Inno-Bator: Development of an Autonomous Egg Incubator Integrated with Camera Assisted Candler using Labview and Arduino Nano Microcontroller

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Abstract – **This paper presents the design of an incubation system for autonomous temperature and humidity control using Arduino microcontroller interfaced and coded using Labview programming which also includes important functions to hatch eggs which are candling infertile egg identification using basic image acquisition and egg turning that employs crank-rocker mechanism and a hatching chamber. The design revolves around fusing all the elements of egg incubation and hatching turning it into one device and monitoring it through a single computer in which the user can have real-time data of the day-to-day status of the incubator's parameters and functions autonomously without having to consistently check and adjust in order to obtain optimal parameters. The speed of the automatic candling program is 1.129 seconds the performance of the incubator held an optimal temperature of 36° Celsius with humidity between 40% and 60% with an optimal level of 50%.**

I. INTRODUCTION

Artificial incubators have been popular throughout the modern world as well as in the past way back ancient times. Based on historical records, Van Den Sluis mentioned that in ancient Egypt, eggs were incubated inside buildings made up of mud bricks divided by rooms and heated by burning straw and charcoal. They control the temperature by opening vents and manholes for the heat to escape and have openings for the smoke to exit. Humidity is induced by placing moistened jutes inside and eggs were manually turned twice per day. It was not until the 1749 that the first mechanical incubator was invented by Reamur in Paris, France and the first incubator to be commercialized was the work of Hearson in 1881.

Artificial egg incubators' objective is to recreate a brooding hen's environment so that the eggs would hatch into a healthy chick. The parameters or factors that are needed to be controlled by the incubator are temperature, humidity, ventilation and egg turning. If all of these factors are regulated, this will provide the perfect environment for the development of the embryo. As technology advances more and more manual techniques turns into automated processes. Commercial state-of-the-art hatcheries now have sensors that detect these certain parameters and adjust it according to the optimal value so that there will be no discrepancy in the incubation process. Though technological advancements have riddled the field of incubation of eggs, incubation may still run into several issues. The breeder needs to check these common incubation problems: Temperature difference inside the incubator, as well as humidity, inadequate ventilation, irregular turning of eggs and egg sanitation. With this an incubator must possess a reliable program and hardware system and an accurate reading from its sensor so as to function as an effective incubator to handle the eggs for 21 days straight without requiring any human intervention [1]. Also candling of eggs need to be done by hand because traditional candling are done manually. Besides being a tedious job because the handler must individually check for development of an egg the temperature changes of handling the egg outside the incubator can also affect the mortality rate of the eggs [2]. There are many digital techniques that differentiate good eggs for incubation and bad eggs that are not fit for it, though this researches does not apply specifically for detecting fertile eggs but these studies greatly influences viability for incubation. One method applied an adaptive threshold based on discontinuities determination the filtered images for detecting eggshell defects such as dirt and cracks which used 120,640 by 480 images to train the machine vision system which had an accuracy of 99% [3]. Other studies include finding blood spots and obtaining dirt severity to classify the eggs as infertile as this influences egg fertility, such is the case of M.H. Dehrouyeh et al. They have obtained an accuracy of 90.66, 91.33, 80.33% on finding blood spots of egg from intact, defected and low dirt eggshells respectively and 88% and 86% for dirt detection on high dirt and low dirt in eggshells respectively [4]. A near-infrared hyperspectral imaging system was developed to detect fertility and an embryo development. After imaging on each day, developing embryos in randomly selected eggs were stopped by injecting sodium azide (NaN_3). All the eggs were divided into two classes, fertile eggs and non-fertile eggs. This study is not like the others as accuracy degrades for day 1 and 2 of incubation. Results stated as day 0 accuracy is at 100%, 78.8% at day 1, 74.1% at day 2, 81.8% at day 3, and 84.1% at day 4. Result showed that texture information is more useful to detect early embryo development than detecting fertility before incubation [5].

As a solution the researchers are aiming to incorporate and design an egg candling mechanism inside an incubator which in turn will reduce the time invested in candling and will detect undeveloped eggs and classifies it from the rest of developing eggs to avoid the contamination of the incubator due to the phenomena of "exploding eggs" and premature death of chicks due to mishandling of eggs; and an effective system for temperature and humidity control to produce the optimal incubator parameters for the development of chicks. The quality of embryonic eggs is affected by pre-incubation factors that influence the egg hatchability, chick quality, bird survival and chick growth performance [6]. The optimal temperature for the incubation of eggs is 37º to 37.5 º C and relative humidity of 55% [7][8]. The system uses temperature and humidity sensors that can measure the condition of the incubator and automatically change for the suitable condition for the egg [9]. This study is limited only to different chicken egg breeds with white shelled eggs. For the candling function this study includes a camera that will capture an image during the 10th day of incubation to distinguish those that isn't developed to efficiently eliminate these undeveloped eggs.

