IoT-Based Incubator Monitoring System with Convolutional Neural Network Egg Classifier for Balut Production

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***Abstract*—Some business operators in the balut sector express some worry about the traditional methods of balut and penoy production. There are several issues that need to be monitored on a consistent basis, some of which include varying levels of temperature and humidity, infrequent egg flipping, and poor ventilation. Apart from this, the eggs they obtained from other farms were of low quality, which had a considerable influence on the quantity of balut and penoy produced. The pace at which chicken and duck eggs develop into abnoy baluts can be affected by several factors, which can have a knock-on effect. In addition, the embryo growth in the incubator is not routinely monitored, which might result in some eggs that have reached their full maturity earlier than intended. In order to provide an accurate reading of the requirements, the incubator that will be deployed must be equipped with dependable software and standardized hardware. This will enable it to function as both an effective incubator and a quality classifier.**

Keywords—Balut, penoy, CNN, keras, Internet of Things, Egg Incubator, Candling

I. Introduction

Philippines is well-known for its extensive native cuisine as well as its diverse selection of street food. One of the unusual delicacies that many people, especially those from other countries, have probably never had is called balut. It is possible to make balut using eggs from either ducks or chickens, but the majority of the time, duck eggs are used. This is not only due to the fact that duck eggs have a better flavor, but also because, in comparison to chicken eggs, they have a lower rate of infertility. After being prepared by boiling, balut may often be purchased from sellers on the street in the Philippines. At least sixteen to twenty-one days have to pass before an egg from a duck may be regarded fit for human consumption in the kitchen. A great number of vacationers are intrigued by the prospect of tasting something new, which contributes to the allure of this delicacy.

When the duck eggs or chicken eggs have been collected on the farm, the next step is to transport them to the "Balutan," which is the area where the eggs are allowed to develop within an incubator. There are a few basic classifications that may be used to determine the quality of an egg both on the outside and on the inside without actually breaking the egg. One of the things that helps owners of "Balutan" is being able to assess whether or not an egg that has been harvested has its integrity intact. In the past, the eggs would first be covered with a blanket before being placed in a jar or basket to begin the process of incubation. In the conventional method of incubation, the temperature of the incubator is determined by the amount of heat that is naturally created by the eggs. Today, as a result of advances in technology, it is possible to create artificial incubators. These incubators are capable of providing and establishing the conditions necessary for incubation, which makes the incubation process more efficient. Controlling the ventilation, humidity, and temperature of the incubator, as well as rotating the eggs, are some of the conditions necessary for the embryo to develop into a chick. An artificial egg incubator's primary function is to recreate the environment of a mother hen's nest as closely as possible so that the embryo can develop in a healthy and secure manner prior to hatching.

With the help of modern technology, eggs may be incubated in a variety of various methods. In spite of this, there are still certain problems associated with the utilization of artificial incubators, which is to be expected given the ongoing development of technology. The result is an egg from a duck that has not yet fully matured if the settings are not appropriately regulated. A duck that has been unnaturally fertilized is known as an Abnoy. A balut is a duck that has been abnormally fertilized and has a dead chick inside of the egg.

To address the issue of abnoy baluts, the researchers want to design an egg quality classifier and an egg candling device that will be deployed within the incubator. These will be used to determine the maturity level of duck and chicken eggs, with the ultimate aim of lowering the number of Abnoy baluts generated by balut companies.

II. Related Review Of Literature

Balut is a well-known dish in the Philippines that is prepared with eggs from a duck that have been processed. One of the most important goods produced by the Philippines' duck industry [1]. Balut is a Filipino delicacy consisting of a warm-served, hard-boiled duck egg that is about two to three weeks old. Depending on how long the duck egg is incubated, a partially grown duck embryo may have distinguishable traits such as its beak or even some feathers by the time it is hatching. The eggs produced by this duck are used to make a dish called "balut" as well as salted eggs. The word "balut," which meaning "wrapped" or "encased in bags during the process of incubation, is where the word "balut" came from because this was the practical method that it was done. The best time to incubate a balut is between 16 and 18 days, during which the embryo will be wrapped in a white coat but will not have completed its development [2]. A good price may be expected to be paid for such a Filipino specialty.

It is the 16th century when it is said that traders brought the practice of creating eggs that are then incubated to the Philippines when they established themselves along the coasts of Laguna de Bay [3]. Despite this, the people who create balut, also known as "mangbabalut," have centralized the information and abilities necessary to make balut. During that time period, a particular village in the vicinity had an abundant supply of ducks, which were referred to as "itik" by the locals.

In the Philippines, "Penoy" and "Balut" are two well-known brands of egg products. These egg products were considered a delicacy over the entirety of Vietnam and were used in a variety of dishes and snacks. In Southern China, it is beneficial since it may be used both as food and medicinal. However, due to a lack of knowledge of the goods as well as the existence of regulations or legislation on the product, the neighboring nations in Southeast Asia and other areas of the world do not use these egg products [4].

According to the findings of a study, an incubator that is both efficient and cost-effective for the hatching of eggs with little involvement from humans should be developed. This article discusses the designing and implementing of a microcontroller-based electric power incubator device. Assuming that the fertility of the eggs is high, the increased hatching rate that may be achieved with the manufactured incubator is due to its improved humidity and temperature. The viability of the incubator was evaluated by placing inside of six eggs that were thought to be viable. The overall survival rate was determined to be 67% of the total (4 out of 6 eggs). It is also possible that the two eggs that are still in there weren't fertilized all the way, which is why they haven't hatched yet [5].

Saniya et al. showed evidence that they had created a smart incubator for quail's eggs. This microcontroller-based incubator would alter the humidity, temperature, and inversion of quail eggs automatically. In connection with the technology known as the Internet of Things (IoT), which assists agricultural workers in monitoring the incubator from a remote place. The average rate at which quail eggs are able to hatch successfully is 87.55 percent [6].

In another research study, the humidity and temperature of an incubation chamber are shown to be automatically controlled by the implementation of Arduino, which was programmed and created with LabVIEW software. The research also contains the essential aspects of hatching an egg, such as the candling procedure to identify fertilization using image processing and the egg-turning mechanism, which is a crank-rocker mechanism. The user is able to keep a daily record of the circumstances that are present in the incubator. According to the findings, the hatching rate was 69.44 percent, and the precision for identifying viable eggs was 91.43 percent [7].

Tolentino and his colleagues focused their research on creating an automated egg incubator equipped with a camera-assisted candler for the purpose of egg maturity identification applicable to commercial balut and penoy duck eggs. The incubator consists of a multi-layered chamber that has a heater, fan, and DHT11 sensors mounted in it. In order to monitor and ensure that the parameters within the incubator are kept at their ideal levels, DHT11 sensors are interfaced with a Raspberry Pi 4. Per layer, there are trays that have the ability to hold 20 eggs and are positioned on rollers. These trays are created from fluorescent bulbs and come with built-in candlers. Eggs need to be turned at regular intervals during the incubation process, therefore these rollers are set to rotate the trays automatically every 8 hours for a period of 5 minutes. There are cameras set up to take pictures of the candled eggs on the first, tenth, and eighteenth day after they have been laid. The outcome will be shown on a monitor that has a user-friendly graphical user interface, which will assist the vendor in determining the state of the eggs contained within the incubator as well as their level of maturity. The classification of balut, penoy, and fresh eggs was carried out with the assistance of a region-based convolutional neural network, also known as an R-CNN or RCNN [8].

