0$

So since the shear strength of the Aluminum = 6.89×10^9 N/mm
From the calculation, Maximum bending moment of the eggs (300) is 1.013865×10^1 kN/mm which is less compared to the shear strength adopted (6.89×10^9 N/mm).
Therefore, the aluminum tray used can withstand the load of the eggs.

2.9 The Control System

The control system consisted of one 15 W transformer. The power demand was then 76 W. The control system was designed such that:

- The temperature can be varied as desired;
- The turning mechanism was designed to be varied between the range of 1hr to 8hr intermittent turning;
- The humidity range can be set to 45 % to 55 % for the first 18 days of incubation; and 60 % to 75 % for the last 3days.

2.10 The Heat Source

This consists of four (4) DC headlight bulbs. The bulbs occasionally went on and off for temperature regulation. This meant that the power demand of the bulbs would be inconsistent for one hour. However in order to get the maximum performance it was assumed that they are constantly on. This way, the reduced actual power demanded more backup power which is dual power time or compensation for minimal regulation. If 1 bulb consumed 15W, therefore four bulbs will then consume:

4x15 = 60 W

2.11 The Air Circulating System

This consisted of a total of four (including the fan of the cooling system) 12 V, 0.35 A DC fans.

1 fan = 12 x 0.35 = 4.2 W

4 fans yielded, 4.2X4 =16.8 W

2.12 Estimated Total Power Demand and Battery Requirement

The total power estimated to be 60+16.8+21.28+76 = 174.08 W
This was the power demand for one hour. The minimum runtime requirement of the incubator was 8 hours.
Hence, 174.08 x 8=1392.64 WH
Since the battery that was to be used was 12 V, the suitable ampere-hour rating was

$$\frac{1392.64}{2} = 116.05 \text{ AH}$$

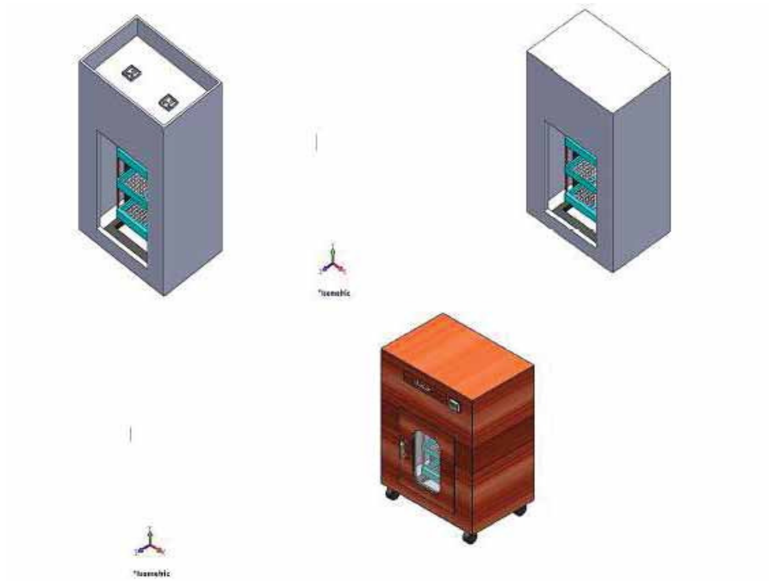

Figure 3: CAD Model of the Incubator

3.0 RESULTS AND DISCUSSION

It was observed that the total heat generated inside the incubator was 60watt; while the total heat used in raising the temperature of the incubator was (Q_I = 51.059798 W) but the total heat losses through the plywood and glass window are (Q_L = -0.529899 W).

3.1 No-Load Test

First, a no load test was carried out to determine the working possibility of the incubator, and the following data were obtained after one week of continuous testing. The results obtained were then plotted using Microsoft Excel, as shown in Figure 4.