Poultry hatching businesses will benefit in this study as it will help lessen the time and human contact by automating candling process and remedies the improper way of controlling the temperature and humidity inside the incubator which in turn leads to unfertilized eggs. Through this study, impractical control of parameters and tedious and timely traditional candling will be resolved.

II. Methodology

A. Block Diagram

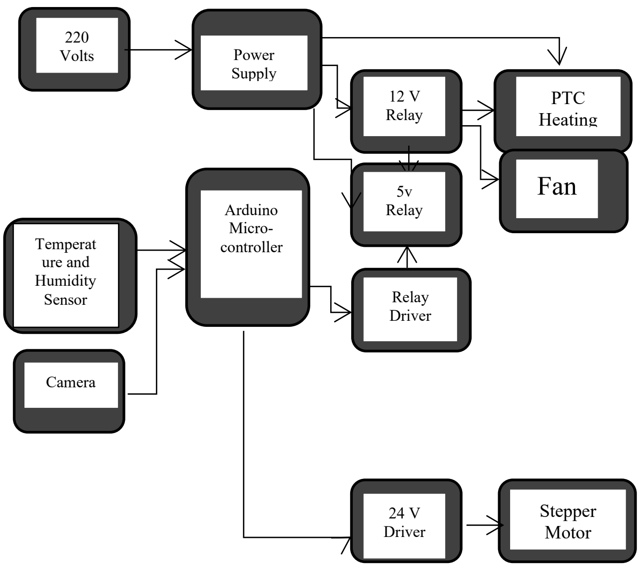


Fig. 1 System's Block Diagram

Figure 1 shows the block diagram for the autonomous incubator. The inputs in the system of this study are the temperature and humidity sensors, the camera which will capture the image of the egg during candling process and the power source. Automatic control of the incubator is achieved through the sensing of parameters by the DHT11 sensor installed therein. Then these data are processed by the microcontroller in which it decides whether it will switch the devices that will control these parameters: humidity, temperature, and ventilation.

B. Hardware Development

- **Temperature and Humidity Correction System**

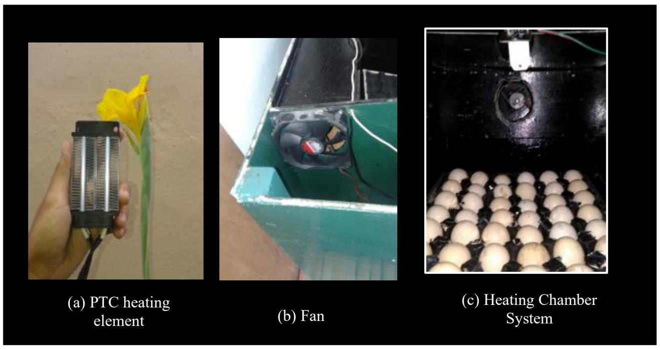


Fig. 2 Temperature and Humidity Correction System

The correction system for the temperature fluctuations consists of the PTC heating element partnered with fan and the detection system is Arduino Nano with DHT 11 sensor was installed. Once the temperature drops below the threshold the detection system sends a signal to the correction system turning on the whole system and turns off if temperature exceeds threshold. The temperature sensor is installed at the far side of the tray directly in the line-of-sight of the fan distributing the heat.

- **Egg Turning Motor Control System Design**

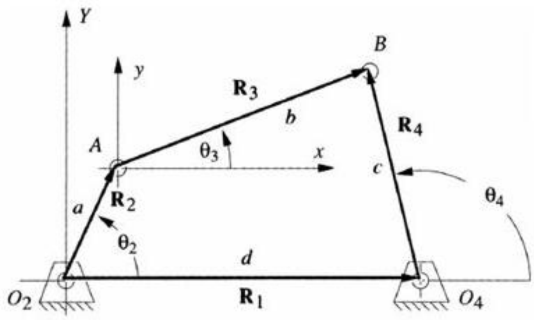


Fig. 3 Crank-rocker Mechanism

$$\tan\left(\frac{-\theta_4}{2}\right) = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

