

Design, Construction and Testing of a Digital Industrial Incubator

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Abstract

This paper presented the design, construction and testing of an improved digital industrial incubator. This research aimed to produce a reliable and efficient industrial incubator; the method uses digital temperature and humidity sensors for more accurate temperature and humidity control in various industries. The system overcomes the disadvantage of analog-based thermostat systems for stable and precise operation. The design incorporates a digital temperature sensor to detect temperature and pass on the data to the microcontroller. The 328 microcontroller processes data and sends the temperature and humidity to be displayed on the LCD screen. The most critical performance limitation in incubators was explored to find improved solutions. The problems associated with transient or momentary shut-off due to voltage or current surge during operation were overcome through improved design by adopting an improved stable compensation circuit. Other issues faced by commercial incubators due to non-uniform temperatures and the loss of some hatching eggs were addressed by integrating high-performance condition sensors in the design. The system displays both temperature and humidity in the LCD. When it exceeds our set limit, it automatically switches off load (heater) to control the temperature. The incubator has a hatching capacity of thirty eggs, factors that were considered during the performance evaluation of the technology were temperature 37 °C and humidity 55% till hatching. Turning of eggs was achieved with the use of a permanent magnet motor mechanism controlled by the programmed for one minutes for six hours each. Thirty fresh and matured eggs were collected from the breeder and were used to test the incubator. The test results show the average hatchability was 92.2% and infertility of 7.8%. This indicates that the incubator had outstanding results that will boost poultry production in the country.

Keywords: Arduino Uno, egg-hatching, egg incubator, humidity control, IoT, and temperature control.

1.0 Introduction

An egg incubator keeps eggs warm under specific conditions, such as temperature and humidity, so that the embryo can develop and hatch within a particular period. The most critical operations factors are constant temperature and humidity, which must be maintained over time [1]. Naturally, the process was carried out by either lying on the egg, called brooding, or buying under the ground using geothermal heat or heat generated from rotting vegetation, earth, and other material created from a gained compost heat [2].

The world's population growth is increasing daily, and the demand for proteins in our diet increases, especially in rural areas where many people, particularly children, suffer from malnutrition. This has resulted in massive poultry products.

According to [3] 80% of these products consumed by Africa had to be produced by private individuals and families. Therefore, this had become a source of business as they tackle the demand for protein [4]. Before now, farmers had to depend on local mother hens to aid eggs with tons of chicks. However, more chicks were lost due to this process as some eggs were prey to reptiles and neglected by the mother hen [5]. To avert this, an artificial incubator was introduced. Furthermore, for the sake of mass production, industrial incubators have been submitted [6].

Historically, the increased agricultural sector's development and commercialization and the quest for a more efficient incubation process means that the natural incubation process could not keep pace with the vast increase in the population [7]. To sustain the growing population, a device that can

perform the function of natural incubation can help agricultural production of eggs would be of paramount importance. The most common industrial incubator technologies available were those that regulate parameters such as temperature, humidity, ventilation, and timely turning of the egg 4-6 times daily for the development of the embryo into a chicken within 21 days [1]. This assists farmers in produced chicken from eggs without the mother's consent (hen). Digital incubators that can handle fertilization without human intervention have been developed. In addition, these incubators created a secure environment for the eggs, protecting them from reptiles just as the mother hen does. Other innovations include integrating a wireless interface to the incubator to use mobile phones to control and monitor remotely [8].

The poultry industry existed to promote the United Nations' sustainable development goals [9]. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. The S.D.G.'s objectives were to improve which was hindered by protein deficiency, a major global burning problem. However, one emergency solution to this challenge was meat and eggs from Nigerian farming's alternative approach to meet the protein needs of the poor society [10].

Hatcheries were essential in poultry production, and artificial egg hatcheries were robust solution

to the expected rise in the poultry industry; however, hatcheries in Nigerian produce broiler chicks. Farmers in Africa face several challenges ranging from cost, poor power sustainability, parametric data harvesting to aid better production, and poor production due to poor reliability resulting from the faulting of sensor [11]. In this research, the reliability of the machine was to be investigated. Furthermore, the machine's reliability will be increased to ensure better yield.

