**Abstract**—In this study, a smart hybrid incubator was constructed and tested. To increase production of day-old poultry chicks, the incubator has solar power system to compliment power shortage in the event of failure from the national grid. The capacity of the incubator is 720 eggs. During the performance evaluation of the system, a temperature of 38.5 °C and humidity 64% were maintained. Turning of the eggs’ tray was achieved by a microcontroller that control the electric motor at an angle of 45° after a period of six hours. Fresh eggs of Broiler, Noiler chickens, guinea fowl and turkey were tested twice from 6th May to 3rd June, 2020 and 7th June to 3rd July,2020. Fertility of the eggs were determined by candling method after ten days of laying the eggs after which fertile eggs were returned to the incubator. The system hatching rate of the incubator was between 88.6% to 96.1%. The automatic turning of the eggs was effective throughout the period. However, turning should stop some few days prior to hatching; that is three or four days maximum, because the embryos are moving into hatching position and need no turning. Therefore, three days to hatch the eggs were transferred to the hatching basket or hatcher. Utilizing the solar power indeed has provided a solution to the major constraint of power failure or inadequacy for commercial poultry farming.

**Keywords:** Incubator; Hybridization; Microcontroller; Hatching, Renewable energy; Chicks.

**I. INTRODUCTION**

An incubator is an electro-mechanical device that used to provide temperature and humidity for fertilization of eggs (Ozioma et al.,2016). Egg fertilization is an important factor in the hatching of poultry eggs. It is possible to hatch eggs without the consent of the mother hen. The fertilization of egg embryo remains a priority of any farmer since his profits depend on hatchability rate of the eggs, this embryo when mature well will give birth to a chick. It is therefore necessary to manage the fertilized eggs with care which latter develop into a normal chicken. The eggs required warmth either naturally or artificially as the case may be. The natural method required the bird to provide the warmthness or the required temperature by sitting on the eggs in an open space (Idoko et al.,2019). Poultry is a kind of domestic birds that can be kept at home by human so that their eggs are collected. It is second most widely eaten meat. Poultry farming include egg hatching and brooding. Incubation is a process whereby poultry eggs under goes to hatch their eggs, embryo is developed within the egg (Ramli et al., 2015). Incubation is also being described as technology by which eggs are incubated and hatched with the help of man-made technology called incubator. The incubator controls the temperature and humidity in preparation for hatching process and also provides fertile egg with the moist warm air and artificial stirrer as the embryo emerges into a poultry within a period of 21 to 41 days (Osanyipeju et al.,2018).

Hatching of eggs comes in two different ways naturally (here mother chicken provides the warm by direct contact with egg for the required period) while the artificial egg incubator technology that provides opportunity for farmers to produce chicks from eggs without the consent of the mother hen. Artificial incubation it is one of the fastest 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 (Salawu, 2020). Artificial incubation procedures of eggs hatching were originated in both chines and Egyptian, chines developed a method of burning charcoal to supply the required heat, the Egyptian incubator was developed by constructing a large brick incubator which was heated with fire right in the room where the eggs are kept for hatching (Ajani, 2020).

Modern poultry industry incubation requires mechanical systems to replace the broody hen for egg incubation which was commercialized into large scale only within the period of 60 - 70 years (Adeoye,2015). The three important parameters for incubation of eggs are the relative humidity (warmed surrounding the egg), temperature and egg turning in terms of angles of inclination of egg tray as its wing in either side of the axes within the incubator. The ambient temperature has a strong relation with the incubator it forms the basis for calibrating the incubator chamber temperature against the ambient temperature and this relationship can be used for predicting the incubator temperature at any given time for unknown ambient temperature (Osanyinpeju et al.,2018). In addition, ventilation is yet another important factor during the incubation process. While the embryo is developing, oxygen enters the egg through the shell and carbon dioxide escapes in the same manner (Mohd, 2008). The air vent openings are gradually opened to satisfy increased embryonic oxygen demand as well as to take care of humidity during the hatching period. Unobstructed ventilation holes, both above and below the eggs are essential for proper air exchange (Mohd, 2008).

