Development of a Small Scaled Microcontroller-Based Poultry Egg Incubation System

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Abstract— **Owing to an increase in the commercial production of chickens and demand for local consumption as a source of protein in both rural and urban areas in developing countries. This paper proposes a cost-effective incubator for hatching poultry eggs with minimal human involvement. The paper describes the design and implementation of a prototype microcontroller-based electrical incubator system. The developed incubator has optimized temperature and humidity that facilitates higher hatchability rate provided that the egg fertility is high. The prototype incubator was evaluated by loading it with 6 presumed fertile eggs. The percentage of hatchability obtained was 67% (4 out of 6 egg). The remaining two eggs were not hatched as they may not have been fully fertilized.**

Keywords—Electrical incubator, microcontroller, sensors, poultry, hatchability

I. INTRODUCTION

Protein is a major part of the nutritional diet of a basic human being. In this regard, it is of great importance that people gather about more information on how they can improve on the introduction of foods that contain these nutritional contents. The poultry industry has become one of the most efficient producers of protein for human consumption, this turn around occurred in the 1930s and 1940. The main reason for the shift from pork and beef was that poultry requires much shorter time to produce than beef and pork as normally a broiler requires just six weeks to produce, hence the shift became a necessity to feed the populations [1]. Artificial poultry production has been part of human society for ages. It began being implemented by the Chinese and Egyptians thousands of years ago as they used primitive techniques in the production of poultry [1]. One might not go as far as to say these methods were not helpful to their social organisation structures however with the increase in human population over the years it is of great importance that better techniques are looked at so that the general population can be fed, and malnutrition can become a thing of the past for this generation. In this account, it can be regarded as of great importance that poultry production is understood and practised with great skill and precision so that the larger population can be fed.

II. RELATED WORKS

Over the years a considerable amount of work has been carried out in developing an electrical microcontroller-based incubator system. The implementation has been based for example using PIC16 series microcontroller [2], ATmega89C56 microcontroller [3]. Recently too Arduino UNO development board platform has also been adopted [4], mostly tailored for use in developing countries. One common challenge inherent in these implementations was low hatchability rate, largely due unstable power supply prevalent in developing countries [5] [6] and unfertilized eggs. This work aimed at improving on these challenges, by ensuring a steady power supply throughout the entire incubation process. Thereby improving on the hatchability rate.

III. MATERIALS AND METHODS

The materials that were used in the development of the prototype incubator system can be divided into two types, namely: electrical and non-electrical materials. The electrical materials include the microcontrollers, egg turning DC motor with high torque, temperature and humidity sensors, low-speed axial fans, thermostat, high-density cable, metal crates, and a high watt inverter for power substitution. As for the non-electric components, the materials include two wooden boxes for oil-lamp incubators, insulated plastic cooler boxes for the semi-electric, forced-air incubator, and a five-feet refrigerator scrap for the high capacity incubator.

A. Model description

The incubator shell was designed to accommodate a maximum of ten eggs. The shell materials were chosen from the readily available local materials. Figure 1 shows the constructed incubation chamber shell.

Figure 1. The prototype designed egg incubator chamber shell

The shell has two compartments the upper compartment accommodates the electrical components of the design like the microcontroller, LCD display, and the motor driver. The bottom compartment accommodates the sensors and the egg tray.

The Arduino is the heart of the automation of the project design. The Arduino is programmed to monitor the temperature and humidity of the incubation chamber [7]. The egg rotation is also monitored by the Arduino. The design implements the DHT22 for humidity sensing and the LM 35 for accurate temperature sensing [8]. The electric heater is driven by Triacs that are driven by optocouplers this allows for the monitoring of power that is supplied to the heater so that the temperature can be maintained. The LCD display gives a real-time update of the status of the incubator. The buzzer is triggered when there is anything wrong with the incubation process or when the incubation process is done. The proposed design block diagram of the incubator is presented in Figure 2, showing how the different components are interconnected.