2.0 Materials and Method

2.1 Description of the System

The developed incubator was constructed using locally sourced plywood sheets. Two plywood sheets, each measuring 0243.84cm in length and 0121.92cm in width, were cut and joined together to form a rectangular box. According to design specifications, the plywood sheet were cut and assembled using screws. The door was attached to the box using hinges and featured transparent glass for viewing the interior. Additionally, a Styrofoam insulator was used to prevent heat loss. An egg turner was placed inside the box to ensure proper egg rotation. A control box was mounted on top of the incubator and necessary connections were made. Once the connection was activated and tested as shown in Plate 2.1.



Plate 2.1: Shows the industrial incubator

2.2 Sources of the Materials

The materials and instruments used for the design, construction and testing of a digital industrial

incubator with their specification are shown in Table 2.1 below.

Table 2.1: materials and instruments used for the design, construction and testing of a digital industrial incubator

MATERIALS/ INTRUMENTS	SPECIFICATION
Microcontroller	ATMEGA 328p
Digital temperature and humidity sensor	DHT 11
Wi-Fi module/VGPS	ESP886
Heater/ (Bulb)	200W
Permanent magnet motor	TYC-50
Timer module with USB and display	HWC- M421
Digital multi meter	Astro Ai 2000 count
Plywood sheet	½ sheet
Styrofoam	½ form
Gun	1 bottle

The materials/components used in the design, construction and testing of a digital industrial incubator were specifically sourced from locally available in the market and based on functionality, reliability and availability.

2.3 Circuit of the System

The device consists of different modules to make a complete system. Each component consists of electronic components that were put together as shown in a block diagram. This practically shows the overall view of the system. It consist of microcontroller, (ATMEGA 328) temperature and humidity sensor, (DHT 11) humidifier, real-time clock, (DS 1307) Wi-Fi (VGPS) module, egg turner (TYC-50) and heater (200W). The choices of component were based on reliability and efficiency. The circuit of the egg incubator includes the microcontroller (ATMEGA 328) for controlling the overall incubating system, shown in plate 3.2. The device operates between 37°C to 38°C, and the humidity was between 55-70%. The controlling system includes the DHT11 sensor and RTC DS1307 sensor to measure the temperature and humidity inside the incubator. RTC DSC1307 automatically indicates the Real-Time Clock, which counts seconds, minutes, and hours, respectively. The microcontroller controls the fan through the fan driver to maintain the humidity and controls the motor used for changing the position of eggs utilizing the motor driver. The temperature and humidity readings of the

incubator machine can be seen via the LCD. To maintain the uniform temperature and humidity inside the incubator.

2.4 Software Designs Using Simulation

In this research, proteus software 8.13 model was used for both simulation and PCB design, while Arduino compiler was used to program and compile the microcontroller. The Arduino IDE is a cross platform application written in java and was develop from the IDE for the processing programming to artist and other beginner that have little knowledge of software development. It include a code editor with features such as syntax and upload a programs to the board with a click. The Arduino IDE comes with a C/C++ library which makes many common input/out operations easier. Circuit was made by picking/selecting all the components based on the designed that were assembled to form the system using simulation software program, the component in a schematic/simulated environment to run and stop the code to the microcontroller. Proteus is a software that allows to simulate many component include ATMEGA 328p, LCD, DHT11, battery, GPS, heater, capacitor, relay etc. as shown in Plate 2.2

The following steps were taken for the design and simulation;

1. The software was lunched and the dash board was displayed. A new project was created by clicking on “ new project”
2. The project was named, and development board was selected. The ATMEGA 328 microcontroller was chosen and the project was finished
3. The schematic template was selected. A PCB (Printed Circuit Board) layout was generated, featuring the ATMEGA328 microcontroller.
4. Various components were added to the design by navigating to “Pick Device” menu, typing in the component name and selecting the desired specification
5. Once all the components were selected, the “terminal” button on the dash board was clicked. The input/output, ground, and other connections were then selected and heighted the ATMEGA 328 and run the simulation as shown in Plate 2.2

