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CONSTRUCTION AND TESTING OF A LOCALLY MADE EGG INCUBATOR

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ABSTRACT

An electrically powered egg incubator suitable for hatching fowl (chicken) eggs has been designed and fabricated using the available local materials to achieve efficient performance. The need to embark on this project arose as an effort to contribute in the production of more chicks for poultry farm. The incubator has the hatching capacity of 60 eggs (two crates of eggs). Factors affecting egg incubation include temperature, humidity, ventilation, heat and egg turning rate. These factors are necessary for efficient performance of the incubator. Temperature range of 35.0 – 40.0 ^{o}C is suitable, but controlled at 37.5^{o}C by a thermostat. This temperature is close to the bird's own temperature of 37.0 ^{o}C. Humidity was controlled in stages. It was maintained at 60% for the first 18days and raised to 70% for the remaining 3 days. Adequate ventilation is provided when the door of the incubator is opened daily, which also serves as the gateway for the escape of excess carbon (iv) oxide. Filament bulb was used as a source of heat to the incubation chamber.

Background of the Study

In order for the poultry farmers in the country not to lack behind in meeting the ever increasing demand for poultry products and day-old chicks in particular, there is need for more incubators. This project is set out in essence to improve in the design and fabrication of electrically powered incubator by incorporating automated systems for turning and temperature maintenance. It is also patent to state here, that in design of this incubator indigenous material will be used and also the technology for operation will be simple which will further make the machine to be cost effective and little maintenance requirement. The complexities involved in the fabrication of incubators manufactured in the developed countries are too advanced in terms of materials, technical expertise and are very expensive to come by for less develop countries like Nigeria to cope with (Alabi and Isah, 2002).

Among the locally made incubators, many still lack the technology to automatically turn and automatic were fabrication without proper design specification, others pose a problem of maintenance liability. It is therefore in light of the challenges that this project work was embarked upon. Without a thermostat, the temperature and humidity were not easily ascertained, it was also discovered that not all eggs were hatched and led to waste of eggs (Nakage *et al.* 2003).

The relevance of this study constitutes an aspect of encouraging or promoting food production and security which is very significant in our present dispensation of global economic melt-down. This incubator will prove its importance to the individual, small scale and large scale industry in that; It will be cost effective which will make it affordable to the individual. Its design is simple and hence will pose no operational problem and maintenance challenges. The systems will optimize egg incubation and increase efficiency.

Factors to be considered in Incubation Process

Length of Incubation

Chicken eggs require 21 days to hatch, but the incubation period for the eggs of other species of poultry varies. The approximate periods of incubation required for various species of poultry and game birds are:

Table 1: Periods of incubation required for various species of birds

S/N	BIRDS	DAYS
1	Chicken	21
2	Turkey	28
3	Duck	28
4	Muscovy Duck	33 – 35
5	Goose	29 – 31

6	Guinea	26 – 28
7	Pigeon	16 – 18
8	Ring neck pheasant	23 – 24
9	Mongolian pheasant	24 – 25
10	Bobwhite Quail	23
11	Japanese Quail	17 – 19
12	ChukarPatridge	22 – 23
13	Peafowl	28

Source: Benjamin and Oye (2012)

Temperature

The fertile egg will resume development when it is placed in an incubator, and the recommended temperature for the incubation varies that is from 99-103°F with no harmful effects. If the temperature stays at either extreme for several days, the hatch may be reduced. Overheating is much more critical than under-heating; it will speed up rate of development causing abnormal embryos development in the early stages, and lower the percentage of hatchability (Nakage *et al.*, 2003).

Humidity

Humidity is of great importance for the development of chicken that is from their embryonic stage. During incubation (embryonic development) moisture is lost from the egg through the tiny holes on the shell; this increases the size of the air cell, which after 19 days of incubation occupies about one-third of the egg. Although a variation of 5 to 10% is acceptable, the relative humidity of air within an incubator for the first 18 days should be about 60% during the last 3 days (matching period) should be nearer 70%. When the humidity is lower than the recommended it causes excess evaporation of water, while high humidity prevents the evaporation of sufficient amount of water from the egg. In both cases, hatchability is reduced (Nakage *et al.* 2003).

