Design and Fabrication of Low-Cost Incubator to Evaluate Hatching Performance of Egg

Md. Janibul Alam Soeb, Muhammad Rashed Al Mamun, Shamima Shammi, Minhaj Uddin, and Rukon Ahmed Eimon

***Abstract* — In this study, a poultry egg incubator was designed, fabricated, and tested to evaluate its hatching performance. The incubator consists of a microcontroller with egg turner trays and incubating chamber of 116 nos. of egg capacity. The hatchability of the developed incubator was 79.3% and 87.1% hatchability during manual and automatic trials respectively. The temperature in the developed incubator was within the acceptable incubation temperature ranges from 37.6 °C to 38.6 °C. The average relative humidity in the developed incubator was maintained at 63.6% at manual and 55-65% at automatic trial. The eggs were turned manually approximately at 6 hours of interval. On the other hand, in the automatically controlled trial, it was done by egg turner maintaining exactly 6 hours of interval. It is noted that the percentage of hatching in rice husk incubators is below 55% which is much below comparing with the developed incubator. Also, the newborn chickens in rice husk incubators are unhealthy as they don't get a sufficient amount of heat. Besides, in the sand incubation technique, kerosene-based hurricane lamps are used which produce Carbon Dioxide. The developed incubator is environment friendly because it doesn't produce any by-product that is responsible for harming the environment. Also, after the successful trials, we have found the benefit-cost ratio was 1.42 which was quite satisfactory. The egg incubator can maintain the optimum conditions for the hatching of the chicken eggs and is capable of incubating and hatching the chicken eggs effectively. If the developed incubator is commercially supplied to the end-user, it will be a beneficial process of hatching for the farmer of Bangladesh.**

***Key words* — Low-Cost Incubator, Microcontroller, Hatching Performance, Automatic Turn.**

I. Introduction

The poultry business is one of the best-rising and most beneficial businesses in Bangladesh and it is a promising sector for poverty reduction in Bangladesh. In Bangladesh, for mitigating the need for protein, the people of this country eat fish as it is available here because of being a riverine country. Nowadays the demand for fish is increasing day by day as the population is increasing at a very alarming rate. On the contrary, the rivers are losing their ecological balance for supplying enough fish due to the several causes of water pollution. People are using their land for household construction, building, and industrial purposes largely. So, the commercial fisheries also can't contribute to this sector as demand. As a result, the availability of fish is decreasing which increasing the price of fish in the local market. In this situation, poultries are taking a large part to fulfill the demand for protein in this region. The total poultry population of Bangladesh is approximately 307.46 million and among them, the chicken population is approximately 259.41 million in the year 2013-14 [1]. Total egg production in Bangladesh in the year 2013-14 was approximately 6745.28 million in number [1]. About 89% of rural households rear poultry and contribute 20.8 % of the country's total egg and 37.3 % of meat [2]. The hatching is an obvious part of any poultry farm. Several technological advancements have resulted in the employment of artificial techniques for incubation eggs. This artificial process has been around for thousands of years, and it has only kept improving with time [3].

Abu Musa Bin Mohd Adid designed and developed the system of an egg incubator that able to incubate various types of egg named Smart Egg Incubator System for Various Types of Egg (SEIS) [4]. The entire element will be controlled using a programmable integrated circuit (PIC). The PIC is a type of microcontroller that can process data from a sensor and will execute the control element to change the condition of SEIS. Chukwu et al. designed and fabricated an automatic temperature regulating egg-incubator using the principles of thermoelectricity. This is aimed at solving the problem of temperature fluctuation usually experience by poultry farmers which leads to production loss. Its workability is about 70% efficient [5]. These incubators are comparatively sophisticated by its manufacture and also complex to operate comparing the incubator developed in this study. Also, the expense of the developed incubator is also less than the two incubators.