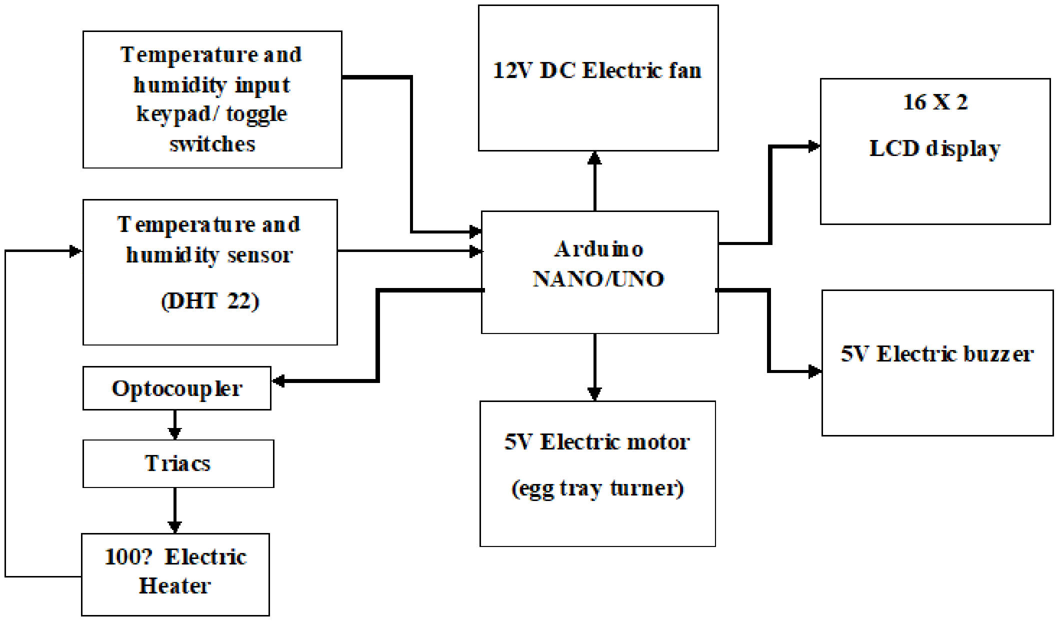

Figure 2. Block diagram of the proposed design

During the proposed system implementation, factors such as cost, availability of components, functionality and reliability were considered. The system implementation was also divided into two parts namely the hardware and software design considerations. The hardware and software design are discussed in the subsequent subsection.

B. Hardware Design Considerations

The hardware unit consists of the following sub-unit: The sensor unit, user interface, the microcontroller unit, the real-time clock, the display unit, the current driver unit, the actuator unit and the power supply unit. These sub-units are discussed subsequently:

1) Sensor unit:

The DHT 22 with the help of the LM 35 has the abilities of accurately recording the temperature within the incubation chamber [9], the information is sent to the Arduino in analogue format [10] at pins A4 and A5 of the Arduino chip as shown in Figure 3. The humidity is measured using the DHT22 sensor [7].

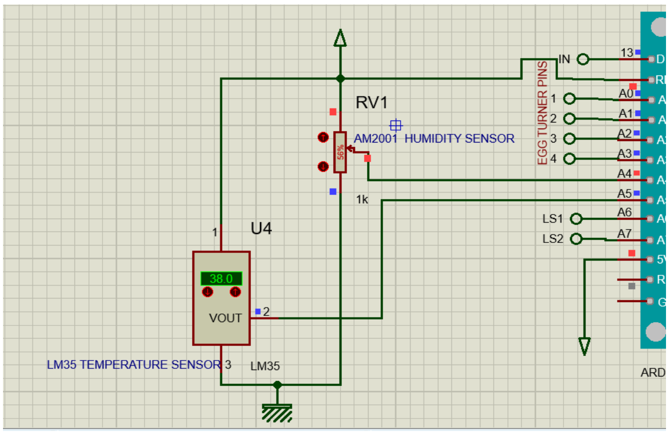

Figure 3. Sensor Unit

1) The microcontroller unit:

The Arduino NANO/UNO is a popular development board that provides an easy interface for analogue and a digital input as shown in Figure 4 with its pins' layout. When programmed and the code uploaded to the Arduino, it's functionality would be to receive signals from the temperature and humidity sensor. Through programming, the Arduino can make an intelligent decision on whether to allow the electric heater to be switched on or to activate the mist spray within the incubator. The temperature and humidity values obtained from the sensors is sent to the LCD display by the Arduino microcontroller.