Turning of Eggs

When eggs are put in an incubator, lay them on their sides and turn them at least three times a day. Turning prevents the embryo from sticking to the shell membranes, as it will if it is left in one position too long. Good results can be obtained by turning the eggs the first thing in the morning, again at noon, and the last thing at night. It is best to turn the eggs more than three times a day, they should be turned an odd number of times so that the egg will not be in the same position every night because that is the longest stretch of time between turns. When you turn the eggs, move them to a different part of the tray to offset variations in temperature in the different parts of the incubator. Continue to turn the eggs day 2 through day 17, but do not turn them after day 17 (Odunsi, 1998).

Ventilation

As the embryo develops it uses oxygen and gives off carbon dioxide. Thus, sufficient ventilation within the incubator is required to ensure an adequate supply of oxygen and the proper removal of carbon dioxide. The best hatching results are obtained within 21% oxygen in the air the normal oxygen level in the atmosphere. The embryo will tolerate a carbon dioxide level of 5%. Since the normal oxygen and carbon dioxide concentration present in the air seem to represent an optimum gaseous environment for incubating egg, no special provision to control these gases is necessary other than to maintain adequate circulation of fresh-air at the proper temperature and humidity (Nakage et al. 2003).

Fertile Egg Quality

From the smallest canary eggs to the largest ostrich eggs, high quality fertile eggs should always be considered rare and fragile. To successfully hatch eggs, begin with fresh, clean, fertile eggs. Eggs can be produced “on site” or purchased from many sources. Commercial hatcheries will ensure good fertility, but often will not ship small quantities of eggs.

Storing Fertile Eggs

Fertile eggs are alive. Each egg contains a living cell mass that develops into an embryo, and finally into a chick. Each incidence of improper handling reduces the probability of a successful hatch. Fertile eggs usually are gathered over a period of time before an adequate number of eggs can accumulate for incubation, or until the incubator is available for a new set of eggs. These normal situations require that, before incubation, eggs must be stored properly to ensure hatchability.

Cleaning and culling

Cracked, poorly shaped, soiled and unusually large or small eggs should not be incubated. These eggs rarely hatch and they increase the probability of introducing infection into the incubator. Eggs should not be washed. Washing or wiping with a damp cloth removes a protective layer that coats the egg. Soiled eggs should be cleaned by gently buffing the soiled area with fine sandpaper. Washing eggs transfers disease infection agents from the surface to the inside of the eggs. If an egg is washed, it should be washed briefly in 110°F water that contains a commercial egg sanitizer. Washing an egg in water that is cooler than the egg itself causes egg contents to contract. Contraction of egg contents draws water into the egg through pores in the shell. This water carries infecting microorganisms into the egg. If fertile eggs are produced “on site” at the business location, the breeding stock must be maintained and supported for maximum health and fertility. Basic egg production is severely affected by day length and lighting control.

Fumigation

Fumigation is an operation aimed at destroying organism that may kill the embryo or infect the hatched eggs (chicks) by exposing the organism to poisonous gas. Fumigation should be carried out before the use of incubator for hatching eggs.

Storage time

Ideally, eggs should be set in the incubator as soon after gathering as possible to maintain egg quality. If eggs are to be stored before incubation, the best hatchability occurs when eggs are stored for less than 7 days from the time they were laid. However, some species are more sensitive to storage than other species. Hatchability decreases rapidly in eggs held in storage for more than 10 days. Storing eggs longer than 2 weeks also can extend the normal incubation time as much as 1 day.