Implementation of the Internet of Things is the focus of the research carried out by Aldair (IoT). The humidity and temperature levels are monitored by two separate sensors within the incubator. The microprocessor acts as a station that receives the data and then transmits a control signal to the controllers, instructing them to adjust the temperature so that it is appropriate for the setting of eggs. The fabricated incubator has a motor driver that tilts the egg at an angle of 45 degrees for a period of four hours. Users are now able to access the farm through the use of a web page that may change the parameters that were discussed earlier thanks to the Internet of Things. Every variety of egg is cultivated within the incubator [9].

The development of an incubator that is powered by electricity and can accommodate regional building materials. This incubator will be used on hatch-proof chicken eggs. A hatching capacity of 540 eggs is going to be developed as a result of this study with the intention of assisting both small and medium-sized chicken farms. In this investigation, the conditions that were employed include maintaining a humidity level of 55 percent and a temperature of 37 degrees Celsius. This led to the production of 387 viable eggs, 29 infertile eggs, 325 hatched eggs, and an overall dependability of 84.06 percent. The research accomplishes its two goals of integrating the hatchery and the setter into a single system and demonstrating its value to chicken producers operating on a smaller scale [10].

The utilization of a microcontroller as a component of a low-cost incubator, which typically makes use of publicly available resources and materials, is necessary in order to accomplish cost-effective development. The research makes use of three primary components: the housing, which ensures sanitary conditions and provides sufficient thermal insulation; the forced air, which regulates the heat all over the egg; and the automated egg tray turning device, which enables the correct development of the extra-embryolic membrane while the egg is being incubated. These three components are as follows: the housing; the forced air; and the automated egg tray turning device. A number of parameters, including temperature, humidity, and the rotation of the eggs, were monitored with the help of the microcontroller. During the course of the research, a four-line liquid crystal monitor was utilized in order to display the characteristics as well as the present state of the device. The results of this study demonstrated that it is possible to successfully incubate eggs from both ducks and chickens. The outcomes of the experiment demonstrated that there is a one hundred percent chance of hatching [11].

Another set of research was conducted with the sole intention of determining the effects of egg turning angle and frequency on hatchability, as well as the incidence of unhatched broiler embryos that had their heads located at the narrower end of the egg. The focus of the study is on two separate trials, each of which consists of two tests, to determine whether or not an angle of less than 45 degrees would be preferable for incubating eggs. Eggs were collected from flocks that had been turned over for 18 days and ranged in age from 51 to 61 weeks. During the first phase of the experiment, the eggs were subjected to temperatures of 30, 40, and 45 degrees on a 24-hour basis. The hatchability of the eggs did not alter as a result of the first experiment, but the frequency of malposition did rise at a 30 degree angle. Experiment 2's contributions to the findings were the same, with a rise in the frequency of malposition at an angle of 30 degrees [12].

Another study focused primarily on the consequences of shifting to alternative egg specifications as its primary research question. In their investigation, the researchers applied four different therapies altogether. The first operation in the series does not contain any turning points at all, whereas the second procedure has one, the third procedure has two, and the fourth treatment is provided four times each day. According to the findings of the study, there was a reduction in egg weight that ranged from 9.86 percent to 11.51 percent. The greatest rate of hatching was 72.90 percent and it occurred when the eggs were flipped three times a day. The vast majority of eggs hatched from the equatorial region, but some hatched from the point that was furthest to the end of the egg. Farmers who used a hurricane lantern incubator were strongly encouraged to flip the eggs manually in order to get better results in terms of reduced egg weight loss and increased chick hatchability. According to the findings, it would be in everyone's best interest to rotate the eggs three times a day [13].

The Convolutional Neural Network is a powerful tool for the classification of photographs. CNN's capacity to classify images was also investigated, but this time with large-scale image sets of data such as ImageNet. Although numerous studies on the tool with small-scale datasets were identified, few focused on CNN's classification capabilities. In this study, they made use of CNN to carry out a quality assurance test on the items as well as an evaluation of its capacity for categorization. CNN's effectiveness in ensuring the high quality of manufactured goods has been validated by this finding [14].

They trained a huge, deep convolutional neural network to classify 1.2 million high-resolution photos into 1,000 distinct categories for the LSVRC-2010 ImageNet Contest. In order to speed up the training process, they chose neurons that did not saturate and a very potent GPU version of the convolution process. They made advantage of a recently established regularization approach known as "dropout," which turned out to be effective, in order to lessen the weight of computing work in completely linked layers [15].

The use of Convolutional Neural Network of Keras and Tensor Flow was used in another study to demonstrate the amount of time required to train, test, and develop an object-detection model in an airplane using a constrained computational environment. During the training of the system on the Tensor Flow computer network, sixty thousand photographs were used at twenty-five distinct epochs. The training time for each epoch lasts between 722 and 760 seconds [16].

In recent years, deep learning, which makes use of a convolutional neural network (CNN), has garnered a lot of interest due to the improved efficiency it offers in image processing. The approach in question allows for the use of the images themselves in the process of learning; but, it does not permit the use of an extracted feature prior to the learning process. Significant facets are capable of being automatically taught. In another piece of study, the researchers discuss the fundamental increased technological of deep learning using CNNs along the real path (data collection, CNN implementation, and training and testing stages) [17].

In a separate research study, the researchers provide an overview of the application and performance of sensor technologies for the poultry business. It evaluates the possibility of novel performance-related technologies that may be integrated into manufacturing facilities and identifies classic sensing techniques at the same time. The temperature, humidity, light, wind speed, and quality of air are among the major ecological elements that are helpful to the poultry sector. However, this list is not exhaustive (in specific, CO2 and NH3 levels). The current industrial method with regard to the evaluation of these factors, in addition to the influence of these variables on the health and wellbeing of birds, is evaluated, and the modifications brought about by advances in technology are also investigated and discussed [18].

Another study demonstrates how the Raspberry Pi may serve as the microcontroller for the PiBator egg incubator. The Raspberry Pi is a low-cost ARM-based computer designed primarily for use in computer science classes. During gestation, the idea is to construct a less dangerous and better-organized environment [19].

