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Design and Development of a Low Cost Semi-Automated Battery-Powered Egg Incubator with Temperature and Humidity Control

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Abstract
Artificial egg incubation is important in poultry production as it controls the environmental factors on the development of embryos. Effective incubation requires a certain level of control over temperature, humidity, ventilation and egg turning. In this paper, the design and development of a semi-automated egg incubator with low cost but with standard incubation parameters mentioned in the existing literature is provided, and a dual-power (AC/DC) operating system is proposed as one of the changes. To assess experimentally, three temperature conditions were taken collectedly, i.e. T_1 = 36.5 °C, T_2 = 37.5 °C, and T_3 = 38 °C and humidity and ventilation conditions maintained fixed. A W1209 thermostat was used to control temperature, and a water-tray-based approach with the help of forced air circulation was used to control humidity. The proposed system has an automatic inverter and battery backup unlike most of the current incubator designs that only use an AC power supply, allowing a continuous operation during power failures. When chicken eggs were experimentally tested, the hatching rate was approximately 80%. The proposed incubator has good reliability, low cost and high suitability in rural poultry farming and educational purposes.

Keywords: Egg Incubator, Low-Cost Design, Semi-Automated System, Battery-Powered Incubator, Temperature and Humidity Control, Poultry Farming

Introduction
The global demand for chicken meat, a crucial source of protein, continues to escalate in tandem with population growth [1]. An ideal and automated egg incubator can only approximate the characteristics of a bird during the incubation process [2]. The popular method used in the production of poultry is that of artificial incubation in which eggs hatch under specified environmental conditions regardless of natural brooding. In the natural incubation, a hen gives the required warmth and care but artificial incubation can be more productive and have better control and can operate throughout the year [3]. Effective artificial incubation mainly relies on proper control over the temperature, humidity,

ventilation, and egg turning since these factors have a direct effect on embryo development and hatchability [4].

The most sensitive factor during incubation is the temperature. Past experiences have indicated that embryo develops best in chicken eggs with the incubation temperature range of about 37.5°C to 38°C during the first incubation phase with minimal modification being made towards hatching. In the same manner, humidity should also be regulated appropriately to facilitate desirable moisture loss by the egg since too much or too little humidity may cause death of the embryo, late hatching, or poor chicks [5]. Ventilation should also be done correctly to provide oxygen and eliminate carbon dioxide generated by the growing embryo. Although there is a lot of research on automated incubation systems, a lot of commercially available incubators are still costly, and they can only use continuous AC power. In rural and developing areas, power disruptions and absence of finances greatly diminish the incubation success. This has seen small farmers depending on cheap or mini incubators which do not ensure good environmental conditions, resulting in high embryo mortality rates [6]. Thus, there is a high demand of a low-cost reliable incubation system that supports normal incubation biological parameters and also meets the challenge of power reliability. The study is aimed at designing and developing an egg incubator that is semi-automated, adheres to incubation conditionology found in prior literature, but has a dual-power (AC/DC) operating system that switches itself automatically. The presented design will have the ability to offer a 24/7 performance even in the presence of power blackouts, higher reliability, and low cost, which is appropriate to rural poultry feeding and teaching.

Literature review and theoretical background

The poultry industry is a significant food production activity especially in South Asian nations where eggs and meat are valuable sources of food. Artificial incubation of eggs has become common to increase hatchability by availing controlled environmental factors that promote embryo development until they hatch [7]. The major factors that determine the success of artificial incubation are the maintenance of right temperature, humidity, ventilation, and egg turning during incubation as shown in Figure 1. Temperature is regarded as the most important parameter during incubation of eggs. This has been confirmed in past research that incubation temperature during the initial days of incubation in the range of 37.5 °C to 38 °C results in desirable embryo development and increased hatchability. Any departure out of such an ideal range may lead to hatching delay, mortality of embryos, or poor chicks. Another important factor is relative humidity that directly influences the rate of loss of moisture in the egg. The humidity of about 55-60 per cent during early period of incubation then rising to over 70 per cent during hatching has been found to give the developing embryo good growth conditions so that it successfully hatches [8]. Incubation is also crucial in ventilation and air quality. The embryos that are developing need the supply of oxygen and correct elimination of carbon dioxide that is produced in the process of metabolism. The lack of ventilation may result into low embryo growth and hatchability [9]. Alongside this, turning of the eggs is necessary, especially at the initial stages of incubation to ensure that the embryo does not adhere to the eggshell membrane. A number of incubation systems available in literature use microcontrollers and state-of-the-art sensors to control temperature, humidity, ventilation, and turnover of eggs. These systems are very accurate yet tend to make the systems complicated and expensive. Other inexpensive incubators use simple control mechanisms, but must be powered by continuous AC power which restricts their usefulness in rural locations where unstable power supply exists [10]. One significant weakness that has been discovered in the existing literature is that there is no reliable dual-power (AC/DC) operation with automatic changeover [8]. The common power failures in less developed areas have a major impact on the performance of the incubators even when the biological parameters have been adjusted properly. Thus, an incubation system is required which will preserve proven incubation conditions as well as provide continuous operation during the power failures. The current study fills this gap by adopting a semi-automated incubator with low cost and dual AC/DC power supply and battery backup without any adjustment of common incubation parameters relevant to earlier studies.