Embryonic Development

Embryonic development is a continuous process that can roughly be divided into three different phases. They are differentiation, growth and the maturation. Typically, differentiation of organs occurs in the first days of incubation. The growth and the maturation of the organs occur in the later phases of development. Each of these phases requires specific incubator conditions. As the embryo grows, its metabolic rate increases and this is accompanied by increased heat production. Consequently, the natural pattern of the embryo and eggshell temperature shows an increase towards the end of incubation. In the incubator we must differentiate between the temperature set point at which the incubator operates and the temperature of the air at the level of the eggs, which determines the temperature of the egg and embryo. At the start of incubation the embryo produces little heat and eggs must be warmed. This means that the air temperature must be higher than the egg temperature. As the embryo grows, metabolic heat production increases, the air surrounding the eggs must be cooled such that heat is removed from the eggs by so doing overheating can be prevented Odunsi (1998).

Physiological Processes within the Egg

Many elaborate physiological process take place during the transformation of the embryo from egg to click. These processes are respiration, excretion, nutrition and protection.

For the embryo to develop without any anatomical connection to the hen's body nature has provided membranes outside the embryo's body to enable the embryo to use all parts of the egg for growth and development. These "extra-embryonic membranes are:

- ✓ Yolk sac
- ✓ Amnion
- ✓ Chorion
- ✓ Allantois

The yolk sac is a layer of tissue growing over the surface of the yolk. Its walls are lined with a special tissue that digests and absorbs the yolk material to provide sustenance for the embryo. Yolk material does not pass through the yolk stalk to the embryo even through a narrow opening in the stalk is still in

evidence at the end of the incubation period. As embryonic development continues, the yolk sac is engulfed within the embryo and is completely reabsorbed at hatching. At this time, enough nutritive materials remain to adequately maintain the chick for up to two days.
The amnion is a transparent sac filled with a colorless fluid that serves as a protective cushion during embryonic development. This amniotic fluid also permits the developing exercise. The embryo is free to change its shape and position while the amniotic fluid equalizes the external pressure. The slow and gentle rocking movement apparently aids in keeping the growing parts free from one another, thereby preventing adhesions and resultant malformations.
The chorion serves as a container for both the amnion and yolk sac. Initially, the chrion has no apparent function but later the allantois fuses with it to from the choric-allantoic membrane. This brings the capillaries of the allantois into direct contact with the shell membrane, allowing calcium reabsorption from the shell.

The allantois has four functions:

- It serves as an embryonic respiratory organ
- It receive the excretions of the embryonic kidneys
- It absorbs albumen, which serves as nutriment (protein) for the embryo
- It absorbs calcium from the shell for the structural needs of the embryo

The allantois differs from the amnion and chorion in that it arises within the body of the embryo. In fact, its proximal portion remains intra-embryonic throughout the development.

Functions of embryonic membranes

Special temporary organs or embryonic membranes are formed within the egg, both to protect the embryo and to provide for its nutrition, respiration and excretion. These organs include the yolk sac, amnion and allantois.
The yolk sac supplies food material to the embryo. The amnion, by enclosing the embryo, provides protection. The allantois serves as a respiratory organ and as a reservoir for the excreta. These temporary organs function within the egg until the time of hatching and form no part of the fully developed chick.

Functions of the embryonic Blood vessels

During the incubation period of the chick, there are two sets of embryonic blood vessels. One set, the viteline vessels is concerned with carrying the yolk materials to the growing embryo. The other set, the allantoic, vessels, is chiefly concerned with respiration and allantois. When the chick is hatched, these embryonic to the blood vessel case to function.

- The clear fluid surrounding the chick is the amnion.
- The yellow area covered with a blood system is the yolk sac.
- The dense blood system in the piece of egg shell is the allantantois.
- The milky, clear material to the right of the shell is remaining white or albumen.

Philip claner (2016) “physiological processes within the egg”. (Penn state college of Agricultural Sciences youth safety).

MATERIALS AND METHOD

Material Selection

The selection of the materials for the construction of an egg incubator was done carefully, bearing in mind a design at minimum cost affordable by all levels of poultry rearers and hatchers, the following considerations where made while selecting the materials:

a. Availability of materials
b. Sustainability of the materials for the working condition in service and
c. The cost of the materials
d. The durability of the material and its compatibility with the climate and environmental conditions.