III. Methodology

A. Conceptual Framework

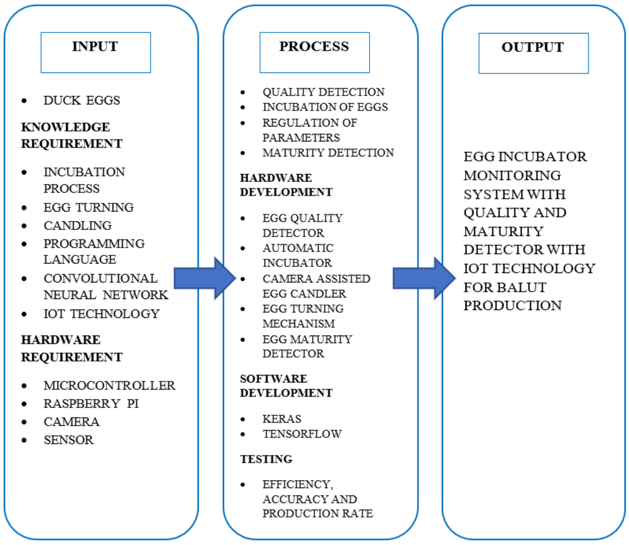


Fig. 1. Input Process Output (IPO) Model

Figure 1 shows the Input Process Output Model of the study. For the collection of information for this study, we will be using eggs laid by viable hens and ducks. The egg will initially be put through an Egg Classifier, which will determine the egg's overall quality before moving on to the next step. After then, it will go through a number of stages of incubation, and then eventually, it will be put through testing to determine its level of maturity. The knowledge criteria for the project include having a fundamental understanding of programming languages and IoT Technology, as well as having the ability to candle eggs using a convolutional neural network, the process of egg turning, the right method of incubation, and the candling process with the use of the convolutional neural network. Users will be able to access the incubator by means of a web page that makes use of Internet of Things technology and allows for the modification of the parameters described before. The process of candling determines whether or not the embryo will be viable, and the convolutional neural network will be used to process images taken by the camera and to identify the maturation of the eggs. Incubation will help the egg develop properly; egg turning helps the egg avoid the embryo from attaching to the sides of the shell; the candling process determines whether or not the embryo will be viable; and the convolutional neural network will be used. A few of the components that went into the construction of the incubator include the microcontroller, raspberry pi, camera, and temperature and humidity sensors.

When it comes to the hardware of the prototype, the first thing that needs to be done is to examine the eggs with the camera in order to establish their quality. The next step is going to be the automatic incubation, which is going to be followed by the phase in which the parameters of temperature and humidity are going to be automatically managed by utilizing the sensors that are being utilized to monitor the project. After that, the candling will be carried out with the camera still active in order to identify and monitor the fertility of the eggs. A Raspberry Pi that is connected to the camera serves as the basis for the implementation of the Convolutional Neural Network.

The knowledge criteria for the project usually involve having a fundamental understanding of programming languages and IoT Technology, as well as having the ability to candle eggs using a convolutional neural network, the process of egg turning, the appropriate method of incubation and the candling process with the use of the convolutional neural network. Users will be able to access the incubator by means of a web page that makes use of Internet of Things technology and allows for the modification of the parameters described before. The candling procedure is what determines whether or not the embryo will be viable, and the convolutional neural network will be used to process the pictures that are acquired by the camera in order to assess whether or not the eggs have reached their mature state. The candling procedure determines whether or not the embryo will be viable, and the convolutional neural network will be utilized. The incubation process will assist the egg in developing normally, and egg turning will assist the egg in preventing the embryo from becoming attached to the sides of the shell. The microcontroller, Raspberry Pi, camera, and temperature and humidity sensors are only some of the components that were used in the creation of the incubator.

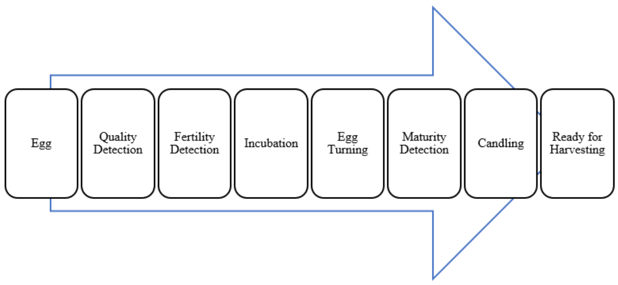


Fig. 2. Conceptual Framework of the Study

Figure 2 shows the conceptual framework of the study. It illustrates the steps involved in putting the system into operation. Starting with depositing the eggs in the container that will determine their quality as well as their fertility. Following that, it will go through the process of incubation, during which the eggs will be turned once every six minutes for a period of nine hours. This procedure will ensure that the heat is distributed well and will assist the eggs in preventing the embryo from adhering to the edges of the shell. After an incubation period of ten days, the eggs will be candled to distinguish between those that would develop into penoy and those that will become balut. Following this step, the eggs will continue to be incubated, and a detection method will be used to determine whether they have reached the appropriate age for harvesting, which is 18 days after they were laid.

B. *Research Process Flow*

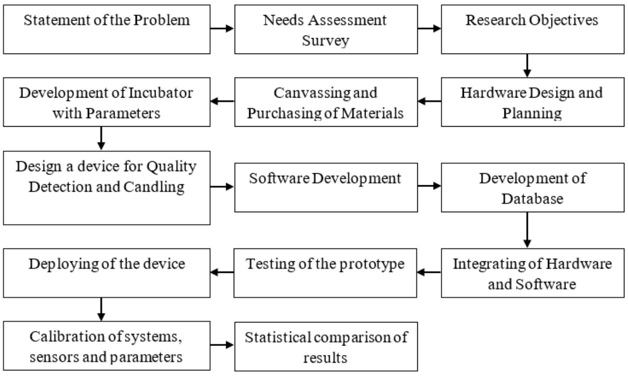


Fig. 3. Research Process

The procedure that the researchers are going to go through, which will also be followed by the attainment of the objectives, is depicted in Figure 3.

C. *Materials and Equipment*

TABLE I. BILL OF MATERIALS FOR THE INCUBATOR

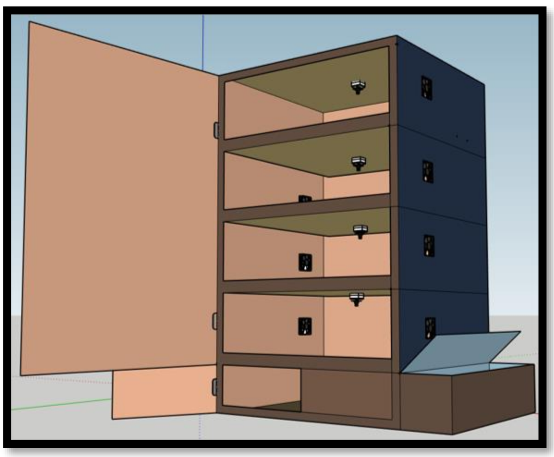
MATERIALS	QUANTITY	UNIT COST (Php)	TOTAL COST (Php)
Plywood ¼ inch	1	350	1400
2x2 inch Coco Lumber	2	180	360
1inch Wood Nail	1/4kls	40	10
Black Enamel Paint 1L	2	140	280
White Enamel Paint 1L	2	150	300
Green Enamel Paint 1L	2	155	310
Paint Thinner	1	50	50
2-inch Brush	2	30	60
1-inch Brush	2	15	30
Silicone Sealant	1	285	285
1ftx1ft Acrylic Board	4	150	600
Arduino Mega	1	600	600
Temperature and Humidity Sensor DHT11 Gravity	2	265	530
Nema 23 Stepper Motor	1	1900	1900
DQ542MA Motor Driver	1	2000	2000
S-350-12(12-29A) Power Supply	1	1300	1300
S-350-24(24V-14A) Power Supply	1	1300	1300
Bosch Relay	1	350	350
12v Relay	2	10	20
PTC Heating Coil	4	150	600
Fan	4	300	1200
LED Lights	16	140	2200
Assorted Screws			50
Wires			200
Raspberry Pi	1	2810	2810
Camera	4	1700	6800
Monitor	1	1400	6400
Grand Total			**31,945**