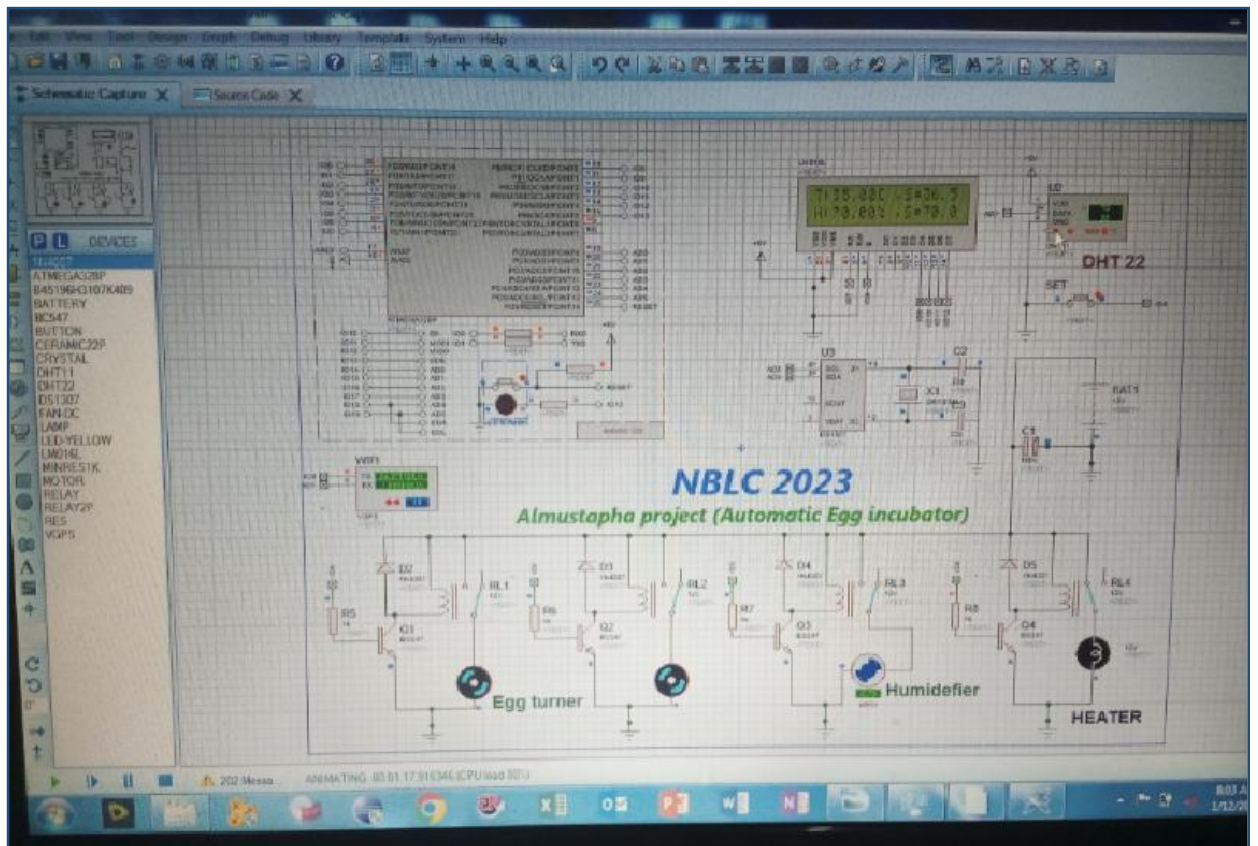


Plate 2.2: Design and simulation an industrial incubator

2. 5 Design and Development of the System

The study was achieved via the use of two Arduino controllers (ATMEGA 328) as shown in Figure 2.1. Controller A always communicates with Controller B when active. Whenever any of the sensors fail, controller A notifies controller B, which takes over the production process to ensure that the production process was not truncated halfway. This means that all control systems attached to A was left dormant, and those on B were made active. The temperature sensor (DHT 11) was used to measure the temperature in the hatching environment. The literature specifies that the heater was turned off when temperatures exceed 37°C to 38°C [12]. The heat source was turned on when the temperature goes below the reference. The humidity sensor (DHT 11)

measures the humidity in the hatching environment. When the humidity was less than the humidifier was made active for some time before being deactivated. The TYC-50 permanent magnet motor (egg turner) turns the egg at regular intervals, the real-time clock keeps track record time, and the Wi-Fi module sends data to the cloud for remote monitoring. Initially, when powered, Controller A and the accessories attached to it were active.

2.6 Development of Hardware

The hardware was developed as presented in this sections, the outcome shown in Plate 2.3 retains heat to limit the power used in the incubation process. This was achieved using stereotype foam as a lagging material.