Eq. 1 Equation of output angle

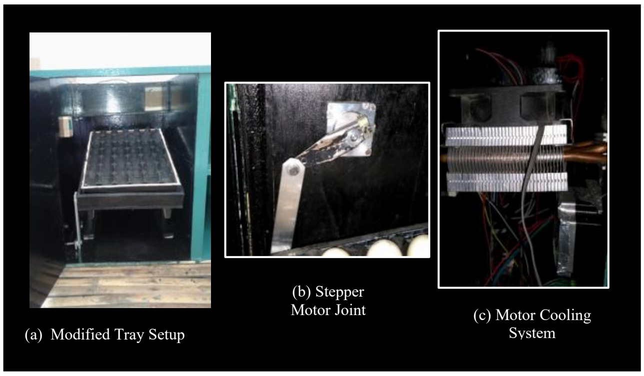


Fig. 4 Egg Turning System

The modified tray has LED strip lights below where eggs can be illuminated without removing the eggs from the tray has been installed. Egg turning mechanism that employs a crank-rocker inspired design turns the eggs 45 degrees both sides every 8 hours per day. The timing program is uploaded in the Arduino Nano. The stepper motor is installed with a fan cooling system partnered with heat sink to reduce the heat the motor is experiencing.

- **Camera Assisted Candling System**

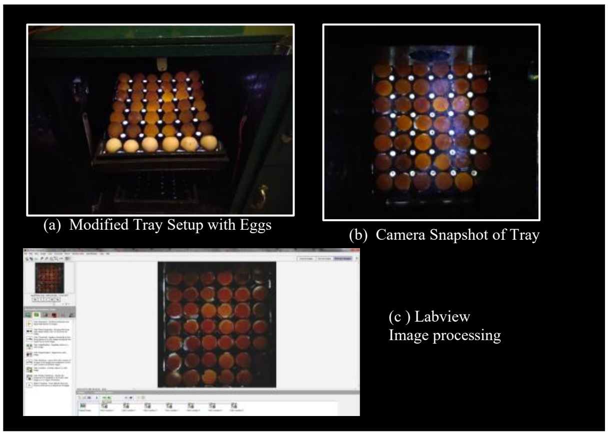


Fig. 4 Automated Candling Program

The camera is installed directly at the top of the incubator overlooking the tray. The camera should capture all the eggs in the tray so in processing the image all could be color detected and identified whether the egg is a porous egg with no semen or a fertile egg. The programming software used for the processing is Labview with NI Vision Assistant.

C. Incubator Testing and Data Gathering

The researchers tested the incubator's system functionality and at the same time gather data for validation if the incubator does maintain the right level of humidity and executes the program accurately.

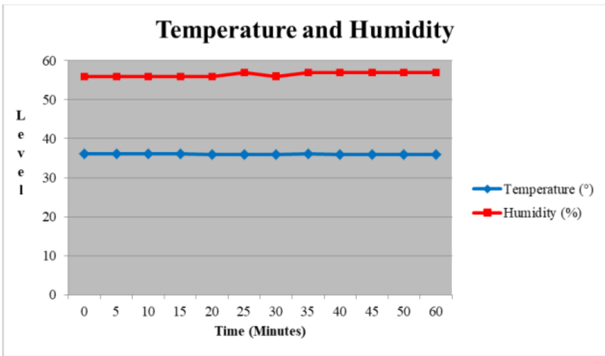
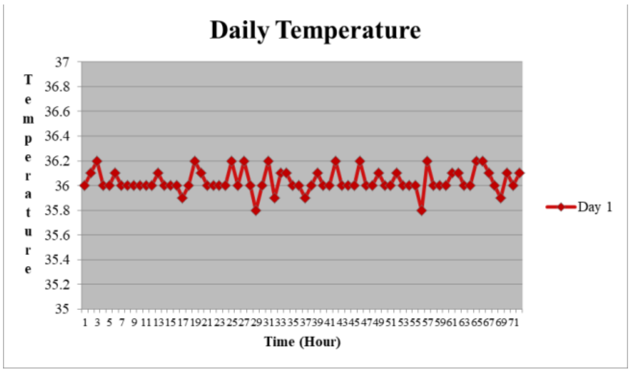


Fig. 6 Temperature and Humidity Level

Temperature and humidity is gathered every 5 minutes for an hour to test if the incubator can maintain the optimal temperature and humidity.



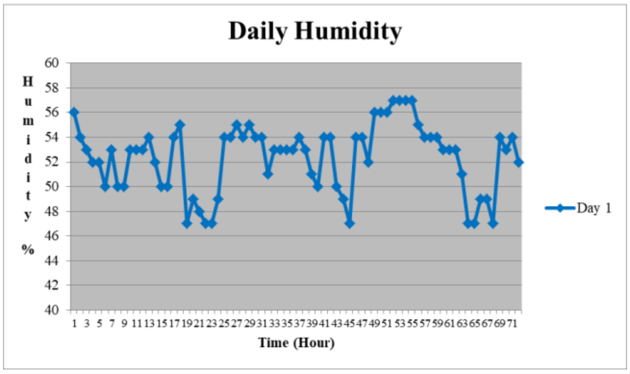


Fig. 7 & 8 Incubator Endurance Test Readings for 3 days

Figure 7 & 8 shows the performance of incubator for 3 days of continuous usage. Data shows that the temperature was held on to optimal level (36 degrees) and humidity on its acceptable level which is between 40% and 60% with 50% as the optimal level.