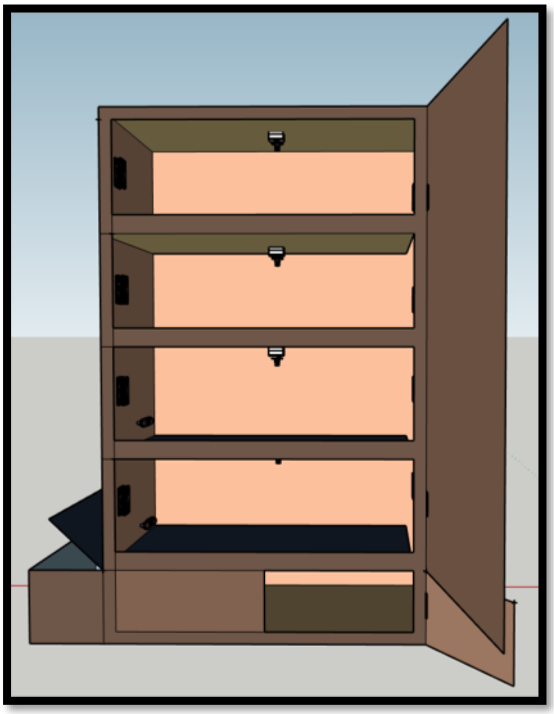
Table 1 shows the list of material and the corresponding prices that will be used in the construction of the automated incubator.

D. *Designing the Incubator*

The prototype will be artificial incubator with a size of 6ft by 4ft by 3ft. On the left side of each layer, there will be a fan, and on the right side, there will be a heater. The temperature and humidity sensors, DHT 11, are situated at the back of the incubator. Each level is 19 inches tall, with the camera positioned at the top of each layer. The circuit boards are kept in a box next to the incubator.

(a)





(b)

g. 4. Prototype of Incubator: (a) Side view perspective (b) front view perspective

Since the study will focus on two separate eggs, it will require various criteria that are tailored to each individual egg. Incubation parameters for chicken eggs and duck eggs have both been the subject of research and consultation by academics. The optimal circumstances for hatching duck eggs are 37.5 degrees Celsius with 60 percent humidity, while the optimal conditions for hatching chicken eggs are 37.5 degrees Celsius with 40 percent humidity. It is necessary to arrange eggs in a tray with extreme caution, and it is also essential to ensure that the appropriate parameters are being controlled for each variety of egg.

The researchers need to conduct candling before incubation so that they can determine the parameters of the candling. This allows them to determine whether or not the egg will be fertile. A little black stain on the egg might serve as a sign of whether or not the egg is fertile. After an incubation period of ten days, the balut and penoy will be categorized according to their respective characteristics. The presence of nerves in an egg is an indication that it will be successful in producing balut, whereas the absence of nerves in an egg is an indication that it will be successful in producing penoy. The development of the eggs will be measured relative to a baseline established by the measuring of the embryo. The information that was gathered from the candle would serve as the foundation for the operation of the system.

Twenty eggs from chickens and ducks will be incubated and candled each day in order to observe the typical development of the egg. The CNN that will be developed using keras and tensorflow will make use of the images that will be captured and utilized.

The design of the prototype is similar to that of the standard modern incubators; it will be made up of four trays, each of which has the capacity to house 20 eggs. The eggs will be flipped three times a day for a total of six minutes. The candling cycle will be completed with the assistance of the LED strips that are installed under the tray as well as the camera that is mounted above each tray. To ensure that each tray has the appropriate temperature and ventilation levels, each tier need to be equipped with both ventilation and a heater. The back of the incubator is where you'll find all of the electronics.

E. Hardware Design

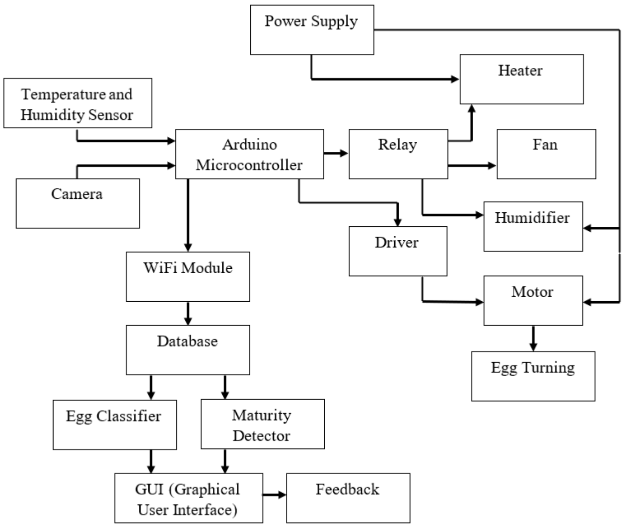


Fig. 5. Project Flow Diagram

It is necessary to design the incubator and attach the fans in order to provide sufficient ventilation. A ventilation system contributes to the reduction of excessive heat, which plays a role in the incubation process. Additionally, this has been used as a component in the regulation of humidity and temperature. The camera that is located at the top of the incubator as well as the camera that is located below the trays are used to scan the trays in order to determine the level of maturity and fertility of each egg. Under each tray, there are LED strips that have been installed to make it possible to simply light candles. An engine that is controlled by an Arduino and is located at the back of the incubator. This engine rotates the trays so that the camera can inspect all of the eggs.