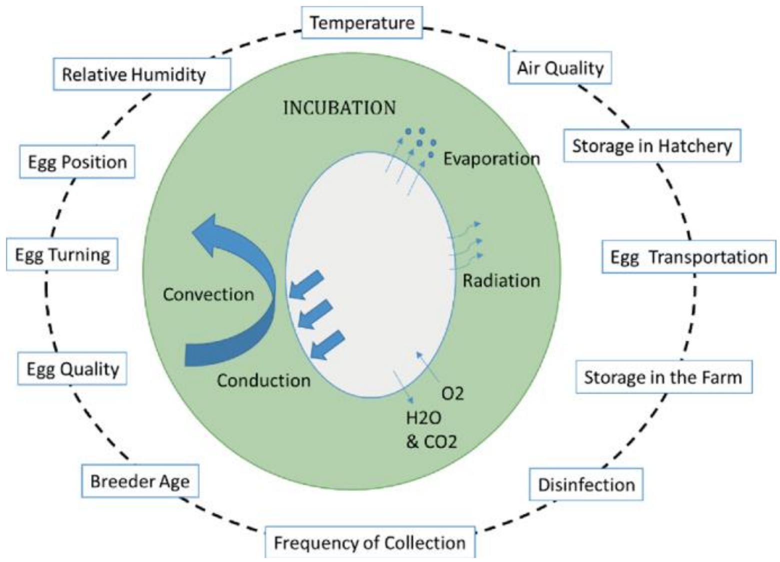

Figure 1: Environmental factors during egg incubation [11]

Research Methodology

The research methodology will comprise four significant steps, including mechanical design of the incubator structure based on cheap insulating materials, choosing and assembling electrical and control components, a dual AC/DC power supply system with automatic switching, and experimental testing with fertile chicken eggs under normal incubation conditions. The parameters of incubation, such as temperature, humidity, ventilation, and egg turning, were chosen according to known values provided in the previous studies to warrant biological reliability and the similarity of the findings.

System Design

Thermocol (expanded polystyrene foam) was used to develop the incubator chamber owing to its superior thermal insulation characteristics, light weight, easy to fabricate, and cheap nature [12]. Insulation of heat is essential to reduce the amount of heat loss and have a consistent temperature in the incubation room. The design was made to hold a number of 80 chicken eggs on a plastic egg tray. Ventilation was done using air holes that were strategically positioned with a DC fan to promote sufficient circulation of air into the embryo area and supply of oxygen. The interior design was such that it helped in even distribution of temperatures and humidity all over the chamber.