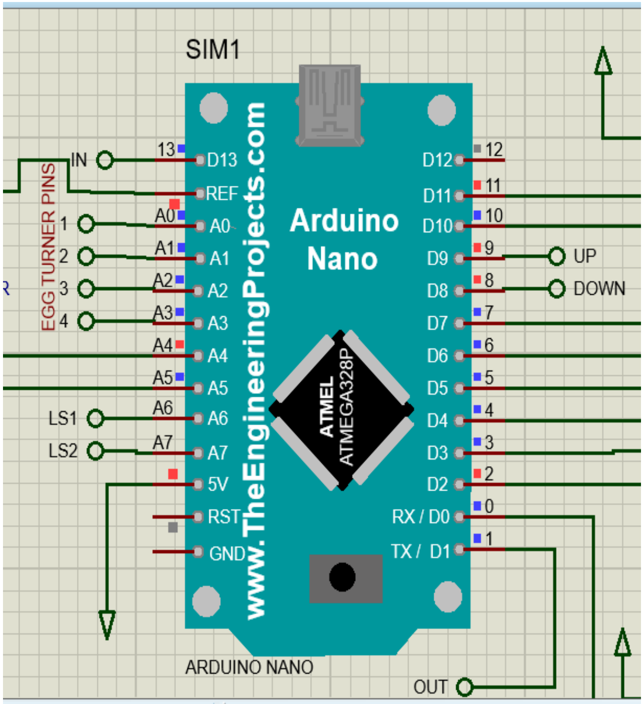

Figure 4 Microcontroller Unit

2) The electric heater temperature unit

For the subsystem in Figure 5, there are two integrated circuits (IC) that handle optical isolation. Optical isolation is the isolation of two voltage sides the high voltage side and the low voltage side the IC responsible for this is the MOC3051. The MOC3051 drives the Triac which in turn drives the heater.

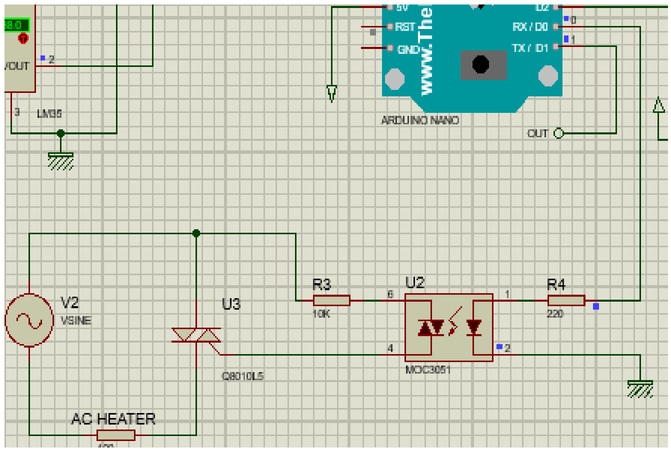

Figure 5. Electric heater temperature Unit

3) Egg turning unit:

Figure 6 depicts is for a 5V stepper motor essential in the egg turning process. The motor is attached to the egg tray getting commands from the Arduino on when to tilt the egg tray through the analogue ports A1, A2, A3, A4.

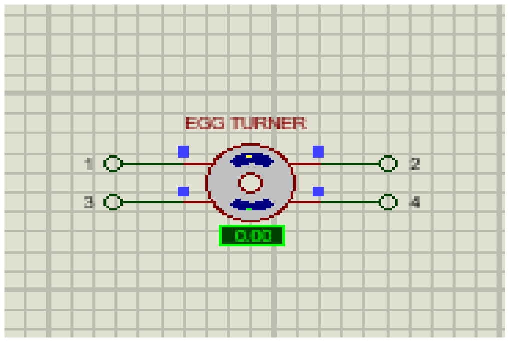

Figure 6. Egg Turning Unit

C. *Software design considerations*

The Arduino IDE firmware handles the control and operations of the incubator system. Arduino IDE is an open source software which makes it easy to write code and upload it on the Arduino UNO/NANO board. The environment of the software is written in Java, however, but simplified to make the software user-friendly [11]. The operational flowchart of the software is shown in Figure 7.