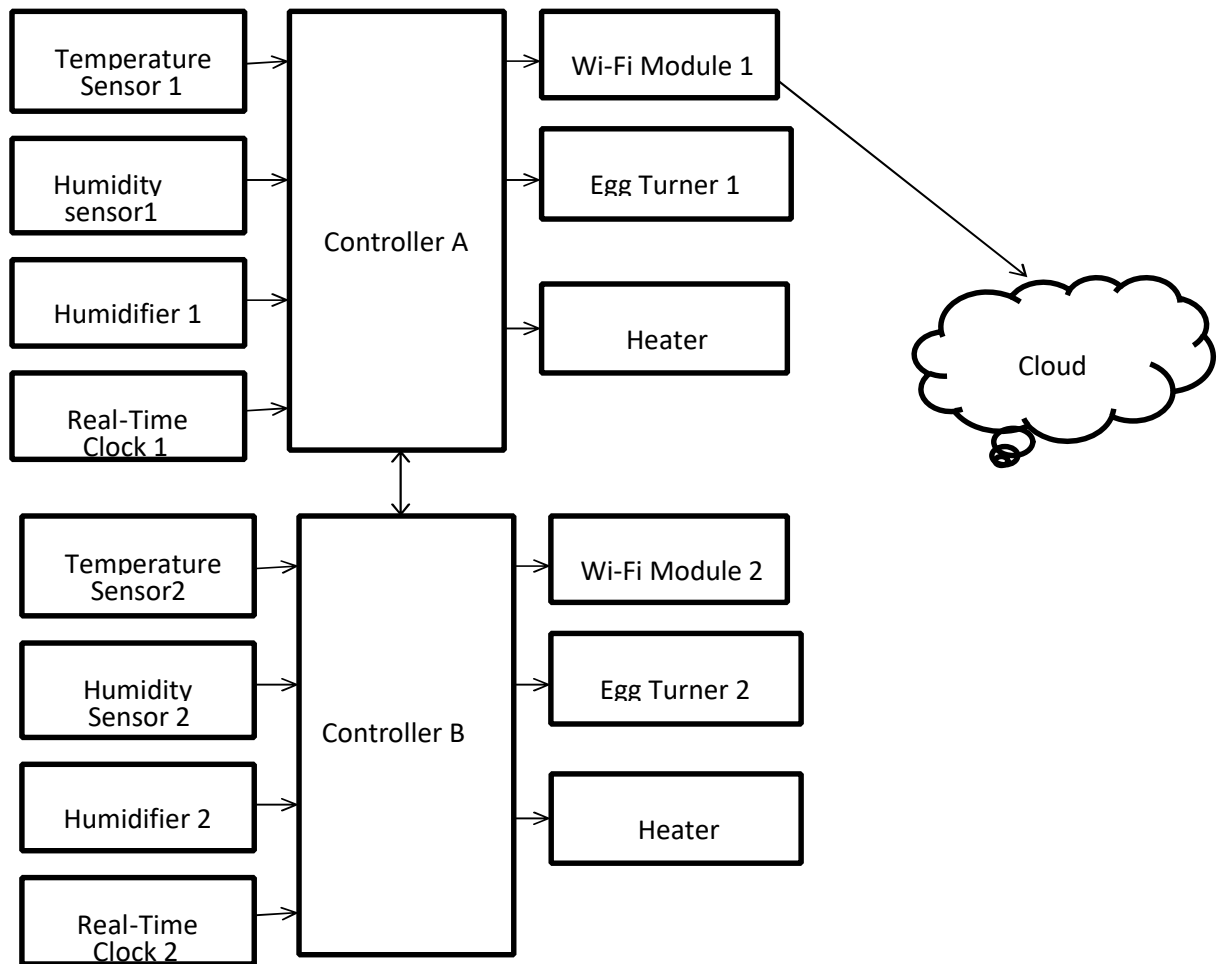


Figure 2.1: shows the block diagram of the control circuit of the hatchery



Plate 2.3: Complete view of the system

3.0 Results

3.1 Testing of the Components Functionality

The testing was conducted on the hardware components. These included a digital temperature and humidity sensor (DHT) liquid crystal display (LCD). Plate 3.1 shows the set temperature,

humidity, running temperature, and running humidity. Compared to incubators developed by [13] titled Design and construction of automated eggs incubator for small scale poultry farmers. The incubator developed in this study was flexible as it can set the desired temperature and humidity. This makes it suitable for different egg-hatching



Plate3.1: Temperature and humidity sensor reading on LCD

To achieve this, the system was powered with 5V 3A buck converters and an ESP8866 WIFI module powered with 3.3V, as shown in Plate 3.2

Furthermore, a 200W heat source (lamp), electric motor, and humidifier were used.