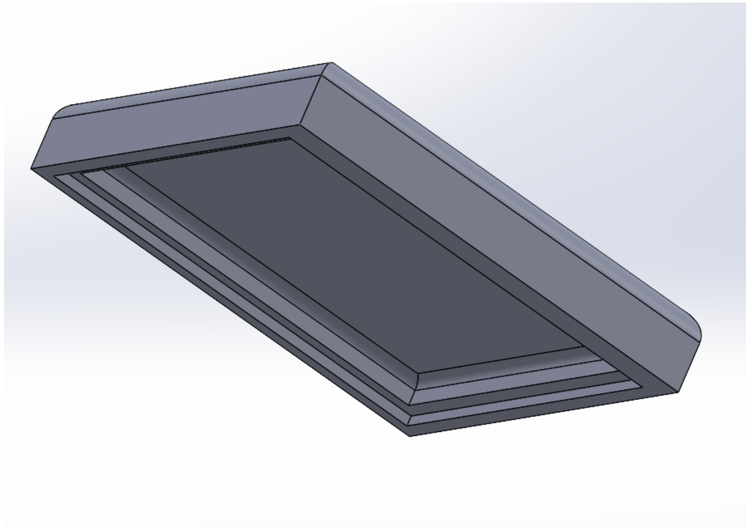

Figure 2: Cover of Incubator

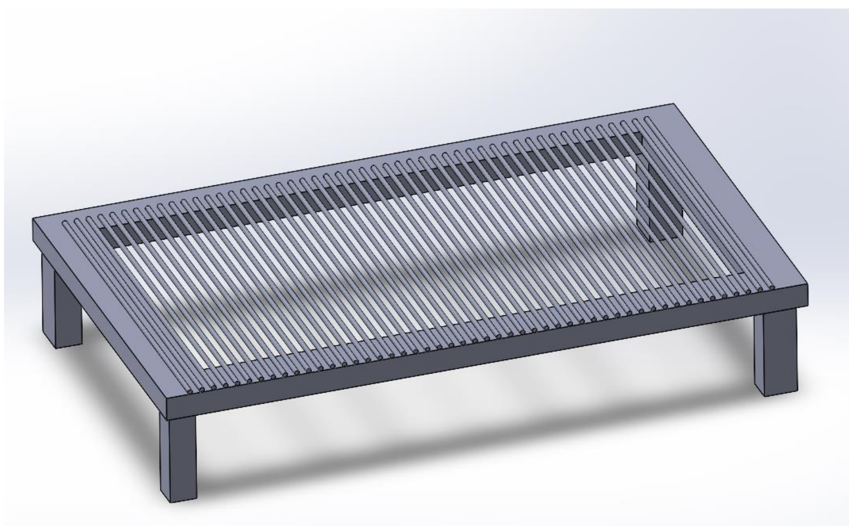

Figure 3: Eggs stand of Incubator

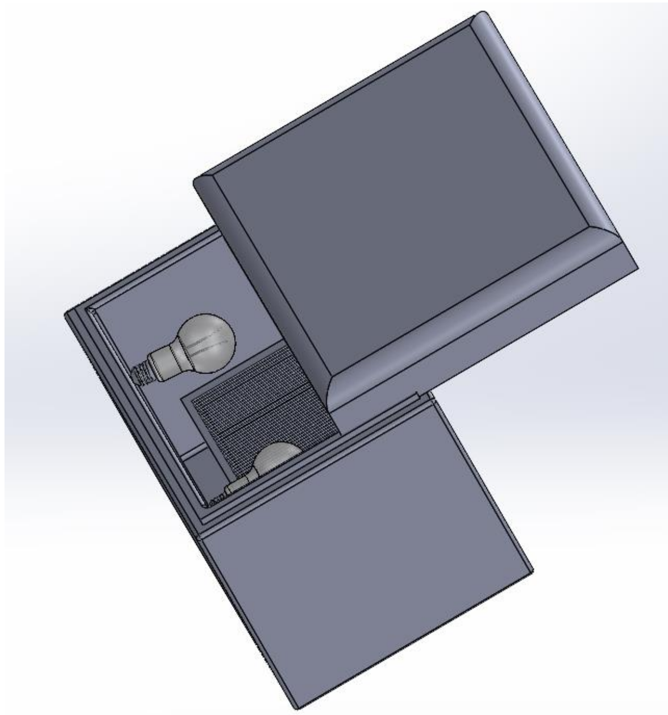

Figure 4: Final CAD Model of Incubator

Control of heating and temperature.

Incandescent bulbs had been used to heat the incubator chamber because they are easy, available and can give stable radiant heat. There were two heating modes that were applied based on the available power source. One was AC mode, in which two AC bulbs 220 V were used during normal mains supply. Followed by DC mode where three 12 V DC bulbs were used when the battery was in backup mode. A W1209 digital thermostat module was used in temperature regulation since it has an automatic ON/OFF control of the heating components. The thermostat will constantly check the temperature inside the chamber and turn on or off the heating bulbs in order to keep the heating to the desired set point. In the course of the experiment run, incubation temperature was kept at the range of 37.5 38 °C with a range of up ±0.2 °C variation, which means that thermal control was consistent.