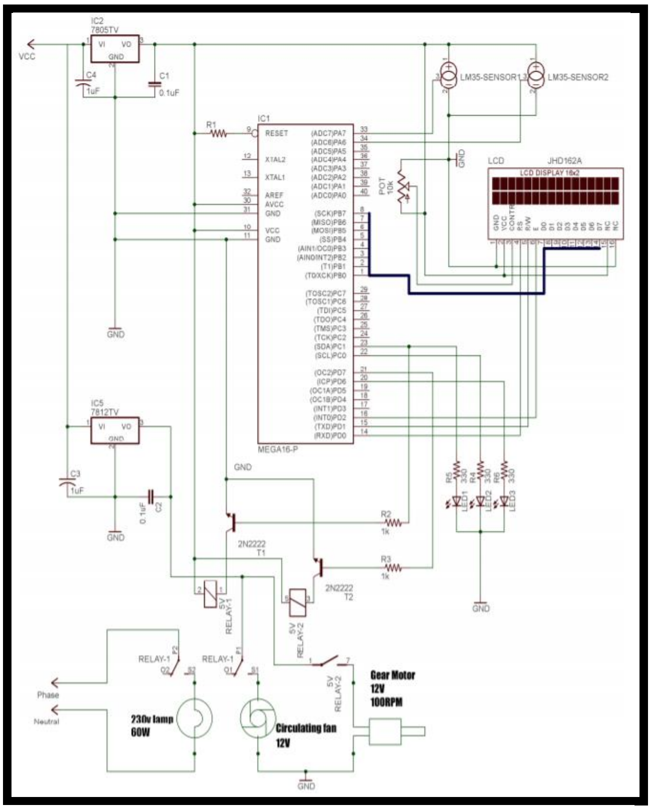


Fig. 6. Schematic Diagram

The displayed diagram above consists of the Arduino Microcontroller, Camera, LCD Monitor, Raspberry Pi, LED Strips, Fans, Humidifier, Sensors, Motor, and Heater. The Raspberry Pi, which functions as the central processing unit (CPU) for the control system of the incubator, includes pre-installed versions of the database, image processor, and algorithm utilized by the incubator. Both the camera positioned on top of the incubator and the camera positioned beneath the trays are utilized to see the eggs, which are subsequently used for quality and fertility monitoring. These cameras are both situated within the incubator. It is connected to the Raspberry Pi, which is the location where the data will be received, and then the Wi-Fi Module will transfer the data to the database for storage. The sensors are also connected to Raspberry Pi, fans, humidifiers, and heaters in order to maintain the essential parameters for incubating the eggs, which can be watched on the LCD Monitor outside the incubator. This will guarantee that the eggs are cared for and incubated appropriately. The installation of fans into the incubator enables it to have the proper design and ventilation. In addition, a motor is attached to the microcontroller in order to facilitate the scanning and rotation of the eggs. LED strips have been affixed to the underside of the tray in order to simplify the process of candling the eggs.

F. Project Components

Camera, Raspberry Pi, Arduino Microcontroller, Wi-Fi Module, LCD Monitor, LED Strips, Humidity and Temperature Sensors, Fans, Humidifier, Heater and Motor are the key prototype project components.

a) Arduino Microcontroller

An Arduino Microcontroller that will largely be utilized to control the motor that will be used for spinning the eggs. Additionally, it is utilized to maintain the temperature and humidity automatically, allowing one to exercise control over the heater and humidifier.

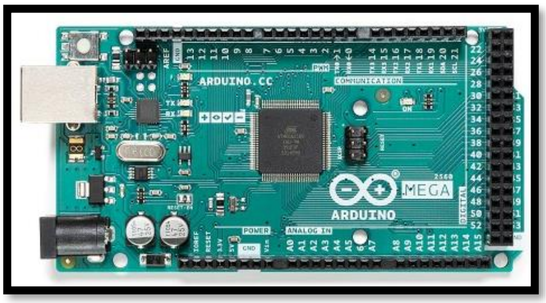


Fig. 7. Arduino Microcontroller

b) Camera

The camera that will be utilized is going to be a Logitech C920 HD Pro Webcam. In order to monitor the level of quality and fertility, this will be mounted on the ceiling as well as the bottom of the trays. A connection has been made between this and the Raspberry Pi. The researchers decided to utilize this camera because it produces high-quality photographs with a high resolution, both of which are essential for the study.

Fig. 8. Logitech C920 HD Pro Webcam

c) Raspberry Pi

In order to implement this plan, a Raspberry Pi 3 Model B+ computer will be utilized. It is intended to be utilized as a programming interface for things like image processing and the algorithms that go along with it.

Fig. 9. Raspberry Pi 3 Model B+

d) LED Lights

Since the LED lights are positioned underneath the tray, it is possible to candle any tray with ease. This will supply the artificial light under the eggs so that the maturity may be monitored and determined, as well as whether or not the eggs are ready to be harvested and used to produce balut.

Fig. 10. T5 LED Tube light 9W

e) Monitor

The Dell UltraSharp U2412M is used as Monitor that will be placed outside the incubator. The temperature, humidity, and activity level within the incubator are all displayed here. This monitor was selected due to the fact that it is readily available and inexpensive.

Fig. 11. Dell UltraSharp U2412M

f) Motor

14W Egg Turning Motor with Gear is used for motor. A motor that is controlled by an Arduino and is put on the rear of the incubator to rotate the trays so that the camera can view all of the trays at once.

Fig. 12. 14W Egg Turning Motor with Gear

g) Sensors

In order to complete the project, a DHT11 Temperature and Humidity Sensor was utilized. The sensor includes an NTC for the detection of temperature as well as an 8-bit microprocessor for the creation of humidity and temperature parameters as serial data.

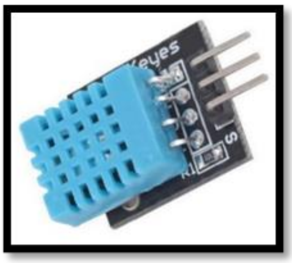


Fig. 13. DHT11 – Temperature and Humidity Sensor

G. *Egg Trays Setup*

Figure 14 illustrates the arrangement of the trays that is appropriate for the incubator taking into mind the quantity of eggs that are being incubated as well as the procedure of flipping the eggs over. The egg must be turned at an angle of at least 30 to 45 degrees. It is because of this that the embryo will not adhere to the sides of the shell. Each tray has a height of one-quarter foot, a width of two feet and a distance of three feet between each other.

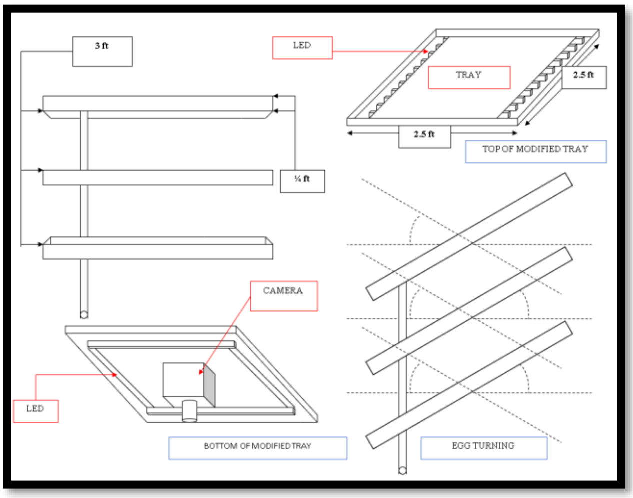


Fig. 14. Egg Trays Setup

H. *Software Development*

The researchers used python primarily as a programming language. Python was used for the development of a CNN, which was necessary in order to determine whether an egg has reached its maturity stage. The candling process is tied to the raspberry, which is also associated with the quality and ripeness detector. Inside of the incubator, an Arduino was employed to enable automated control of both the temperature and the humidity.