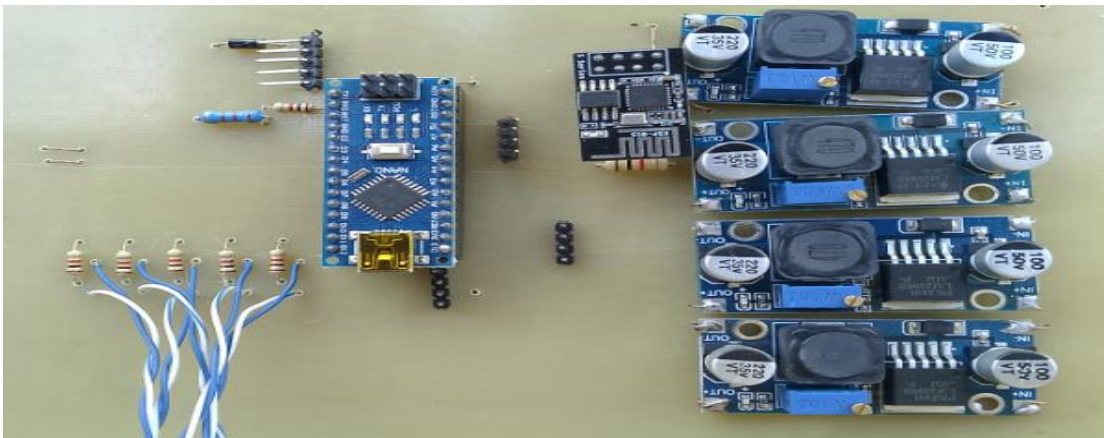


Plate 3.2: PCB board showing Wi-Fi modules and buck converter

3.2 Testing of the Software

After assembling and testing the hardware on printed circuit board (PCB), the program was uploaded via the USB Code to the microcontroller

(Arduino Uno). The program was run successfully, as shown in the Plate 3.3 this device can be accessed by the system remotely once the browser was installed on the computer system or smart phone.

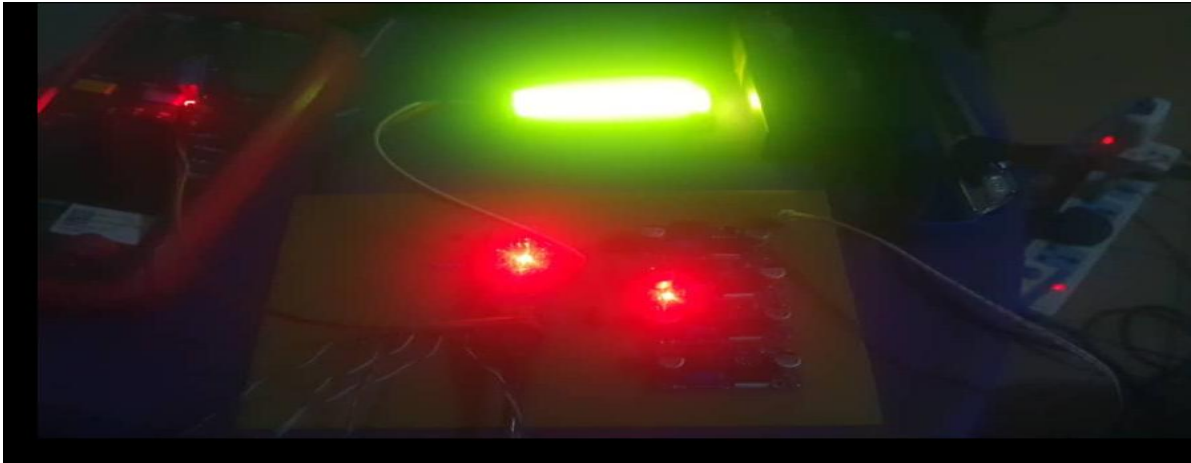


Plate 3.3: Uploading the code to the microcontroller

3.3 Testing of the Incubator

The testing procedure was adopted by [13]. Before the test ran, the incubator was protected from weathered challenges by being placed indoors. The temperature and humidity were set and maintained uniformly at 37°C and 55% respectively. The ambient temperature and humidity were 28°C and 40%. Thirty fresh eggs were selected from the breeders; the eggs were healthy and well-matured. The free heating test was conducted 10-12 minutes before eggs were placed in the incubator, and the command was executed.