Humidity Control and Ventilation

The humidity was corrected by a simple and well-proven water-tray-based technique. The incubator chamber was put in a shallow pool of water and forced air circulation was provided to increase evaporation through the use of a 12V DC fan (0.5 A). Relative humidity was kept at 55–60% during days 1–18 of incubation. The humidity was manually adjusted by adding water when it was necessary. Excessive humidity reduction was not commonly required and was done through momentary opening of the door of the incubator. The DC fan continuously offered ventilation and air circulation so that there was enough supply of oxygen and evenly balanced environmental conditions.

Egg Turning Mechanism

Egg turning was done by hand to achieve appropriate embryo development and avoid the sticking of embryo to the eggshell membrane. During incubation, eggs were rolled 2 to 3 times in a day. The egg turning was discontinued after 18 days as per the usual incubation experience during the hatching process.

Dual AC/DC Power Supply System

The major contribution of the study is that it modifies the dual AC/DC system of power supply into two systems with automatic change over, to maintain power supply to the incubator in the case of power cut. The incubator uses 220 V AC mains supply, and Battery system 12 V DC battery system powered by 12 V, 50 Ah lead-acid battery. The relay-based control system was also used to automatically switch between DC and AC power sources. Individual electrical elements utilized in the power management system are Power relays specifically QYT73 O12DC-ZS (DZK, 12 V coil), CRT-15F-S-DC12V-C and JZX-22F miniature power relay. The Filtering and stabilization element were 50 V, 4700 µF aluminum polarized electrolytic capacitor (SK brand). Under normal working conditions, the incubator operates on AC. In the event of a power failure, the relay system will automatically stop the AC supply and divert the load to the DC battery system using a circuit of an inverter. Upon a mains power cut, AC operation is automatically restored to the system without the need of intervention by the user. This capacitor helps to stabilize the voltage fluctuations and eliminate chattering of the relays during switching to ensure constant control of heating and control components. The battery backup system allows about 6-7 hours of constant power and this is enough to save the developing embryos during normal power failure.

Detailed circuit diagram of the system

Power Input and Automatic Changeover Circuit

The incubator is powered by a dual power system comprising of 220 V AC Main supply and 12 V DC battery backup. The changeover circuit is done automatically with relay to maintain a continuous operation as shown in Figure 5. When there is an AC supply, the system is used in the mains mode and once there is a power failure, the circuit automatically handles the battery mode and does not involve the user.

Power Conditioning Division

To stabilize the voltage when switching the load a 4700 µF, 50 V electrolytic capacitor is placed across the line of DC supply. This eliminates chatter in the relay, reduces voltage change, and insulates the control components connected when switching between power sources. This circuit has a built in automatic system of dual power supply to maintain the continuous performance of the incubator. The changeover mechanism is made of a relay system that allows the use of both the 220 V AC mains and a 12 V DC battery in the event of power interruption. The W1209 electronic thermostat constantly measures the temperature of the chamber and regulates heating coils to keep the required range of temperature to incubate. A DC fan is used to force the air supply to maintain equal temperatures inside the incubation chamber as well as an adequate ventilation.