III. Results and Discussion

A. Traditional and Automated Candling Time and Accuracy Comparison

- **Modified Tray Candling**

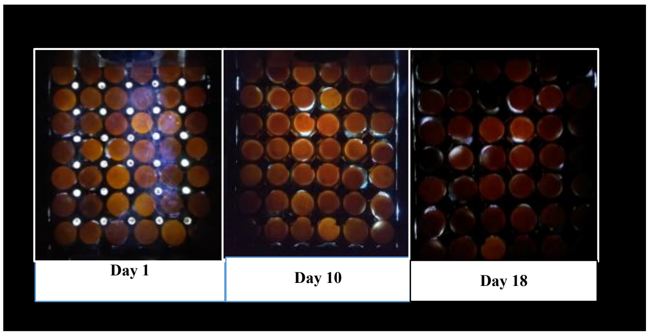


Fig. 9 Incubation Progress

Figure 9 shows the darkening of eggs which indicates growth of the embryo cultured in the egg.

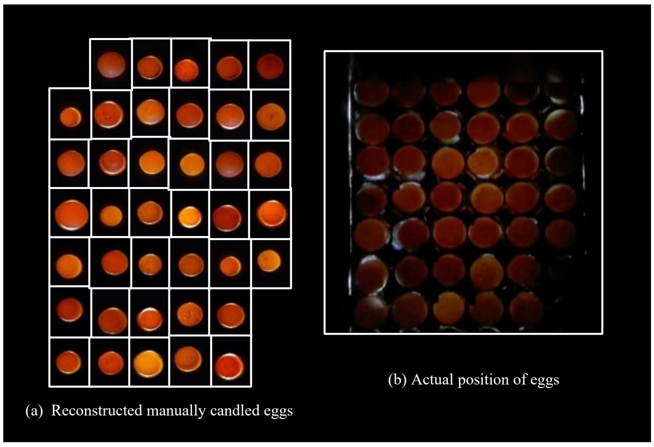


Fig. 10 Reconstructed manual candling versus actual tray candling

Figure 10 shows the difference in imagery of manually candled eggs and eggs candled using the incubator's built-in candling design. In order to compensate for the lighting discrepancy of the incubator's candling, the researchers used image manipulation to heighten the efficiency of image processing done on the eggs.

- **Traditional and Automated Candling Time Comparison**

After 3 trials of manual candling the researchers determined that the average time it took for one breeder to candle all 42 eggs is ***396.667 seconds*** while the time it took for the candling program to process the candling is only ***1.129 seconds*** .By computing for the percent difference the resulting percentage will be in favor of automatic candling. The automatic candling proved to be ***35,034 %*** faster or 350.34 times faster than traditional candling. The large difference in time is due to the program's nature that it detects all the eggs through one picture only while in manual candling the eggs are individually assessed. Tabulated trials can be cited in the full paper.

- **Traditional and Automated Candling Accuracy Comparison**

Table 1 Candling Accuracy Comparison

Sensory Evaluation		Auto Candling	
	Status		Status
Egg 1	FAIL	Egg 1	OK
Egg 2	OK	Egg 2	OK
Egg 3	OK	Egg 3	OK
Egg 4	OK	Egg 4	OK
Egg 5	OK	Egg 5	OK
Egg 6	OK	Egg 6	OK
Egg 7	OK	Egg 7	OK
Egg 8	OK	Egg 8	OK
Egg 9	OK	Egg 9	OK
Egg 10	OK	Egg 10	OK
Egg 11	OK	Egg 11	OK
Egg 12	OK	Egg 12	OK
Egg 13	OK	Egg 13	OK
Egg 14	OK	Egg 14	OK
Egg 15	FAIL	Egg 15	FAIL
Egg 16	FAIL	Egg 16	FAIL
Egg 17	OK	Egg 17	OK
Egg 18	OK	Egg 18	OK
Egg 19	OK	Egg 19	OK
Egg 20	OK	Egg 20	OK
Egg 21	OK	Egg 21	OK
Egg 22	FAIL	Egg 22	FAIL
Egg 23	OK	Egg 23	OK
Egg 24	OK	Egg 24	OK
Egg 25	OK	Egg 25	OK
Egg 26	OK	Egg 26	OK
Egg 27	OK	Egg 27	OK
Egg 28	OK	Egg 28	OK
Egg 29	OK	Egg 29	OK
Egg 30	OK	Egg 30	OK
Egg 31	OK	Egg 31	OK
Egg 32	OK	Egg 32	OK
Egg 33	OK	Egg 33	OK
Egg 34	OK	Egg 34	OK
Egg 35	OK	Egg 35	OK
Egg 36	FAIL	Egg 36	OK
Egg 37	OK	Egg 37	OK
Egg 38	OK	Egg 38	OK
Egg 39	FAIL	Egg 39	FAIL
Egg 40	OK	Egg 40	OK
Egg 41	OK	Egg 41	OK
Egg 42	FAIL	Egg 42	OK