The temperature and humidity setup and the running temperature and humidity were displayed

a)

on the LCD, and the data were also sent to the cloud for remote access. This process lasted for 21 days. The eggs were turned through an angle of 90° up and down and stayed for a minute. The rotation was done for every interval of six hours before it was stopped on the 18th day of operation, and hatching began from 19-21 days of testing. As the testing continued, the eggs were lit during the 7- 9 days of operation to determine the development of an embryo so that fertile, infertile or even dead embryos could quickly be identified and removed from the incubator so that another one could be replaced. However, on the 19th day, hatches began, and the process was successful. Only two of the eggs were cracked, and data were also seen via the thing speak as shown in figure 3.1a and b



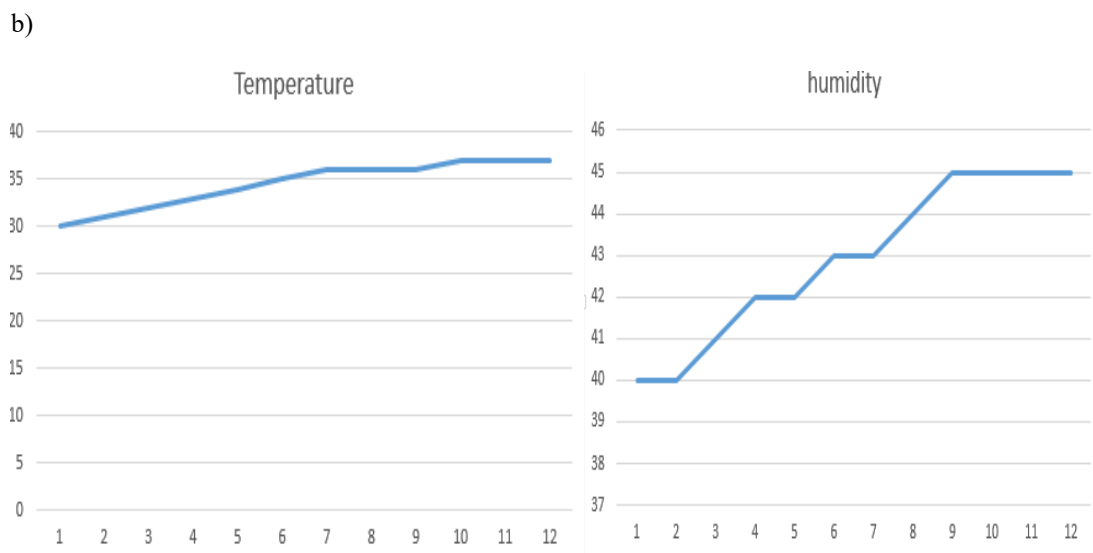


Figure 3.1 a and b: showing temperature and humidity graph

The figure 3.1 (a and b) above shows data of temperature and humidity in an industrial incubator, for each hour of the days until hatching. Then after collecting the data graph were plotted on both temperature and humidity. The average temperature and humidity were maintained at 37°C and humidity 43%. This is because if the temperature goes below 37°C or increases above 37°C the eggs may not hatched or even affect the embryos [14].

$$\text{Hatcherbility} = \frac{\text{Number of Hatched egg}}{\text{Total number of egg}} \times 100\%$$

$$\text{Infertility} = \frac{\text{Number of infertile egg}}{\text{Total number of egg}} \times 100\%$$

Hatchability and infertility rate of the three month October, November and December were done and presented as follows.