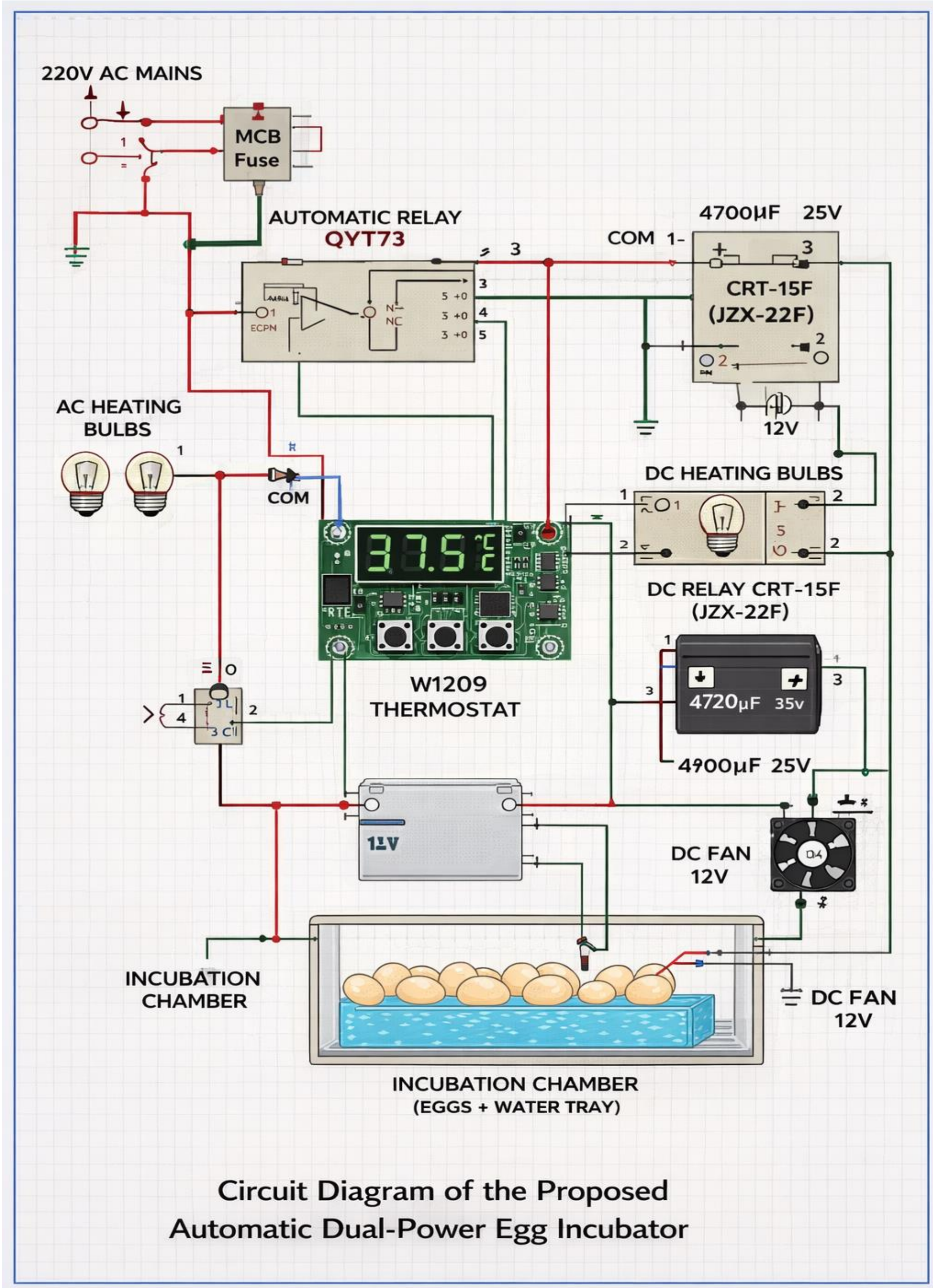

Figure 5: Detailed circuit diagram of the egg incubator system

Circuit of thermostat

A digital thermostat module, W1209, is used to regulate the temperature. The sensor keeps a constant check on the temperature inside the incubator and switches the heating elements with the help of a relay. The controller ensures that the incubation temperature is maintained at the level of 37.5 to 38 °C with a low level of fluctuation.

Heating Circuit

The incandescent bulbs are used in heating. There are 220 V AC bulbs and 12 V DC bulbs, two and three respectively, during mains and battery, respectively. Such set up guarantees steady heat production in both power states.

Ventilation and Humidity Support Circuit

This is done by forced air circulation in the incubator chamber by means of a 12 V DC fan. The fan provides even distribution of temperature, sufficient oxygen supply, as well as helps in keeping the humidity levels constant with evaporation of the water tray being controlled. The relays, thermostat, heating elements and ventilation fan work in coordination of the incubation conditions. The relay based model offers electric isolation, operating stability and aptness in rural settings with non-reliable power supply.

Performance Evaluation of the System

Experimental Methodology

The aim of the experimental study was to test the capability of the proposed incubator to hold the constant temperature and humidity levels and to test the hatchability in the conditions of the real operating. The current work is a practical reliability with a basic control strategy and solid hardware design, unlike fully automated or sensor-fusion-based work, which has been reported in earlier studies. The test of the incubator was performed in a room-scale indoor setting at the normal ambient conditions. The fertile chicken eggs went in the incubator and the system was run on throughout the incubation period. The incubation period was 19-23 days in regard to development of the embryo and the hatching period. A W1209 digital thermostat was used to control the temperature and it works based on ON and off control concept. The thermostat directly operated the heating components without microcontrollers and complex filtering algorithms. This strategy was chosen in order to minimize the complexity, cost and the maintenance of the system.
Humidity was controlled by a water tray which was supplied with the help of forced air circulation and manually corrected in case of necessity. Manual egg turning was also performed 2-3 times per day, 2 times in a day until day 18 of incubation.