The traditional process of hatching the egg in Bangladesh is rice husk incubation. The bamboo incubation box, as well as two (or three) bamboo cylinders, must be put up in a dark room (incubation room), preferably well insulated. The cylinders are arranged in a circle in the center. The rice husk should next be added to the incubation chamber. During the entire hatching time, a gasoline lamp (Hurricane) should be kept in one cylinder alternately to keep the chamber at the ranges of 98-100 °F or 37-38 °C [6]. The percentage of

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hatching is below 63.06% [6] and the newborn chickens are unhealthy as they don't get a sufficient amount of heat. In rice husk incubation, the labor cost is high, hurricane produces carbon-di-oxide, and also it is not a controlled way of hatching.

That is why to mitigate the problems of the traditional incubation process an automatic electrical incubator was needed to be developed which should be low cost as well as environment friendly. In this study, a microcontroller-based automatic incubator was developed by using locally available materials, and then the hatching performance was evaluated. Artificially, in an incubator, environmental conditions must be created by poultry farmers to do this operation within the desired temperature and relative humidity range. These ranges are between 360–390 °C and 50–70%, respectively [7].

II. Design of Poultry Incubator

A. *Incubator Box Design*

The proposed incubator box is made of a locally available plywood sheet which consists of length 243.84 cm and width 121.92 cm. The depth of the sheet was 1 cm. The design of the sheet is shown in Fig. 1 referring to each part of the incubator box. The top and bottom part of the box was kept square shaped of dimension 76×76 cm. The dimension of the left and right sides was 75×45 cm. 72×45 cm was considered as the dimension of the backside of the box.

Two windows were having a dimension of 45×38 cm. For making airtight inside the chamber, there were two small pieces of plywood sheet having a dimension of 4×72cm was considered and attached at the bottom and upper portion of the chamber on the front side.

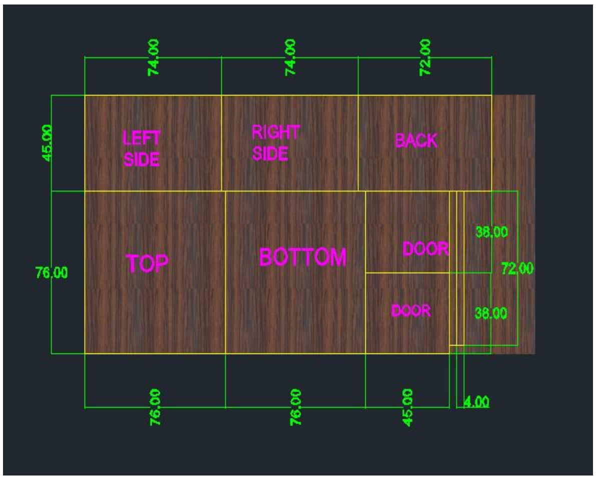

Fig. 1. Designed Plywood Sheet.

According to the design, the different parts of the plywood sheet were cut and joined altogether using the screw. The door was joined with the box by the hinge. There was a circular section with a radius of 9.50 cm that was cut from the middle of the upper portion of the box. Also, there were two small holes for each of the fans and they were placed at the back of the fan. The holes assisted the ventilation process within the chamber. The designed incubator box is shown in Fig. 2.

Fig. 2. Designed Incubator.

B. *Electrical Circuit Design*

This incubator board was made with an Arduino Nano as a microcontroller, a voltage regulator (LM7805CT_NOPB), 2 relays, a battery charger module, two DC power jacks, two 2pin connectors, and a lipo battery cell. To power up this board, there were two DC power jack and a lipo battery. The battery was connected through the connector. To charge the battery there was a battery charger module on the board. To stabilize the board there was one voltage regulator. Because the component used in this board works in a specific power supply. So, to make it work properly and safely it was needed to stop the overflow of the current so that the component on the board did not get affected. The current that's passing through the voltage regulator and power up the board was 1.5 A and it's quite safe and stable for the component on the board. Now to make the board work as expected that there was one Arduino Nano as a microcontroller to control the board. The code was uploaded to the microcontroller to make the board work. After that, 2 relays acted as a switch in desire condition. ON/OFF could be done by using those two relays.