Solar energy has gain significant interest as means of providing the electricity to the incubator for incubation of eggs, this will have answer to the insufficient power constraints faced by poultry industries in remote areas. Continuous supply of electricity in Nigeria is a mirage due to the frequent power failure which also lead to the used of other sources like generators, kerosene and gas, therefore building and utilizing a solar powered egg incubator will improve the result of poultry
chicken farming and the overall living of the farmers and communities in general (Kelebaone et al., 2019).

### II. MATERIALS AND METHODOLOGY

#### 2.1 Materials Used

The construction of the smart solar powered incubator was made from the following:

- **Materials**: Plywood, Humidity fan, Humidity and temperature sensor, Ventilation fan, Solar panels (PV) Inverter, Plastic egg crates, Angle bar, Microcontroller, Chain, Sprocket, Water container. The various parts were fabricated separately and later assembled.

#### 2.2 Mechanical Components

The mechanical components of the incubator consist of:

- Incubator box
- Fan
- Egg turning tray
- Chain and sprocket
- Savor motor

#### 2.2.1 The incubator box

Plywood type of good quality and insulation properties was used to construct the box-like shape to form the main casing of the incubator as shown in Figure 1 below. Plywood was chosen due to ease in construction flexibility and durability. In order to construct an incubator of 720 capacity the dimension 1240mm by 900mm was chosen.

#### 2.2.2 Egg turning trays

The egg turning tray is fabricated from angle bar with dimension of 0.59m \( \times \) 0.79m to accommodate the egg plastic crates. There are four egg trays each containing 180 eggs, they were positioned inside the incubator at an angle of 45° and turns after every 6 hours either side of its pivot to enable uniformity in temperature and humidity level.

#### 2.2.3 Chain and sprocket

The chain and sprocket provided connection between the savor motor and the egg turning trays.

#### 2.3 Electrical and Electronic Components

The electrical component of the incubator includes the electric bulb 100W which serve as the source of the heat to warm the inner unit to temperature of 38.5°C. The solar panels were placed on the roof, battery, charge controller and AC to DC inverter were positioned by the right-hand side of the incubator as shown in Figure 1. Other components are intelligent microcontroller that record and display the temperature, humidity and the turning time of the egg’s tray.

##### 2.3.1 Electric motor (Savor Motor)

The savor motor is used to drive the egg turning tray and tilt it to angle of angle 45° either Side after a period of 6 hours via the microcontroller setting.

##### 2.3.2 Humidity fan

The humidity fan is used to facilitate the temperature and humidity in the incubator in order to keep them within the requirement of the preset values.

##### 2.3.3 Ventilation fan

The ventilation fan provides cooling to an overheated egg incubator and make sure exchange of oxygen-carbon dioxide is maximized. Ventilation fans were installed from the rear as well as the upper end of the incubator to ensure proper humidity and temperature distribution (Dalangin and Ancheta, 2018).

##### 2.3.4 Temperature and humidity sensor

The temperature and humidity sensing device were connected to measure the temperature and humidity of the incubator.

##### 2.3.5 Intelligent microcontroller

The intelligent microcontroller is an electrical hardware, which is programmed to control all the important parameters involved in the incubation process and display the result on the LCD screen.

##### 2.3.6 LCD screen

The LCD screen is an electronic hardware connected to the temperature and humidity sensing device in order to display the temperature and humidity and other related information of the incubator.

##### 2.3.7 The bulb

Two (2) 100 watts bulbs were used to provide the required amount of heat to raise the temperature to 38.5°C.

##### 2.3.8 Relay

The relay is an automatic switch, when the temperature is above the requirement the relay automatically switch OFF and ON when the temperature falls below pre-determined value.