a) Quality Detection Flowchart

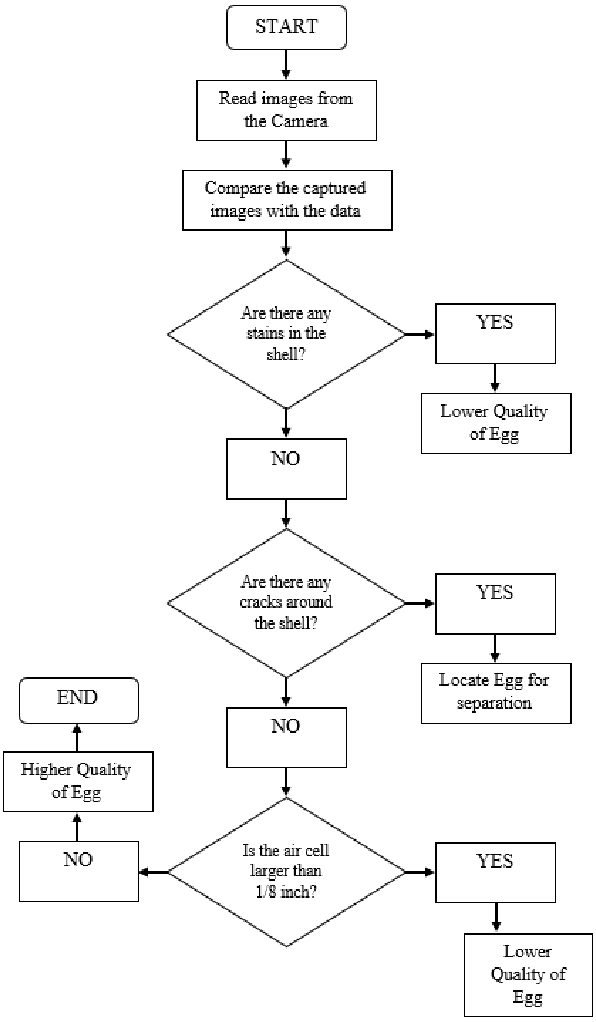


Fig. 15. Quality Detection Flowchart

As shown in Figure 15, the camera will be used to execute the software that is part of the Quality Detection section. The data that has been collected will initially be compared to the photos that have been taken by the camera. The first thing it will do is check to see if there are any stains on or near the shell. If the egg has any stains or molds on or around it, then the quality of the egg is deemed to be inferior. After that, it will proceed to determine whether or not there are any fractures around the exterior of the shell. Cracked eggs around the circumference of the shell will be identified and separated from the rest of the eggs. Near long last, it will go on to determining the size of the air cell, which may be found at the big end of the eggs. If the air cell is more than 1/8 inch in size, then the quality of the product is deemed to be worse. The remaining eggs will proceed into incubation.

b) Control Flowchart of Temperature and Humidity for Chicken and Duck Eggs

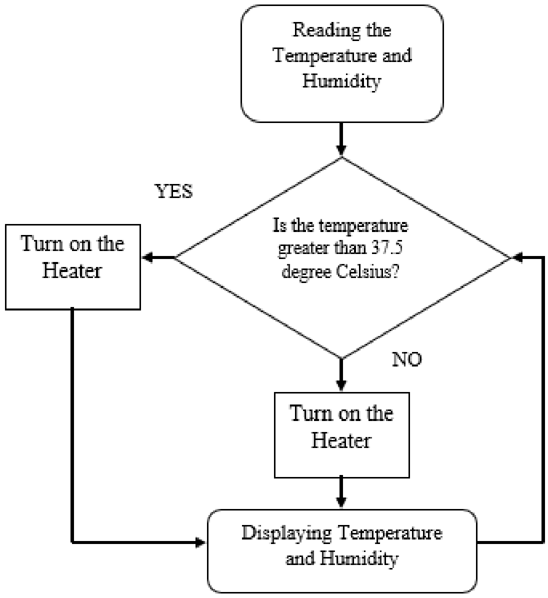


Fig. 16. Temperature and Humidity Control Flowchart

The Temperature and Humidity control flowchart depicted in Figure 16 indicates that both temperature and humidity are automatically regulated. The temperature and humidity of the sensors will be established first. Depending on the conditions, if the recorded temperature is greater than 37.5, the heater will either be turned off or on. Each temperature and humidity value will be presented individually on the screen.

c) Egg Turning Control Flowchart for Chicken and Duck Eggs.

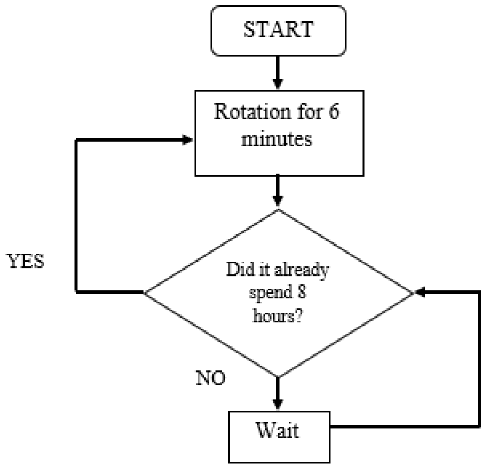


Fig. 17. Egg Turning Control Flowchart

Figure 17 depicts the rotation control flowchart illustrating the automated management of duck and chicken eggs. To begin the process of changing the egg, it is continuously spun for a period of six minutes. The shift is over after six minutes, and the machine then remains idle for the next eight hours before beginning the next operation. This pattern will repeat itself until the eggs have reached an appropriate level of maturity to be processed.