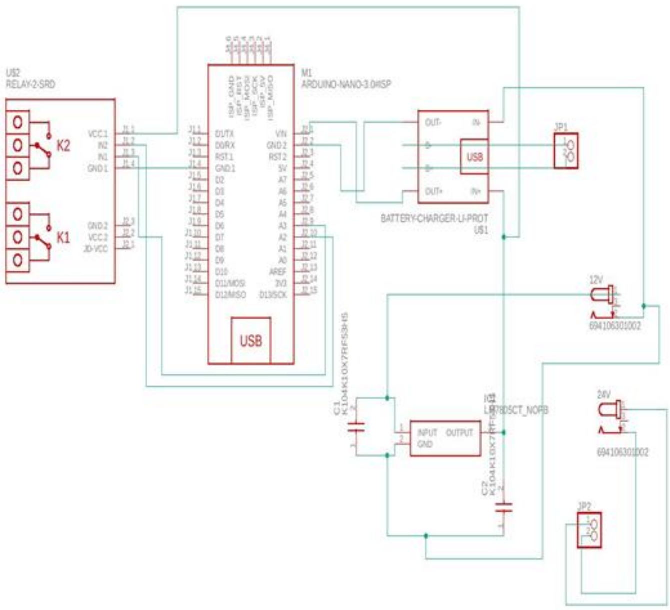

Fig. 3. Microcontroller with Arduino Nano (Proteus View).

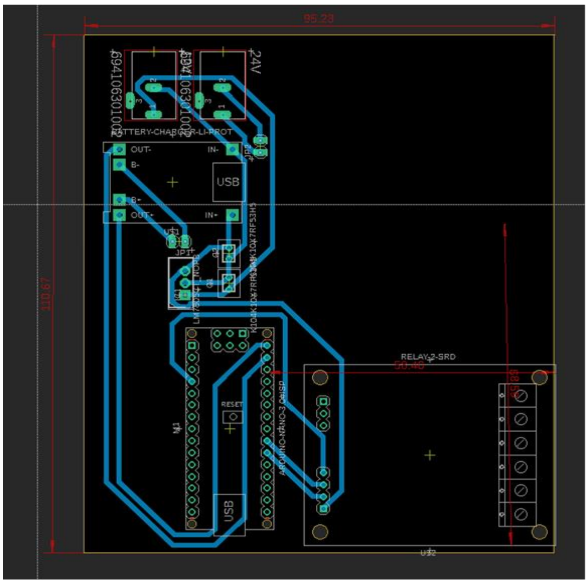

Fig. 4. Printed Circuit Board (PCB) Design of Microcontroller Circuit.

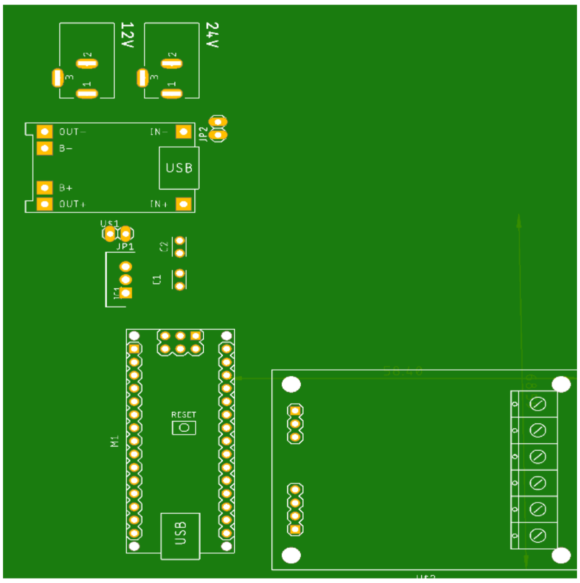

Fig. 5. Printed Circuit Board (PCB) Design of controller CircuitMath.

III. Materials Required

A standard plywood sheet available in the local market was bought which consists of length, width & depth 243.84 cm, 121.92 cm and 1.9 cm, respectively. There are 2 doors in the incubator box. The hinge was used to attach the door to the box. Thermocol sheet covered with aluminum foil paper was used in the inner portion of the box for better heat conservation. Two nos. of 100-watt bulb were used for heat development. The bulb was controlled by the thermostat.