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**Table 1: Condition for various eggs incubation**

<table>
<thead>
<tr>
<th>Species</th>
<th>Incubation period (Days)</th>
<th>Temp F</th>
<th>Humidity (%)</th>
<th>Do not turn after</th>
<th>Humidity Last 3 days</th>
<th>Open vent more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken</td>
<td>21</td>
<td>100</td>
<td>87-85</td>
<td>18th day</td>
<td>90</td>
<td>18th day</td>
</tr>
<tr>
<td>Turkey</td>
<td>28</td>
<td>99</td>
<td>84-86</td>
<td>25th day</td>
<td>90</td>
<td>25th day</td>
</tr>
<tr>
<td>Duck</td>
<td>28</td>
<td>99</td>
<td>85-86</td>
<td>25th day</td>
<td>90</td>
<td>25th day</td>
</tr>
<tr>
<td>Muscovy Duck</td>
<td>35-37</td>
<td>100</td>
<td>84-85</td>
<td>31st day</td>
<td>90</td>
<td>31st day</td>
</tr>
<tr>
<td>Goose</td>
<td>28-34</td>
<td>99</td>
<td>86-88</td>
<td>25th day</td>
<td>90</td>
<td>25th day</td>
</tr>
<tr>
<td>Guinea fowl</td>
<td>28</td>
<td>100</td>
<td>85-87</td>
<td>25th day</td>
<td>90</td>
<td>24th day</td>
</tr>
<tr>
<td>Peafowl</td>
<td>28-30</td>
<td>99</td>
<td>84-86</td>
<td>25th day</td>
<td>90</td>
<td>25th day</td>
</tr>
<tr>
<td>Pheasant</td>
<td>23-28</td>
<td>100</td>
<td>86-88</td>
<td>21st day</td>
<td>92</td>
<td>25th day</td>
</tr>
<tr>
<td>Pigeon</td>
<td>17</td>
<td>100</td>
<td>85-87</td>
<td>15th day</td>
<td>90</td>
<td>14th day</td>
</tr>
<tr>
<td>Bobwhite</td>
<td>23-24</td>
<td>100</td>
<td>84-87</td>
<td>20th day</td>
<td>90</td>
<td>20th day</td>
</tr>
<tr>
<td>Coturnix</td>
<td>17</td>
<td>100</td>
<td>85-86</td>
<td>15th day</td>
<td>90</td>
<td>14th day</td>
</tr>
<tr>
<td>Chukar</td>
<td>23-24</td>
<td>100</td>
<td>81-83</td>
<td>20th day</td>
<td>90</td>
<td>20th day</td>
</tr>
</tbody>
</table>

Measured at degrees F, in a force air incubator. For still-air incubators, add 2-3-degree F. Measured at degree F using wet-bulb thermometer. Use chart to convert to relative humidity.

Source: Mississippi state university Extension services.
III. RESULTS AND DISCUSSION

3.1 Result

The results were obtained based on the following tests

3.1.1 Testing of the unloaded Incubator

After the construction of the incubator, it was protected indoor to avoid the sudden change weather conditions. The temperature and humidity of the incubator was set and maintained between 34.5°C -38.5°C and humidity between 55 to 70% respectively. Table 2 shows the record of the temperature and humidity of the incubator for a period of 5 days.

Figure 1: The incubator system after construction

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Date</th>
<th>Temperature (°C)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st May, 2020</td>
<td>38.5</td>
<td>59</td>
</tr>
<tr>
<td>2</td>
<td>2nd May, 2020</td>
<td>37.5</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>3rd May, 2020</td>
<td>37.6</td>
<td>56</td>
</tr>
<tr>
<td>4</td>
<td>4th May, 2020</td>
<td>37.8</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>5th May, 2020</td>
<td>38.5</td>
<td>64</td>
</tr>
</tbody>
</table>

3.1.2 Testing of the loaded incubator.

After the incubator was tested unloaded with eggs for five days. Variety of eggs was loaded in the machine in order to test its performance as shown in Figure 2. The hatchability and embryo mortality rates of the eggs were determined by using the following relations and the result is as shown in Table 3 below.