The data above shows that during sensory comparison evaluation of the breeder in the farm, The specialist detected there are 7 eggs that are not suitable for incubation anymore which 4 of them are porous eggs or infertile. Eggs 15, 16, 20 and 39 are infertile eggs which do not have semen in the first place while the remaining eggs are eggs that encountered various incubation problems like cracked shell, etc. The camera-assisted candler detected 4 of these infertile eggs but not the other undeveloped eggs. The value for sensory evaluation is 7 eggs detected and for automatic candling the value is 4 eggs detected. As traditional candling is very accurate as it checks for every signs of death in the egg traditional candling garnered **100%** accuracy because 7 out of 7 eggs are porous or infertile right at the start. While automated candling obtained **57.14 %** accuracy since 4 out of 7 proved to be infertile

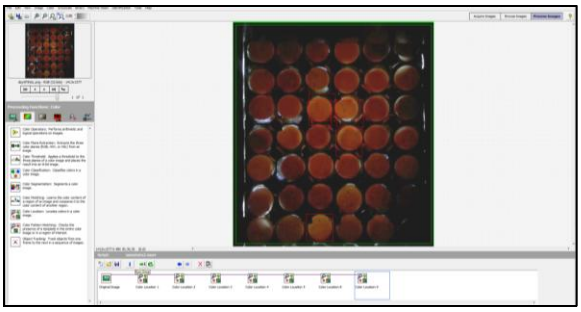


Fig. 12 Color Detection Program of Candling Software

Fig. 12 shows the color detection results made by the program in determining the fertility of eggs after the 10th day of incubation.

- **Hatch Rate**

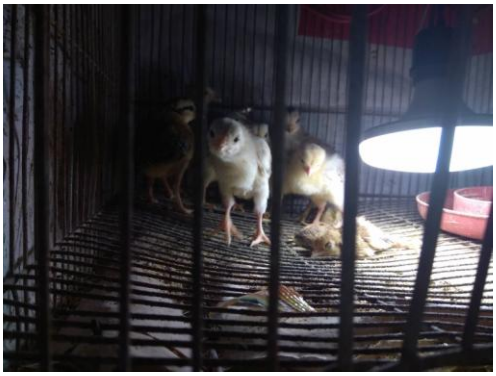


Fig. 13 Newly Hatched Chicks

The figure above shows the newly hatched chicks from the incubation. They are placed in a warm cage immediately by the farm personnel/ caretaker to ensure their survival.

The common hatch-rate for a batch of eggs is ranging from 70% as the highest and about 20% for the lowest. **25** out of **42** eggs were hatched using the prototype incubator which means 18 eggs did not hatch. In those 18 eggs that did not hatch 7 are detected infertile by traditional candling and the remaining 11 eggs are fertile but had pre-incubation problems. Those 11 eggs have developed partially but died in the process of incubation.

The hatch rate percentage of the incubation is **69.44 %** as **25** out of **36** determined fertile eggs were successfully hatched.

IV. Conclusion

Based on the testing conducted and data gathered by the proponents of the study, it can be inferred that the Autonomous Egg Incubator Integrated with Camera Assisted Candler using Labview and Arduino Nano Microcontroller is a viable choice or even a replacement from traditional incubators for incubation as it accurately and autonomously reads and maintains temperature and humidity, controls egg turning and reduces time and effort in candling the eggs as it hastens candling process using image processing and effortlessly monitor egg development due to ingenious design of built-in candling apparatus inside the incubator.

Acknowledgment

The researchers would like to acknowledge Engr. Marvin and Marlon Castro for providing the researchers the necessary setting, items, and ideas needed to start the incubation. They would also like to thank Engr. Lean Karlo S. Tolentino for the unwavering trust and assistance given to them and for all the parents barely supporting the proponents for the completion of this study.

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