Construction Materials

The constructed egg incubator is made up of the following; wood [2x3], plywood [3/4 inches], nails, [various sizes], Aluminum sheet, thermostat, thermometer [Dry and wet bulb], circuit breaker, top bond, paint and glass.

The Component parts of the Machine

a. **Wood [2 x 3]:** This was purchased from the saw mill as shown in Plate 1, plained, saw into various sizes and used to make the form work of the machine.

Plate 1: The wood for the construction of the frame

b. **Plywood (3 quarter):** The plywood was used to make main frame (cover the form work) of the machine, to give it shape that was needed and form the box-like shape.

Plate 2: The plywood

c. **Nails:** Various sizes of nails were used to fasten the wood and the plywood together.
d. **Aluminum Sheet:** A 3.5mm aluminum sheet was used to form the square shaped egg trays, where the fertilized eggs will be placed. The size of the egg tray is 720 mm x 615 mm.
e. **Thermometer:** For measuring the thermometer and other psychometric properties within and outside the box.
f. **Thermostat:** The thermostats is connected to the circuit breaker and lamp holders in order to help regulate and maintain a constant temperature range of 37 – 39^{O}C
g. **Circuit Breaker:** The circuit breaker (60A) was used which is connected to the thermostats and lamp holders in order to prevent damages in case of a volt surge. In the case of a volt surge above the required voltage of 240V the circuit breaker will trip off.
h. **Top Bond**: The top bond was mixed with sawdust as an adhesive to fill the inside edge of the in incubator to pervert head loss.
i. **Paint (oil paint):** Two colours of paint were used in painting the incubator. Green was used in painting the outside part while black was used in painting the inside part of the incubator as a heat retainer.

j. **Glass:** A transparent glass was fixed at centre of each of the doors of the incubator from where the dry bulb and wet build temperatures could be read.
k. **Angle Bar:** The angle bar is 2.5 mm which was used to form the sliding rack for the egg tray.

Construction of the Machine

The construction of the device began by measuring a 930 mm of the 2 x 3 wood, the cutting was done using a hand saw, the length and the width was joined together to form the frame for the left side of the frame as shown in figure 3.1. The same procedure was repeated to form the frame for the right side which was joined together with nails, 930mm of the 2 x 3 wood was measured and cut to be the length and 800mm was measured and cut to be the width of the top and bottom sides of the frame, this was done using a hand saw to cut the wood and nailed together with the other side to form main frame of the machine.
The stand of the machine is of dimension 600mm for each of the four stands. The two trays containing live eggs are supported by wooden racks at the two sides to aid sliding action of the tray inward and outward during turning. Just beneath the trays, is the vacuum created for the water bath. The frame was covered with ¾ inch plywood which was cut to properly cover the frame work.