A 12 V 5 A adapter was used to convert the 220 V electrical voltage to 12 V. This 12 V 5 A was used to operate Thermostat, Cooler fan, Humidifier, Egg turner, and Arduino relay. Some flexible weir was used for the electrical connection such as 220V power source to the bulb, 220 V power source to 12 V adapter, 12 V adapter to thermostat, 12 V adapter to relay, 12 V adapter to 12 V cooler fan, 12 V adapter to Arduino relay, and Arduino relay to egg turner motor.

The thermostat was used to control the temperature and humidity of the chamber. And Arduino Uno R3 was used to control the cooler fan and egg turner tray. The humidifier is a device that develops water vapor from the water. It was required a 12 V power source for its operation. Here the humidifier was used to increase the humidity of the chamber up to the desired range. It was controlled by the thermostat.

2 nos. of the cooler fan were used inside the left and right sides of the incubator. The cooler fan was used to circulate the heat and water vapor throughout the box uniformly.

The trays for egg turning are very important for the positioning of the eggs. The egg incubation chamber was composed of two egg trays that have a capacity of 116 eggs spread in the two trays. Two types of egg trays; one rotates at an angle of 1800 and another 900 were used in the incubator. The distance between the trays was enough to prevent the base of the upper tray from touching the eggs that may be set at the lower tray. In this egg incubator, the eggs were turned four times per day for normal embryonic development to take place.

IV. Equation

Mean= Sum of humidity/(Total no. of Day)

Deviation = Mean – Average humidity

Mean Deviation = Sum of Deviation/(Total no. of Day)

Square of Mean Deviation = (Deviation) 2

Variance =Sum of Square of Mean Deviation /(Total no. of Day)

Standard Deviation = Square Root of Variance

1) Correlation Coefficient

The correlation coefficient of hatchability percentage with the variation of distance from the bulb is observed.

Let, Distance of row from bulb = X

Hatchability Percentage = Y

Number of data = N

correlation coefficient,

$$r = \left(\frac{\Sigma XY - \frac{\Sigma X * \Sigma Y}{N}}{\sqrt{\left\{\Sigma X^2 - \frac{(\Sigma X)^2}{N}\right\}\left\{\Sigma Y^2 - \frac{(\Sigma Y)^2}{N}\right\}}} \right. \quad (1)$$

V. Result and Discussion

A. Full Set-Up of Incubator with All Component

The incubator box was fabricated according to the design and there was no major deviation was found in dimension after the fabrication. The fabricated incubator box is shown in Fig.6.

There are two trials were taken: 1) Manual Trial 2) Automatic Trial. The method of two trials can be separated by the control of humidity and egg turning.

Fig. 6. Full set up of incubator with all components.

B. Evaluation of Egg Hatching Data (Manual Trial)

In the manual trial, turning off the egg and humidity were controlled manually where the remaining parameters like temperature and ventilation were controlled by the bulb and cooler fan respectively. Turning was done 4 times a day at an average interval of 6 hours. But exactly 6 hours of interval couldn't be maintained for schedule issues. The fluctuation of interval time along with Average Relative Humidity (ARH) is shown in APPENDIX A.

Since in manual trial the egg turners were not used, the eggs were turned by hand. The standard turning interval of the hatching period is 6 hours but there was some fluctuation found which is shown in Fig. 7. The graph shows that the turning interval fluctuates between 5 to 7.2 hours.

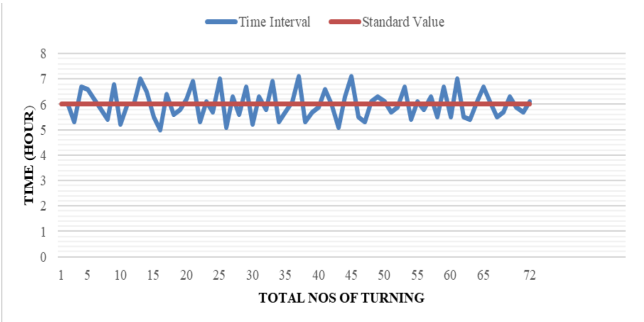

Fig. 7. Turning interval in the incubation process

Be The humidity was maintained by supplying hot water in the chamber. The average daily humidity (from APPENDIX A) in the manual trial is shown in Fig. 8.