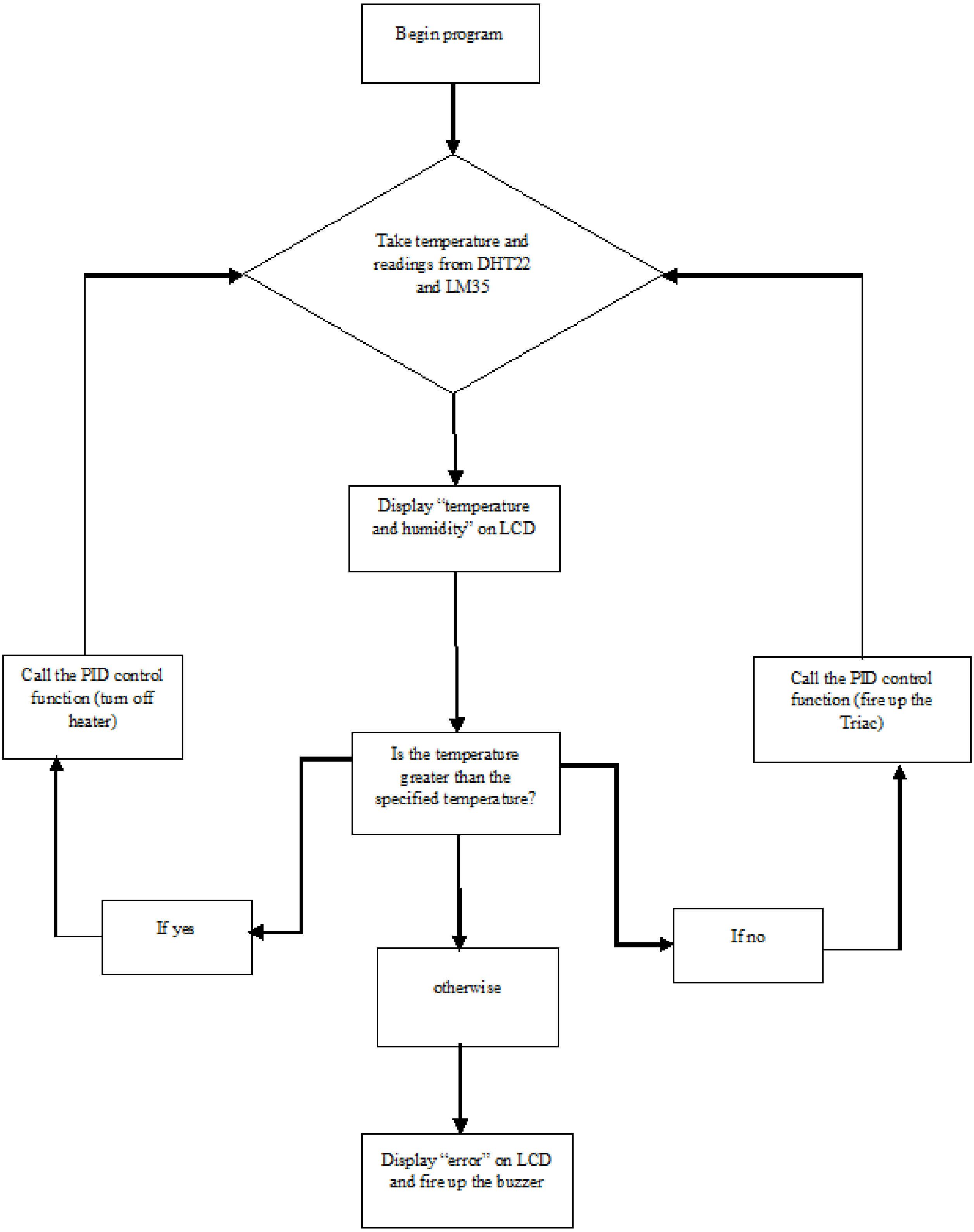

Figure 7. The programme flowchart diagram

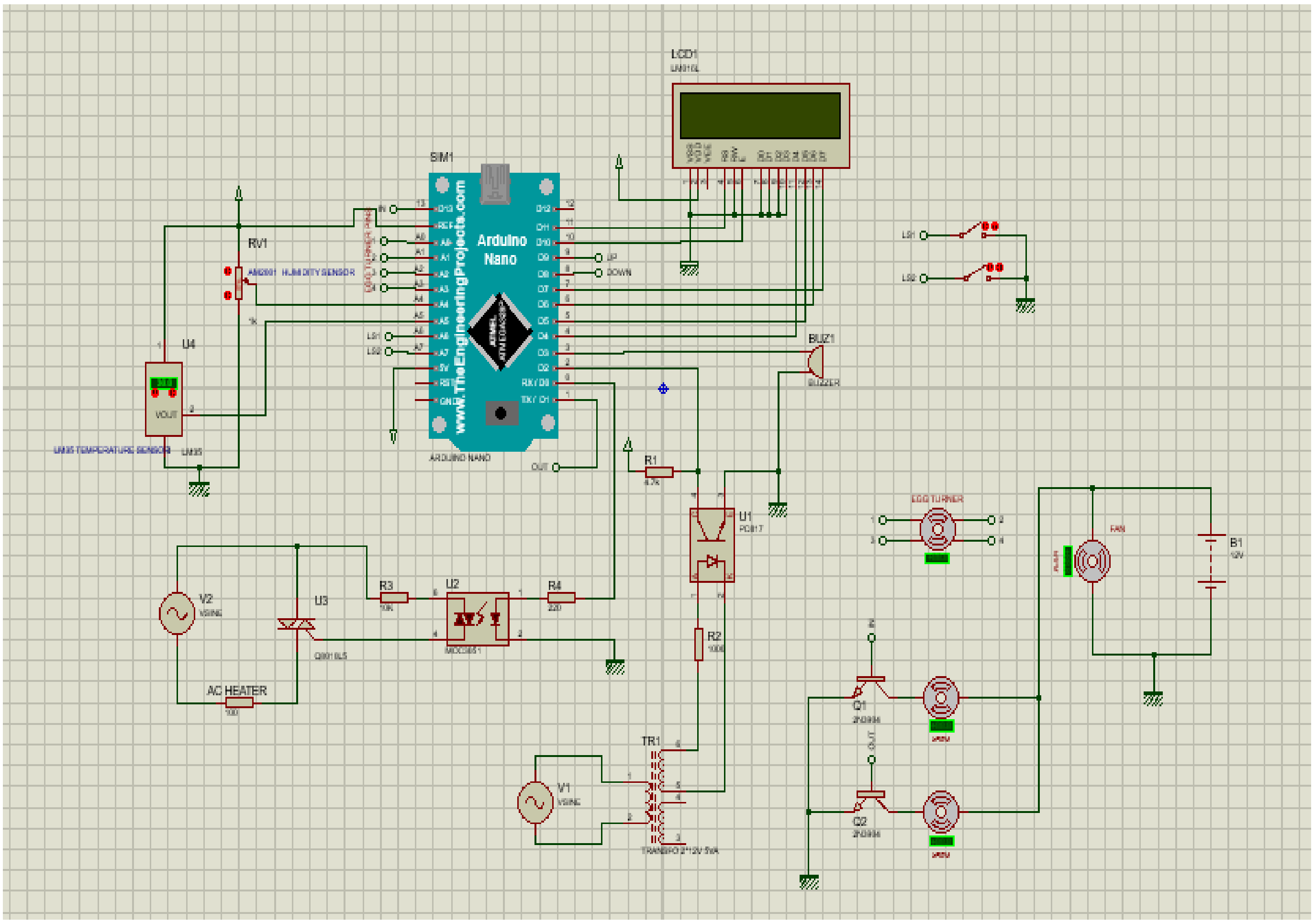

Figure 8 Circuit diagram used for design simulation

Figure 8 depicts the main circuit design diagram used for simulation. The Arduino UNO is the automation device. The code uploaded to the Arduino instructs the Arduino to read the temperature and humidity from the DHT22 and LM35. The temperature and humidity read to determine if the Arduino should fire the Triac so that the heater could be turned on or not. The received temperature is also displayed on the LCD. Given that something has gone wrong with the