d) Fertility and Maturity Detection Flowchart

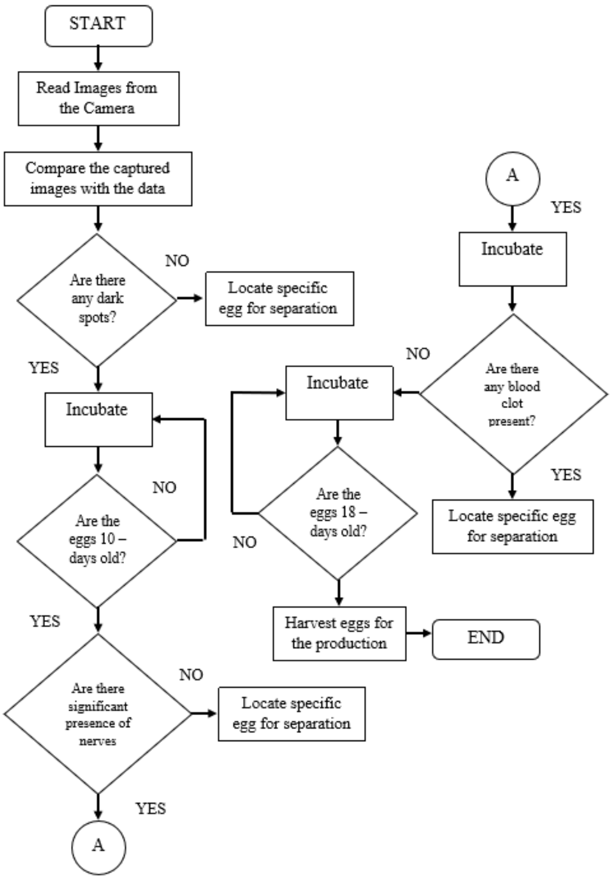


Fig. 18. Fertility and Maturity Detection Flowchart

Candling, which is helped by a camera, was used to execute the maturity and fertility detection program, and Figure 18 offers a flow chart of how the program was carried out. At first, there will be a connection made between the data gathering and the photos that were taken by the camera. The presence of a black spot on the egg, which indicates fertile potential, is the first step in the fertility test process. The processing of eggs requires the collection of those that are sterile. Incubation of fertile eggs will take place for ten days, and then the eggs will be candled. This is where we will observe how far along the embryo is developing. The presence of nerves in an embryo indicates that its development is progressing. Incubation should be performed only on eggs that contain a healthy embryo, and the eggs should be collected before they develop nerves. The incubation process gets underway, and it is imperative that any developing blood clots be stopped in their tracks since it has been demonstrated that blood clots are dead embryos. Eggs that are in good condition will be incubated constantly until they reach the 18th day, at which point all eggs will be suitable for use in the manufacturing of balut.

I. Testing Procedure

The incubator should be able to establish a connection with the Arduino, continue to keep the temperature and humidity at the predetermined levels, and follow the turning schedule that was previously entered into it. It is expected that the incubator will be able to communicate with the Arduino, keep the temperature and humidity at the appropriate levels, and follow the turning schedule that has been entered into it.

It is necessary for the camera to be able to communicate with the software and capture the appropriate image so that it may be processed. It is necessary for the camera to have the ability to communicate with the software and to acquire the appropriate picture for processing.

The software should be able to tell which images or data come from which camera.

J. Evaluation Procedure

Equation 1 depicts the equation to determine the incubator's production rate. The production rate is calculated by dividing the total number of eggs, or the amount of penoy and balut produced in the incubator, by the number of days the eggs were incubated. Multiplying the total number of eggs by the number of days yields this ratio.

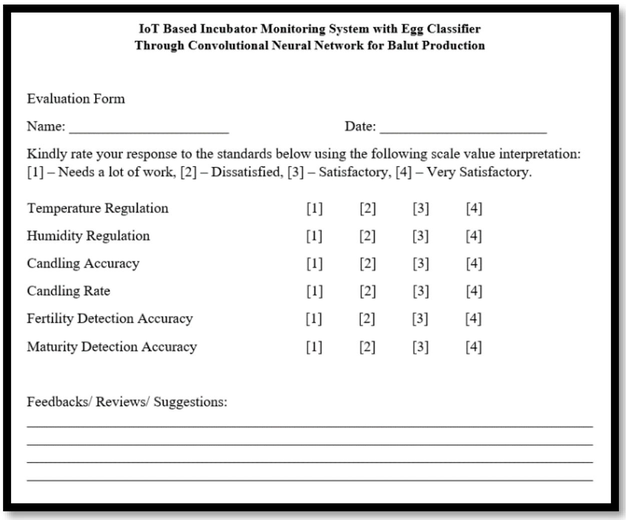
$$Production\ Rate = \frac{No.\ of Balut + No.\ of\ Penoy}{Days\ of\ Incubation}\ x\ 100\% \quad (1)$$

Equation 2 depicts the math to determine the incubator's production rate. The production rate is calculated by dividing the total number of eggs, or the amount of penoy and balut produced in the incubator, by the number of days the eggs were incubated. Multiplying the total number of eggs by the number of days yields this ratio.

$$Percentage\ Error = \frac{Theoretical - Experimental}{Theoretical}\ x\ 100\% \quad (2)$$

Equation 3 depicts the formula applied to calculate the output capacity of the incubator. The output was the number of eggs that Penoy and Balut were able to produce with the aid of the incubator, while the comparison was the number of eggs that were successfully incubated from day one.

$$Efficiency = \frac{Output}{Reference}\ x\ 100 \quad (3)$$



IoT Based Incubator Monitoring System with Egg Classifier Through Convolutional Neural Network for Balut Production

Evaluation Form

Name: ____________________ Date: ____________________

Kindly rate your response to the standards below using the following scale value interpretation:
[1] – Needs a lot of work, [2] – Dissatisfied, [3] – Satisfactory, [4] – Very Satisfactory.

Temperature Regulation	[1]	[2]	[3]	[4]
Humidity Regulation	[1]	[2]	[3]	[4]
Candling Accuracy	[1]	[2]	[3]	[4]
Candling Rate	[1]	[2]	[3]	[4]
Fertility Detection Accuracy	[1]	[2]	[3]	[4]
Maturity Detection Accuracy	[1]	[2]	[3]	[4]

Feedbacks/ Reviews/ Suggestions:

Fig. 19. Evalutation Form

Figure 19 depicts the evaluation form for determining the machine's efficiency. The poultry and Balut business owners will evaluate the equipment by comparing it to the traditional methods of incubation and Balut and Penoy production used in the Balut industries. To determine the machine's efficiency, the mean of the scores per criteria will be computed.

IV. Results And Discussions

The research was conducted as follows: An Automated Egg Incubator for Balut and Penoy Production with Raspberry Pi-Based Camera Assisted Candling and Development Detection Using Convolutional Neural Network is a system that can incubate, candle, turn eggs, monitor egg maturity, and detect if the egg extracted is Bugok, Penoy, or Balut. Microcontroller, camera, sensors, and machine learning are all used in this device.

The Arduino Uno Microcontroller is an open-source microcontroller board that may be used to control temperature and humidity, ventilation, candling, and egg turning. The visual imaging of the acquired photographs of egg's day by day maturity using a Raspberry Pi-Based Camera is analyzed using a Convolutional Neural Network (CNN).

A. Project Structure

Figure 20 show the front view of the prototype. The prototype will be a 6ft by 4ft by 3ft artificial incubator. There are 4 layers. Each layer has a tray with automatic egg turner equipped with LED Lamps underneath for candling

Fig. 20. Front View of the Prototype

Fig. 21. Incubator's tray

Figure 21 shows the incubator's tray. These trays are equipped with motor and tubes for egg turning. There are also LED Lamps underneath for egg candling. This is where the eggs are placed while incubation, quality and maturity detection. The trays can hold up to 20 eggs. Therefore, the whole prototype can hold up to 80 eggs in total.

Fig. 22. Incubator's tray with attached fan

Figure 22 shows that the fan will be located on the left side of each layer, and a heater will be located on the right side. DHT 11 temperature and humidity sensors are located at the back of the incubator. Each layer is 19 inches tall, with the camera positioned at the top.