Hatchability Rate = \( \frac{\text{number eggs hatched}}{\text{number of fertile eggs}} \times 100 \) ... (1)

Embyros mortality rate = \( \frac{\text{Number of dead embryos}}{\text{Number of eggs incubated}} \times 100 \) ... (2)

(Dalangin and Ancheta, 2018)

Figure 2: Incubator loaded with eggs

Figure 3: Hatching process in the hatcher.

Figure 4: Successful Hatched chicks

Figure 5: Sample of unsuccessful hatched chicks

Figure 6: Successful hatched Guinea fowls
The process was repeated for a period between May to July of year 2020. Equation (1) was used to determine the hatchability of the system.

IV. CONCLUSION

Performance test was conducted on the smart solar power poultry egg incubator with a hatching capacity of 720 eggs. The solar power provides a stable power supply to the machine throughout the incubation period. Hatchability rate of the system was between 88.6% to 96.1%. The automatic turning of the eggs was effective throughout the period but three days to hatching, eggs were transferred to the hatcher or hatching basket based on their incubation and hatching periods. Interior temperature was also observed to be 38.5°C. Utilizing the solar power for incubation of eggs provided a solution to a major constraint of power failure for commercial poultry farming.

4.1 Recommendations

After construction and testing of the incubator, the following recommendations were made:

(i) There is need to design the incubator of this capacity putting into consideration the ease and accessibility of the materials and equipment used.

(ii) Lagging of the incubator is required in order to reduce heat lose which usually affect the temperature and humidity of the incubator.

(iii) Information obtained from this work should be made readily available to direct users by relevant authority concerned.

(iv) Sponsorship should be provided by relevant agencies to researchers in order to improve the machine and stop importation of incubators.

(v) There is need to include SMS module in order to monitor the conditions of the eggs and send feedback from far locations.

REFERENCES


TABLE 3: Record of incubation from (6th May to 3rd June,2020)

<table>
<thead>
<tr>
<th>Types of Eggs</th>
<th>Days of incubation</th>
<th>Number of eggs</th>
<th>Fertile eggs</th>
<th>Infertile Eggs</th>
<th>Hatched eggs</th>
<th>Hatchability (%)</th>
<th>Embryo Mortality rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken (broiler)</td>
<td>21</td>
<td>300</td>
<td>286</td>
<td>14</td>
<td>263</td>
<td>91.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Chicken (Noilier)</td>
<td>21</td>
<td>170</td>
<td>152</td>
<td>18</td>
<td>146</td>
<td>96.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Duck</td>
<td>28</td>
<td>40</td>
<td>35</td>
<td>5</td>
<td>29</td>
<td>82.9</td>
<td>17.1</td>
</tr>
<tr>
<td>Guinea fowl (broilers)</td>
<td>28</td>
<td>220</td>
<td>197</td>
<td>12</td>
<td>190</td>
<td>94.4</td>
<td>56.6</td>
</tr>
</tbody>
</table>

TABLE 4: Record of incubation from (7th June to 3rd July,2020)

<table>
<thead>
<tr>
<th>Types of eggs</th>
<th>Days of incubation</th>
<th>Number of eggs</th>
<th>Fertile eggs</th>
<th>Infertile Eggs</th>
<th>Hatched eggs</th>
<th>Hatchability Rate (%)</th>
<th>Embryo mortality rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guinea fowl</td>
<td>28</td>
<td>300</td>
<td>276</td>
<td>4</td>
<td>254</td>
<td>92.1</td>
<td>7.9</td>
</tr>
<tr>
<td>Turkey</td>
<td>28</td>
<td>20</td>
<td>16</td>
<td>4</td>
<td>15</td>
<td>93.7</td>
<td>6.3</td>
</tr>
<tr>
<td>Pigeon</td>
<td>28</td>
<td>20</td>
<td>23</td>
<td>2</td>
<td>20</td>
<td>86.9</td>
<td>13.1</td>
</tr>
<tr>
<td>Chicken (Boiler)</td>
<td>21</td>
<td>100</td>
<td>88</td>
<td>12</td>
<td>78</td>
<td>88.6</td>
<td>11.4</td>
</tr>
</tbody>
</table>

Figure 7: Sample of various hatched birds.