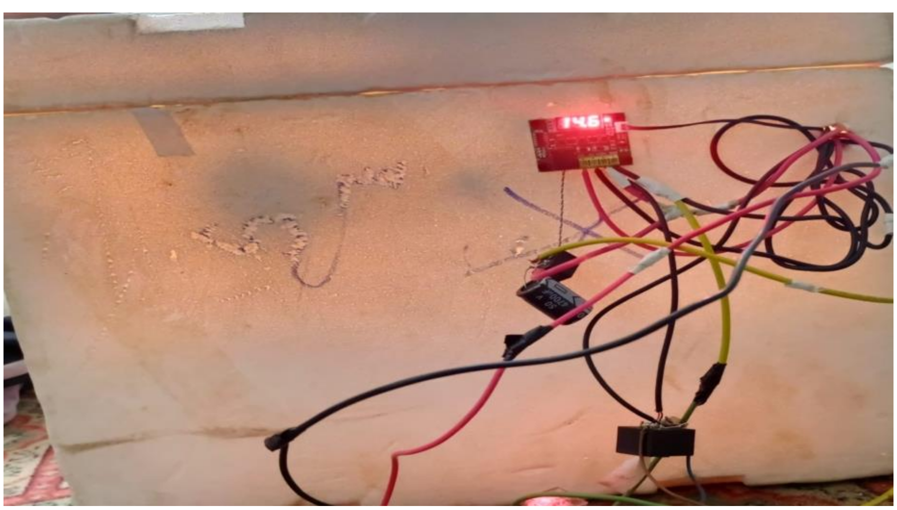

Figure 6: Temperature Monitoring

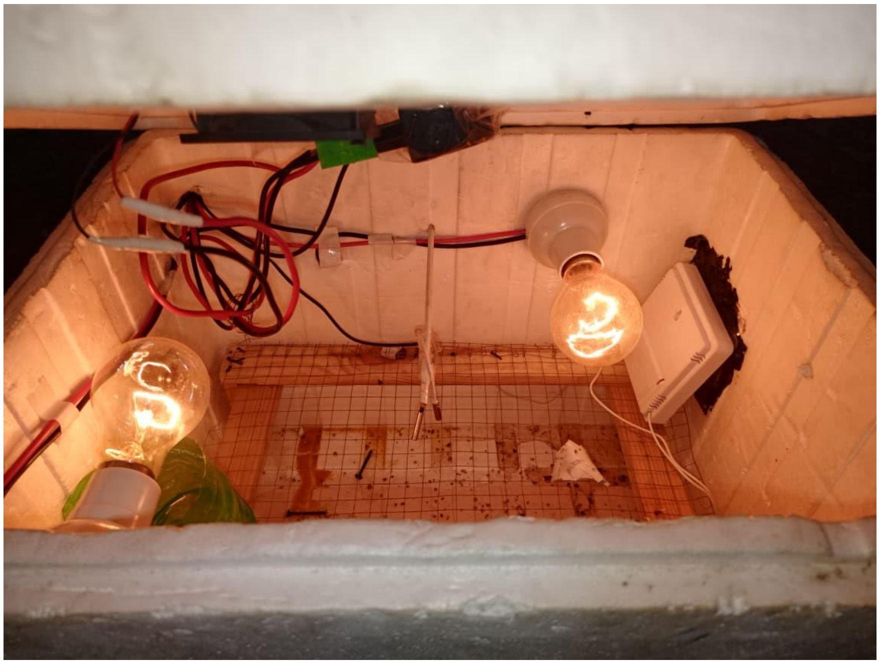

Figure 7: Fabricated Model

Figure 8: Initiation of Egg Hatching

Figure 9: Final Result of Incubation

Stability of Temperature and Humidity

In experimental test, incubation temperature was maintained at 37.5–38 °C, which is generally reported to be the best incubation temperature of chicken eggs. It did not exceed a variability ±0.2 °C and was consistent in temperature control. Relative humidity had been kept to 55–60% during days 1–18, and over 70 percent in his hatching time. There were slight changes in humidity which were rectified through addition of water on the tray when needed.