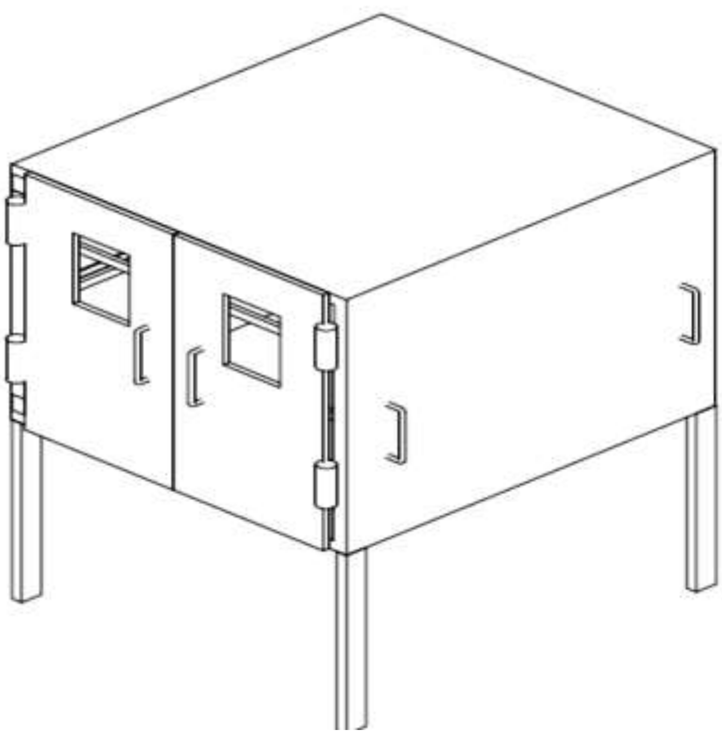

Figure 1: The Egg Incubator

Plate 3: The complete incubator

Description of the Incubator

The main frame of the incubator was made up of 2x3 woods while the body was made with 3quarter plywood of thickness. The 2x3 wood was cut to sizes requirement and nailed together as appropriate. 12mm diameter holes were drilled on the egg trays so that the heat on the egg trays will not directly affects the eggs but spread evenly on all parts of the trays containing the eggs.

Tray supports made of 30mm wood as shown in Plate 3.4 was nailed to the internal part of the frame to aid the sliding action of the trays inwards and outwards. A thermostat was incorporated to serves as a temperature control unit. Two doors were constructed on the incubator, with a transparent glass cut and fixed at the middle of each door where the two trays and the thermometers can be seen and read without opening the door.

Two thermometers were procured, a wet bulb and dry bulb thermometer, a wet wick is tied to the tip by dripping in water around it bulb. The dry bulb thermometer is used without conversation.

To test the incubator, a 1.5mm red and black cable wire was connected to the 60A circuit breaker while the other end was connected to a 13Aplug of quality standard and plug to a 13^{A} socket, the thermostat was regulated to 37.5^{0}c before the incubator was powered. A water bath was filled with water and placed at the based of the incubator to make provision for relative humidity. A constant monitoring of the temperature within the incubator was carried out through a transparent glass within the first ten days to obtain the wet bulb, dry bulb temperatures and the relative humidity.

Plate 4: The internal view of the incubator with eggs

RESULTS AND DISCUSSION

Results Obtained

The incubator was test run for 21 days using native eggs (local eggs) obtained from Fugar and Auchi respectively. Table 2 shows the results of the morning, afternoon and evening wet and dry bulb temperatures and the percentage relative humidity.

Table 2: Temperature readings during test running of incubator

	MORNING		AFTERNOON		EVENING		
Day	**Dry Bulb (ºC)**	**Wet Bulb (ºC)**	**Dry Bulb (ºC)**	**Wet Bulb (ºC)**	**Dry Bulb (ºC)**	**Wet Bulb (ºC)**	**Relative Humidity (%)**
1	35.0	34.0	39.0	37.0	38.0	34.0	93.0
2	38.0	34.0	37.0	35.0	39.0	36.0	76.0
3	36.0	34.0	37.0	34.0	39.0	38.0	87.0
4	37.0	35.0	39.0	36.0	37.0	35.0	88.0
5	37.0	35.0	36.0	34.0	37.0	35.0	88.0
6	38.0	36.0	38.0	34.0	37.0	35.0	88.0
7	38.0	34.0	37.0	36.0	38.0	37.0	76.0
8	38.0	36.0	36.0	34.0	37.0	32.0	88.0
9	37.0	25.0	33.0	31.0	36.0	32.0	38.0
10	38.0	36.0	36.0	34.0	35.0	34.0	88.0
11	37.0	34.0	37.0	32.0	36.0	31.0	82.0
12	38.0	36.0	38.0	32.0	37.0	32.0	88.0
13	37.0	34.0	38.0	32.0	36.0	33.0	82.0
14	36.0	32.0	37.0	31.0	36.0	34.0	76.0
15	34.0	31.0	36.0	33.0	34.0	30.0	81.0
16	38.0	35.0	36.0	32.0	38.0	33.0	82.0
17	35.0	32.0	38.0	34.0	37.0	32.0	81.0
18	37.0	32.0	35.0	33.0	38.0	32.0	71.0
19	37.0	30.0	38.0	31.0	36.0	32.0	60.0
20	36.0	32.0	37.0	35.0	35.0	33.0	76.0
21	38.0	34.0	36.0	37.0	37.0	31.0	87.0
Mean	36.90	33.38	36.86	33.67	36.81	33.38	79.81