incubation process, the Arduino turns on the buzzer, and an error message is also displayed on the Arduino.

D. Model implementation

The prototype design was implemented according to the provided and simulated circuit diagram in Figure 8. The final circuitry implementation is depicted in Figure 9.

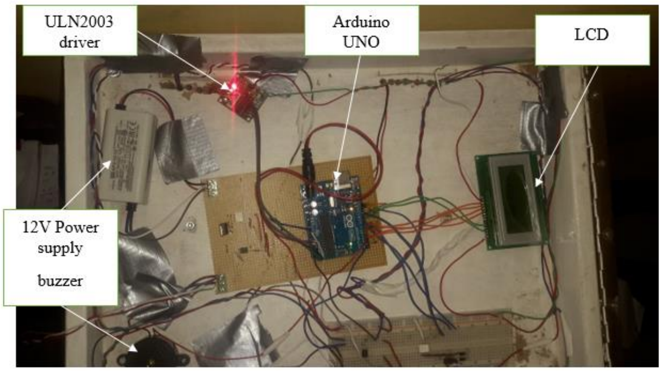

Figure 9. Design implementation

Figure 10 shows the egg turning mechanism with the temperature and humidity sensors. The electric heater was placed at the top centre of the incubation chamber. This allows the heat to be evenly distributed in the chamber, which is facilitated by the electric fan.