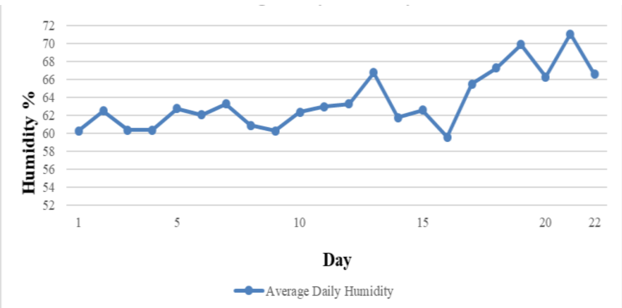

Fig. 8. Average daily humidity in the incubation process.

As in the manual trial, the humidity was maintained manually so the average humidity fluctuates a little from the standard value throughout the incubation period. The standard deviation of average humidity was found at 3.13, the calculation is shown in APPENDIX B.

The mean of average humidity was found 63.6 which is in the acceptable range of relative humidity of any standard incubator. The standard deviation is indicating the deviation of the observed average humidity with the mean of the average humidity. The value measured of standard deviation is 3.13 which means the daily average humidity didn't fluctuate a significant amount. Hence, it can be said the relative humidity within the incubator chamber could be kept in a standard range during the trial.

C. Performance Evaluation (Manual Trial)

There were 90 eggs set in the manual trial. After 7 days, 8 eggs were found infertile by candling. Hence the percentage of the fertile egg was 91.1%. 65 eggs were successfully hatched during the incubation thus the hatchability percentage was 79.3%.

D. Performance Evaluation (Automatic Trial)

In the case of automatic trial, all basic parameters like humidity, temperature, turning, ventilation were maintained automatically. Here, two types of the tray were used based on the turning angle. One is 1800 rotation angle, and another is 900 rotation angles. The hatchability, fertility percentage of raw based on the bulb distance are shown in APPENDIX C. There are 5 rows in 1800 rotation tray which are situated at a distance of 6.35, 8.89, 13.97, 19.05, 24.13 cm respectively. But for 900 rotation tray, 4 rows are situated at a distance of 8.89, 13.97, 19.05, 24.13 cm, respectively. The hatchability percentage for each row is shown in Fig. 9. Among 48 fertile eggs in 1800 rotation tray, 45 eggs were hatched which means the hatching percentage was 93.8% for this tray. On the contrary, for 900 rotation trays, 53 eggs were set for hatching and 43 eggs were successfully hatched. The hatching percentage of this tray was 81.1%. The no. of egg hatched at 20th. 21th. 22th and 23th day was also shown in APPENDIX C. The overall hatched egg was 88 nos. and the percentage of overall hatchability was 87.1%.

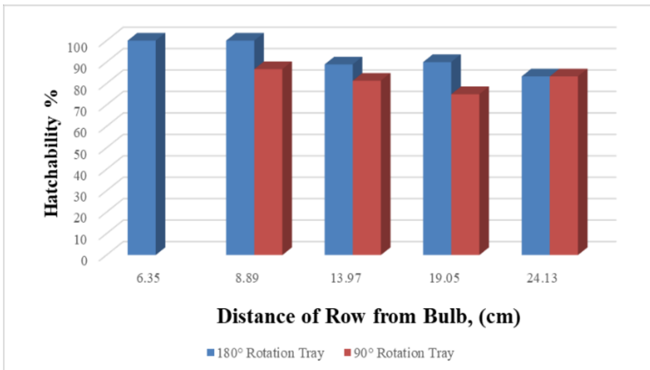

Fig. 9. Hatchability based on bulb distance.

The correlation coefficient between the distance of tray from the light bulb and hatchability is clearly showing that there is a strong negative relationship and a moderate negative relationship between these two parameters in 1800 and 900 rotational trays respectively. Hence, it is clear that with the increase of row distance of bulb the hatchability percentage decreases.