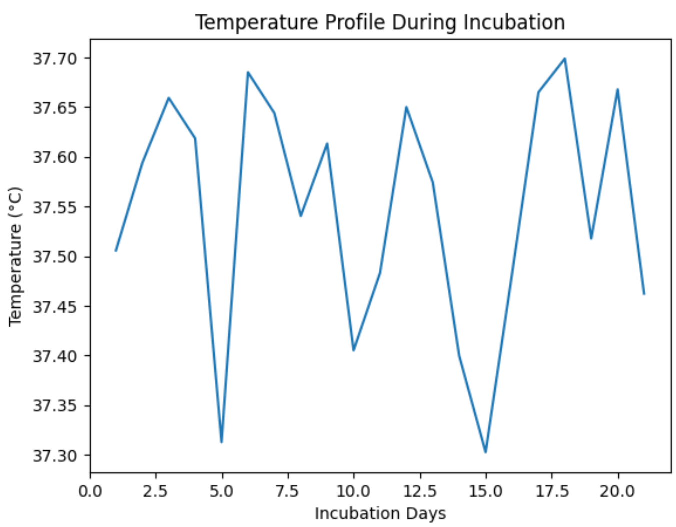

Figure 10: Temperature Profile during incubation

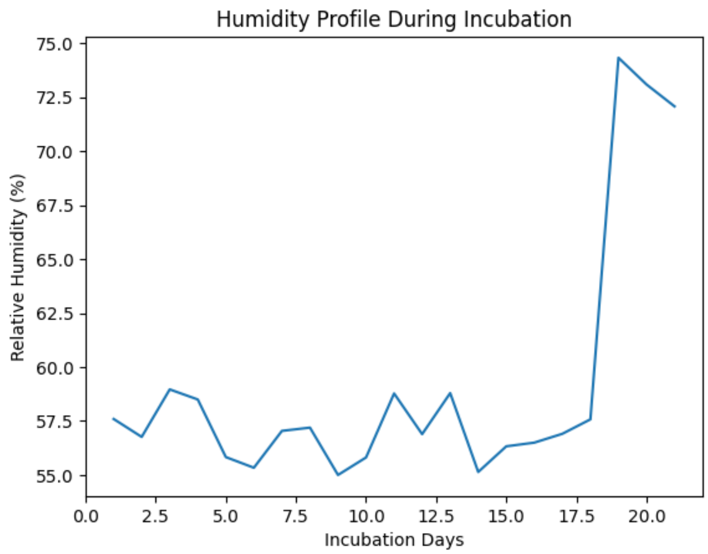

Figure 11: Humidity Profile during Incubation

Result and Discussion

The experimental analysis was done in 2-3 incubation cycles in chicken eggs. In a representative test, 8 of 10 eggs were successfully hatched and the hatchability rate was about 80 percent. The failed instances were blamed on unfertilized eggs as opposed to system failure. It was found that there was no mortality among the chicken after hatching which means that the conditions of the environment in the incubator were good enough to allow the embryos to develop and hatch successfully. The experimental outcomes reveal that the suggested incubator has equal hatchability with more complex and costlier systems that are found in literature, but utilizes much simpler hardware. Stable temperature regulation, efficient humidity regulation, and consistent two-power working together serve to provide the uniform performance of incubation. In comparison to IoT -based or microcontroller-based incubators, the proposed design is more robust, affordable, and user-friendly which is why it would be highly suitable in rural regions, to small-scale poultry farmers, and in education.

Conclusion

The current paper introduced the design and experimental analysis of a low cost and semi-automated egg incubator having a dual AC/DC power supply system. The proposed incubator keeps the standard parameters of incubation parameters such as temperature, humidity, ventilation, and egg turning as presented in prior research with the addition of automatic power switchover between mains power and battery backup being the main contribution. Experimental work with chicken eggs showed that the temperature was controlled on the most favorable range of incubation and a hatchability of about 80%. The automatic switching mechanism using relay that ensured constant operation in the event of power cut made the incubator extreme to areas with erratic power supply. The availability of locally sourced material and basic control equipment had a crucial impact on the costs of the system as it did not create any effect on the performance. The suggested incubator can be used especially in rural poultry farming, small scale use as well as educational or laboratory use. Future research will aim at adding automatic egg turning as well as digital humidity sensing to help automate the system even more, but at a low cost.

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