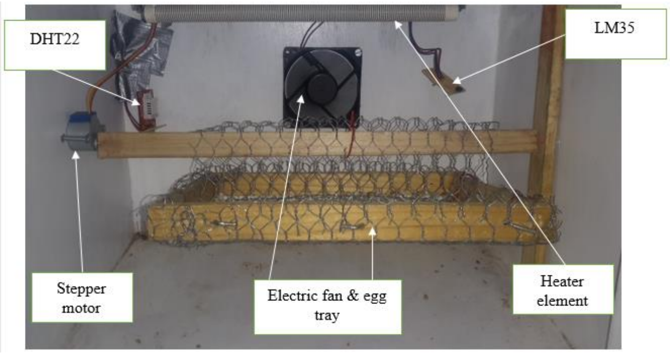

Figure 10 Incubator interior

IV. RESULTS AND DISCUSSION

This study required that an incubation process be conducted in the implementation phase of the study. The poultry eggs were obtained from a local farm. The eggs came from a hen that was in the company of a crock. This increases the chances of having a fertilized egg. Figure 11 displays the steps taken on the first incubation day.

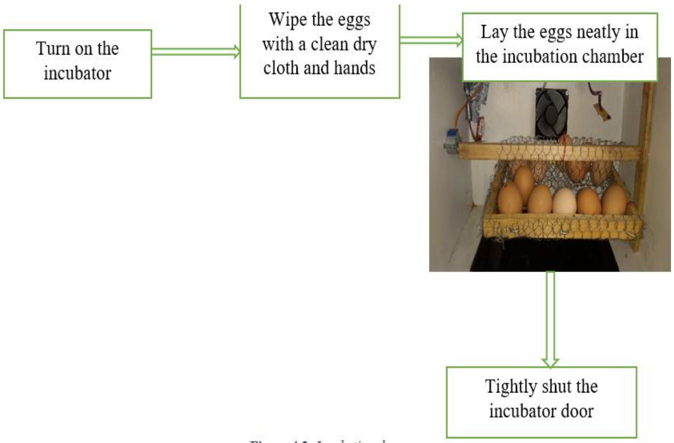

Figure 11 Incubation day one

The eggs were checked on a weekly basis, this was done to check the incubation progress of the eggs. The candle experiment was used to determine the status of the growing embryo in the egg [12].

Figure 12 Candle experiment in day 5

Figure 12 shows an egg that is at day 5 of the incubation process using the candle technique. The egg shows signs of development an indication that the egg is fertilized. The percentage fertility of the incubated eggs is calculated according to equation 1:

$$\text{Fertility per cent} = \frac{\#\text{ of fertile eggs}}{\#\text{ of incubated eggs}} * 100 \qquad (1)$$

From equation 1 the fertility of the incubated eggs becomes:

$$\text{Fertility per cent} = \frac{6}{10} * 100 = 60\% \qquad (2)$$

Hence according to the obtained percentage of fertility one can conclude that the obtained eggs were not well fertilised.
After a period of 21 days of incubation, the first chick was hatched from the incubation process. The other two eggs were hatched after on day 23 and the last egg was hatched on day 25 before the incubation process was terminated. The other eggs that did not show signs of further development. These kinds of eggs do not hatch no matter how long the incubation process is. They may be regarded as not fully fertilized.

Figure 13 Hatched Chick

The percentage of hatchability can be calculated according to the following equation 3:

$$\text{Hatchability percentage} = \frac{\#\text{ of hatched eggs}}{\#\text{ of fertile eggs}} * 100 \qquad (3)$$

From equation 3 the hatchability of the eggs can be calculated as follows:

$$\text{Hatchability }\% = \frac{4}{6} * 100 = 67\% \qquad (4)$$

The hatchability percentage obtained is quite remarkable and a good sign to show that the automated incubation system is well functional. Hence, can be used for the incubation of poultry eggs.

V. Conclusion and Future work

In this paper, the design and implementation of a microcontroller based automated poultry incubation system is presented. The designed prototype system performed as expected based on the study specification. After a period of 21 days of incubation, the first chick was hatched from the incubation process. The other two eggs were hatched on day 23 and the last egg was hatched on day 25 before the incubation process was terminated. This work could be improved on by incorporating the Internet of Things and alternative power supply functionalities. This would result in the usability and reliability of the system.

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