Discussion of Results

The temperature readings during test running of the incubator met the recommended range (Nakage *et al.*, 2003) and showed that the machine was suitable for the incubation of fertile eggs (Table 4.1). The relative humidity observed during the test running of the incubator varied from 38 – 93% as recommended by Oluyemi and Robert (1988) and close to the range 55% – 70% maintained by Odike and Okonkwo (2011) in their incubation.

Table 4.1 shows the incubating chamber temperatures which were maintained at different hours of the day from the first day to the 21st day of incubation. The incubator recorded a minimum chamber temperature of 25°C of the incubation and the maximum temperature of 39 °C. This drop in temperature as indicated in figures 4.1, 4.2 and 4.3 could have resulted from the epileptic power supply experienced during the test running of the machine. Despite this trend, the results generally showed that steady incubation operating conditions could be achieved and maintained using this machine.

Also shown in Table 4.1 is the relative humidity of the day from the first day to the 21st day of incubation. The incubator recorded a minimum relative humidity of 38% of the incubation and the maximum relative humidity of 93% as shown in figure 4.4. Eighteen eggs were set in the test. These eggs where turned three time daily.

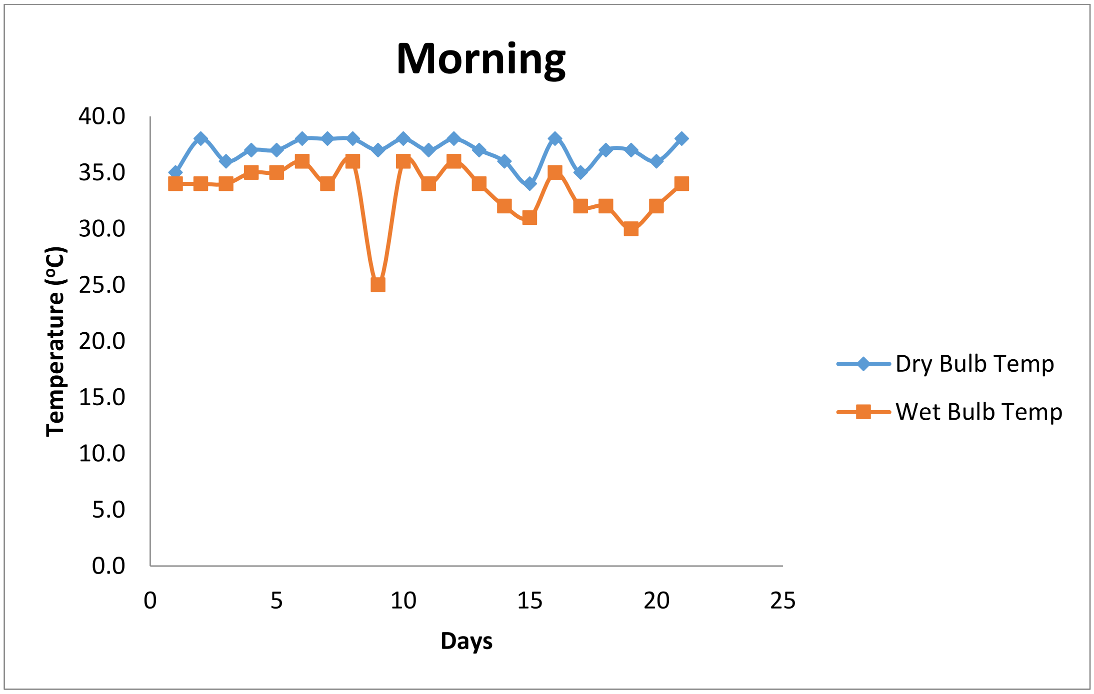

Figure 2: Morning Dry and wet bulb temperature

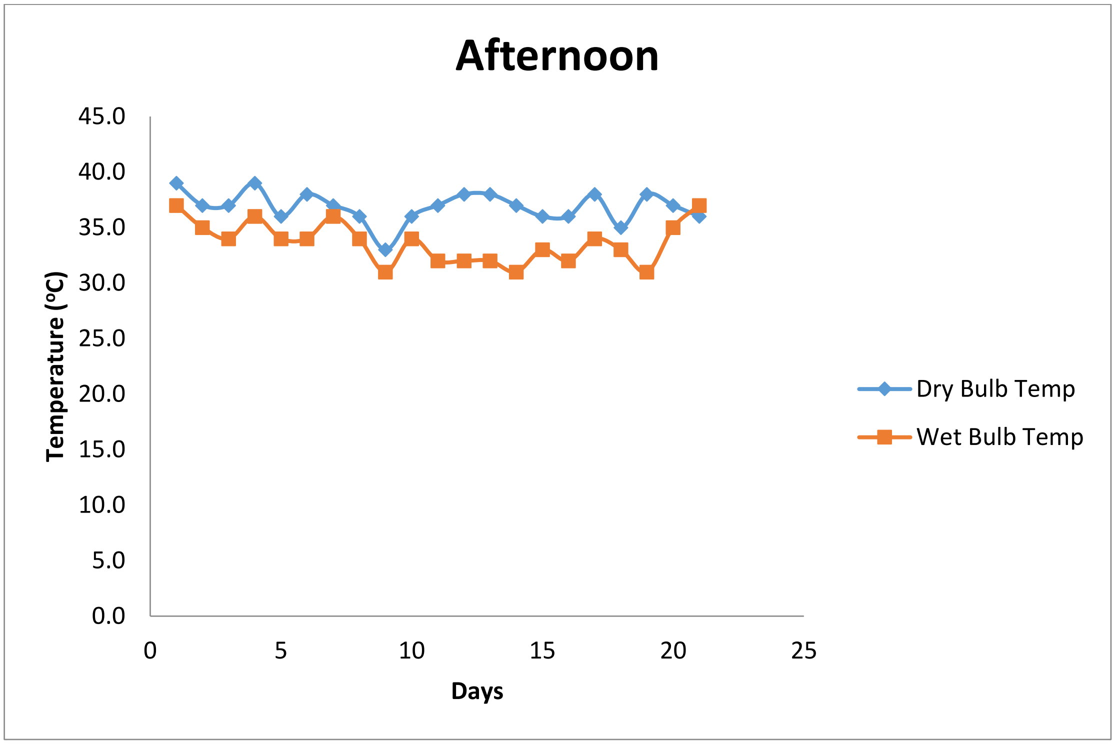

Figure 3: Afternoon Dry and wet bulb temperature

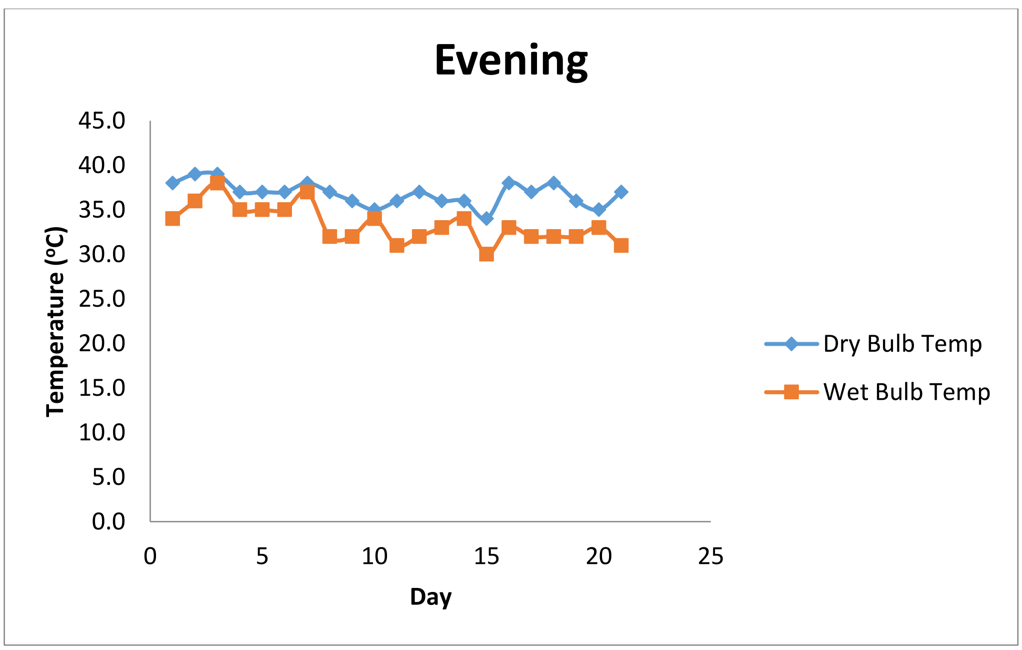

Figure 4: Evening Dry and wet bulb temperature

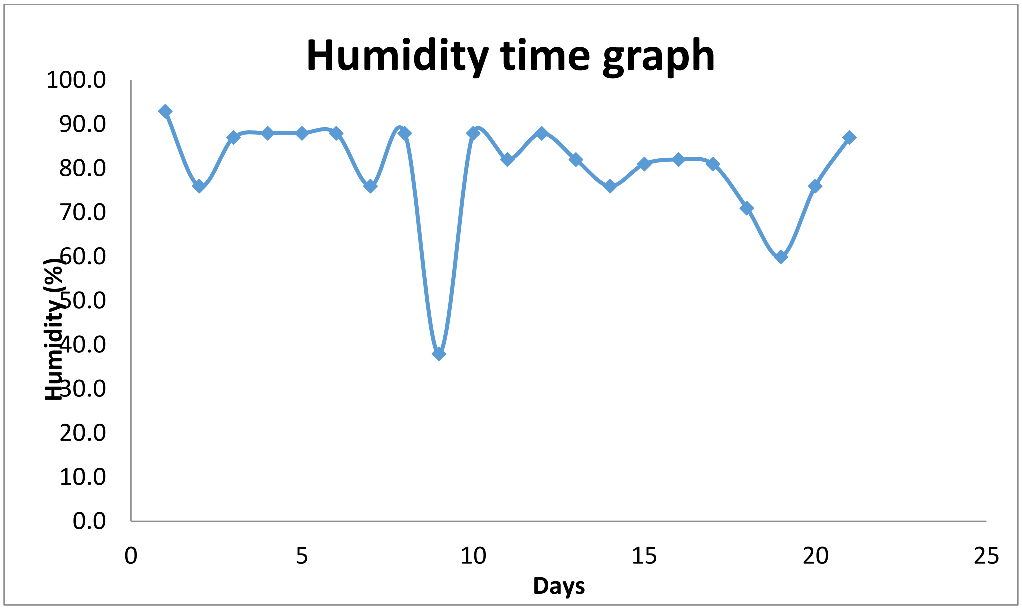

Figure 5: Humidity time graph for the 21 days

Due to the change in time and ambiance temperature, it was discovered that humidity and the temperature in the incubator chamber varies, so the lower the ambiance temperature the higher the humidity and temperature in the incubator chamber.

Conclusion

In this work the equipment designed is portable, affordable and easy to maintain. Evaluation and test was carried out, thus having result for days of the testing, an average value of temperature was gotten to be 37°C, average percent humidity value of 79.81. 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 ducks, turkeys, goose, guinea fowl and ostrich, thus, increasing the country's food production. It is recommended for household use, subsistent poultry farmers to increase the production of poultry products.

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