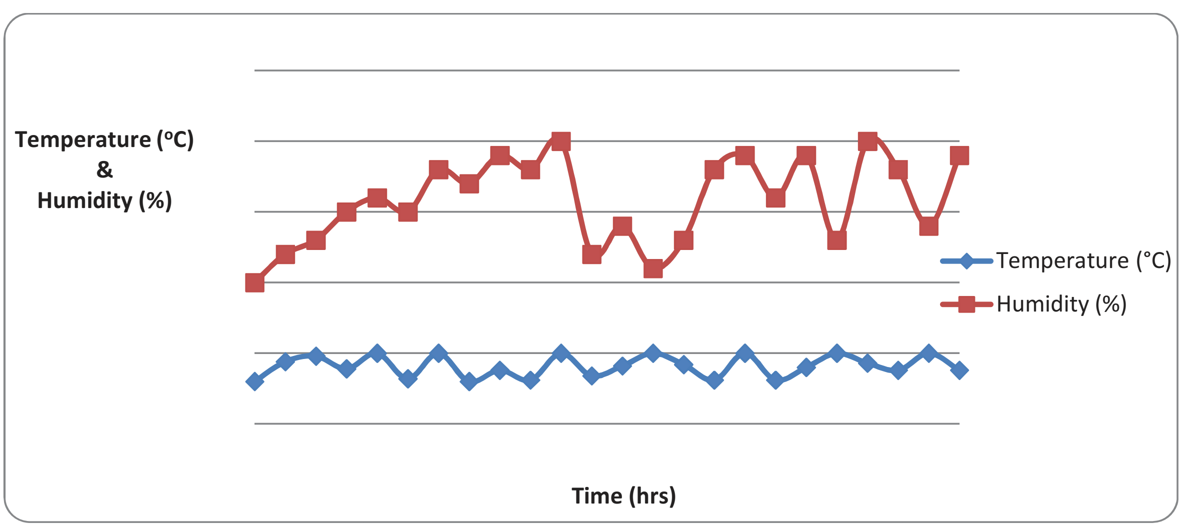

Figure 4: Temperature/Humidity-Time Graph for Day 1

3.2 Main Test

After the incubator has undergone a week of no-load testing and the performance confirmed satisfactory, it was then subjected to the main test. 150 quail eggs and 70 local chicken eggs were used for the test. The results are tabulated in Table 1.

Table 1: Yield from Incubator

Egg Type	Quantity Used	Yield	Incubation Duration (Days)
Quail	150	121	18
Local chicken	70	43	21

The quail eggs were subjected to turning for the first 15 days of incubation, after which the turning mechanism was turned off during the last three (days). Similarly, the chicken eggs too were turned throughout the first 18 days of incubation, and the turning mechanism turned off during the last three (3) days.

The reasons for the low yield obtained were

i) Due to infertility of some of the eggs used;

ii) Still birth of some chicks;

iii) Opening of the incubation at intervals—this caused an irregularity in the temperature and humidity level in the environment of the incubator, thereby affecting the incubation process.

Hatchability = $\frac{\boldsymbol{Yield}}{\boldsymbol{Quantity\ Used}} = \frac{\mathbf{121}}{\mathbf{150}} = \mathbf{81}\%$

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Due to the change in time and ambient temperature, it was discovered that humidity and the temperature in the incubator chamber varies, so the lower the ambient temperature the higher the humidity and temperature in the incubator chamber, but due to the action of the programmable integrated circuit the internal temperature of the incubator was maintained between 38 – 40 degree Celsius; the humidity was kept between 45 - 55 %. In this project, the equipment designed was portable, affordable and easy to maintain. Evaluation and test were carried out, thus having result for days of the testing. The used of dual power system proves to be a safe and sufficient means to ensure continues power supply.

4.2 Recommendations

Since the environmental condition for the hatching of different poultry eggs are within a similar range, the equipment could be used to hatch the eggs of poultry such as ducks, turkeys, goose, guinea fowl and ostrich, thus, increasing the country's food production.

To achieve full automation an electrically controlled humidity regulatory system, which will work with the control system, can be developed. An example of such is a valve type humidity control system.

Further development of the control system can be developed in a higher demand that will sense the outcome of egg hatching.

Finally, adding more than one battery would yield longer backup power time. And more suitable means of raising the humidity in the incubating unit rather than the evaporative moisture pan.

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