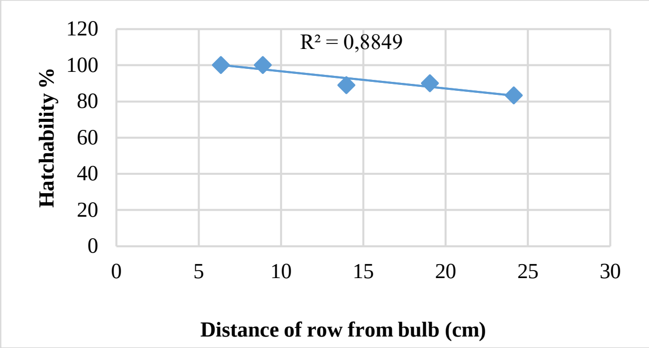

Fig. 10. Correlation coefficient on 180° rotation tray.

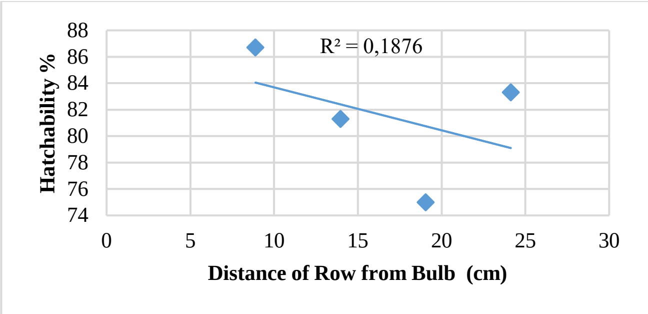

Fig. 11. Correlation coefficient on 90° rotation tray.

The main purpose of developing an incubator as automated was to reduce human efforts and control the environment more precisely. The hatchability percentage raised by 7.8% after automation. The automation also facilitates the turning process in a controlled manner without any effort.

E. Cost Analysis

By calculating box, wiring, labor, humidifier, tray, and thermostat price the total purchase price stand 9500 Tk. (Bangladeshi taka)

From APPENDIX D,
Salvage value, S = 950 Tk.
Thus, CRF = 0.2571.
Capital Consumption, = 2284 Tk. /yr.

2 nos. bulb (200W), Humidifier (24W), 2 nos CPU case fan (32W), and Thermostat with controller (13W) total consume 269W energy. As the 2 trays (12V) were operated for a very short period of time (1 minute per day) so, it was not considered in power consumption. The incubator was operated 14 h/day and the total cost of electricity for 21 days was 633 Tk based on 1 KWh cost 8 Tk.

1) Cost Calculation for Hen Egg Hatching

Egg Price (Hen) =17280 Tk. /Yr.
Repair and maintenance cost and labor cost = 3000 Tk.
VC (Hen) = 27876 Tk.
Total Cost = 30160 Tk.
Average hatchability = 85%.
Total hatched egg per year = 1224.
Total Revenue (TR) = 42840 Tk.
Profit = 12680 Tk.
Benefit-cost ratio = 1.42.

That means if anyone invests 1 taka for a year he/she will get 1.42 taka after 1 year.

VI. Conclusion

In Bangladesh, for higher nutritional deficiencies, about half of the population is unable to work either physically or mentally. They suffer from malnutrition with a negative effect on immunity. That is why animal protein is very necessary for this region’s people and to get a healthy nation, animal protein availability should be increased. Production of a sufficient number of chicks and their survivability determine the success of rural poultry operations. People cannot decide how many eggs should be put under a hen for optimum hatchability. In most cases, they probably put more eggs than the hens can hatch. A significant number of eggs have probably been lost in the country in this way. The matter is important, as egg production from indigenous chickens is very low. All these circumstances demand a low-cost convenient incubator for the farmer. The developed incubator had 79.3% hatchability and 87.1% hatchability during manual and automatic trials respectively. The average temperatures in the developed incubator were within the acceptable incubation temperature range at 37.6 °C. The average relative humidity in the developed incubator is 63.6% (Manual) and 55-65% (Automatic, controlled by the microcontroller). The egg-turner tray rotated every 6 hours in the automated trial. If the developed incubator is commercially supplied to the end-user, it will be a beneficial process of hatching for the farmer of Bangladesh.

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Conflict of Interest

Authors declare no conflict of interest.

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