1. October and November analysis:

$$\text{Hatcherbility} = \frac{28}{30} \times 100\% = 93.3\%$$

$$\text{Infertility} = \frac{02}{30} \times 100\% = 6.7\%$$

2. December analysis:

$$\text{Hatcherbility} = \frac{27}{30} \times 100\% = 90\%$$

$$\text{Infertility} = \frac{03}{30} \times 100\% = 10\%$$

Table 3.1 shows the of the various testing conducted by the incubator

Month/ Year	Testing	Number Eggs	Fertile Eggs	Infertile Eggs	Hatched Eggs	Hatcherbility (%)	Infertility (%)
October	1	30	28	02	28	93.3	6.7
November	2	30	28	02	28	93.3	6.7
December	3	30	27	03	27	90.0	10
	Total	90	83	07	83	276.6	23.4
	Average	30	27.7	2.3	27.7	92.2	7.8

The Table 3.1 shows that the average hatchability of the incubator was 92.2%, and that of infertility was 7.8%. This indicates that the incubator had an outstanding, reliable result and will boost poultry farming in the country and Africa if mass-produced.

However, after evaluating the egg's development, the hatching of eggs was recorded on days 19-21 of the incubation, as shown in Plate 3.4. It should be noted that to ensure high rate of hatched fertile eggs were very important, as not all eggs were fertile. Some eggs were infertile.



Plate 3.4: Show the hatched chicks

4.0 Discussion

The incubator shown in the Plate 2.1 the incubation process started by verification of the entire component included temperature and humidity sensor DHT, relay timer (RTC) then follow by the preheating stage was lunched to allow the incubator case to be proper condition of the incubation. The preheating stage took about 10-12 minutes before the set up temperature and humidity were reached 37°C and 55% respectively, the eggs were put together into the incubator case and the incubation process were done and hatched successfully as shown in Plate 3.4

Thirty eggs were used for the testing for the month of October and November each, out of these 2 eggs were cranked during the October and November. 28 eggs had completely fertile and hatched successfully as shown in the Table 3.1 representing 93.3 % hatchability while infertile were 6.7%.

Also for the month of December 30 eggs were used during the period and 27 eggs were fertile and hatched as shown in the Table 3.1 representing 90% while 3 eggs were infertile representing 10%.

The result of the experimental research show that the developed incubator had the average hatchability of 92.2%. This research was based on the role of temperature and humidity and the result of the incubation process are shown in Plate 2.3. In summary, the temperature and relative humidity were maintained within the incubator throughout the incubation process were 37°C and 55%-70% for the whole process.

However, the developed incubator performed excellently, including power efficiency, compared to the existing incubators. It can operate with the national grid and solar energy, and its hatching rate is 92.2% surpassing the rate of existing

incubators. The developed incubator outperforms exiting incubator by 20% on the Worked on Design, fabrication, and performance analysis of an automatic horizontal egg incubator which had hatchability of 72.22% [15]. It also surpasses existing worked done by [13], [16]. Whose hatchability rates were 89.47% and 83.33% respectively. The enhanced hatchability rate of the developed incubator can be attributed to the innovative design features, including vertical adjustment of the egg tray and motor-clamped mechanism, which is used six times a day.

5.0 Conclusion

The Design, construction and testing of the digital industrial incubator were successfully implemented, achieving a high-performance level as demonstrated by the 92.2% hatching success rate. The incubator's ability to consistently maintain stable temperature, humidity, and egg-turning conditions was instrumental in achieving this outcome. The minimal egg cracked was 7.8%, indicating the need for minor refinements in handling the eggs.

However, the incubator was a robust and reliable system for egg hatching, with significant potential for adoption in Agricultural and industrial sectors where efficiency and scalability were critical. This research contributes to the advancement of automated incubation technologies, offering a viable solution to the challenges of traditional methods, such as inconsistent temperature and humidity control, labor-intensive egg turning, and limited scalability.

6.0 Recommendation

It is therefore recommended that further research work be done to improve handling mechanism, which includes:

- Introduce flexible egg trays to reduce impact on eggs during turning
- Implement vibration-damping material to stabilize the eggs and stress on the shell.
- Additional experiments with larger sample sizes and various eggs, such as duck and turkey, will be conducted to assess the incubator's adaptability.

The digital industrial incubator can evolve into an even more efficient and user-friendly system by implementing the recommendations above. This will broaden its applicability and make it a valuable tool for boosting productivity in poultry firms while reducing manual labor traditionally associated with the incubation system.

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