B. *Temperature and Humidity Data*

TABLE II. TEMPERATURE AND HUMIDITY FOR 18 DAYS

	Temperature	Humidity
1	36.7	60
2	36.7	60
3	36.7	60
4	36.7	60
5	36.09	52.13
6	36.71	52.27
7	37.38	52.68
8	36.33	53.69
9	37.28	52.49
10	36.47	51.87
11	36.8	52.66
12	36.21	53.26
13	36.91	51.53
14	36.55	51.74
15	37.14	53.7
16	36.39	53.62
17	37.45	54.71
18	36.67	55.14

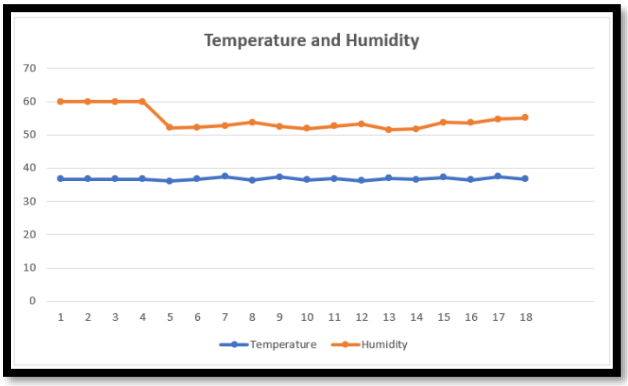
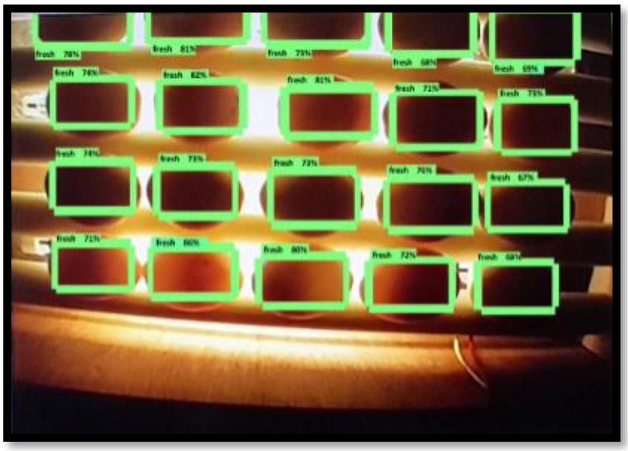


Fig. 23. Temperature and Humidity Chart

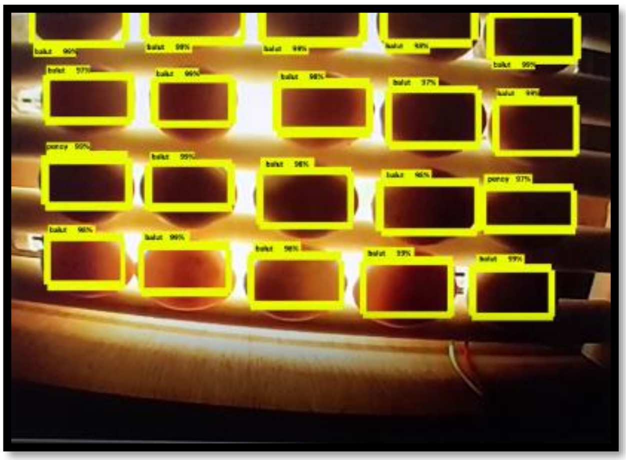
The chart depicts temperature and humidity readings during one incubation cycle. The data show that the incubator was able to keep the temperature between 36 and 38 degrees Celsius and the humidity between 51 and 60 percent, which is very good for an incubator.

C. *Candling Progression*



(a)

(b)



(c)

Fig. 24. Growth of Embryo; (a) Day 1 (b) Day 10 (c) Day 18

These were the most important days of the entire incubation process because the classification of the eggs was based on their maturity level. On Day 1, eggs were similar because the embryo of the egg had not yet developed. After ten days of incubation, there were eggs with darker shadows. This was an indication of progress. Finally, the image displayed varying shadows on the 18th day. It was discovered that eggs with dark colors were classified as baluts, eggs with lighter shadows as penoy, and eggs with no shadow at all as infertile, which were used for salted eggs.

TABLE III. CANDLING TIME COMPARISON

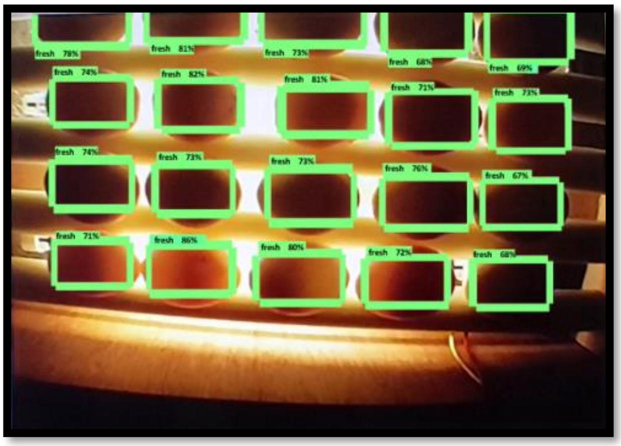
Manual Candling		Automatic Candling
Egg#	Time (s)	Time (s)
1	3s	
2	3s	
3	3s	
4	3s	
5	3s	
6	3s	
7	3s	
8	3s	
9	3s	
10	3s	1s
11	3s	
12	3s	
13	3s	
14	3s	
15	3s	
16	3s	
17	3s	
18	3s	
19	3s	
20	3s	
Total	60s	1s

Table III compares the speed of candling with traditional candling and automatic candling.

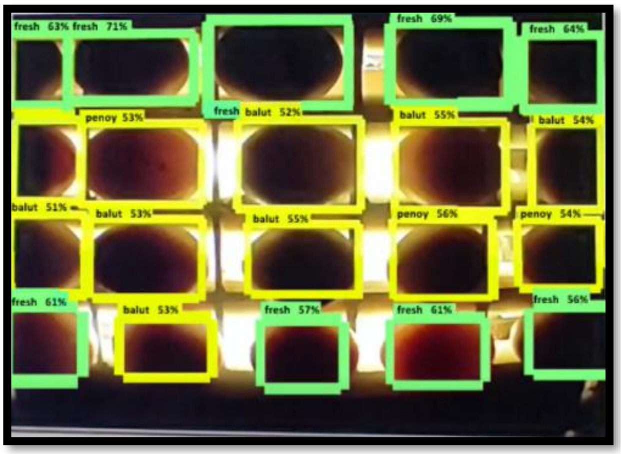
By calculating the mean of the actual time spent in manual and automatic candling, it was discovered that automatic candling produced a faster result than manual candling. The average time for manual candling was three seconds, while the time for automatic candling was one second. By employing the Equation 4 below, the researchers concluded that automatic or camera-assisted candling was 100 percent faster than manual or traditional candling.

$$\%\,Diff = \left(\frac{Manual\ Candling - Automatic\ Candling}{\frac{(Manual\ Candling + Automatic\ Candling)}{2}}\right) x\ 100 \quad (4)$$

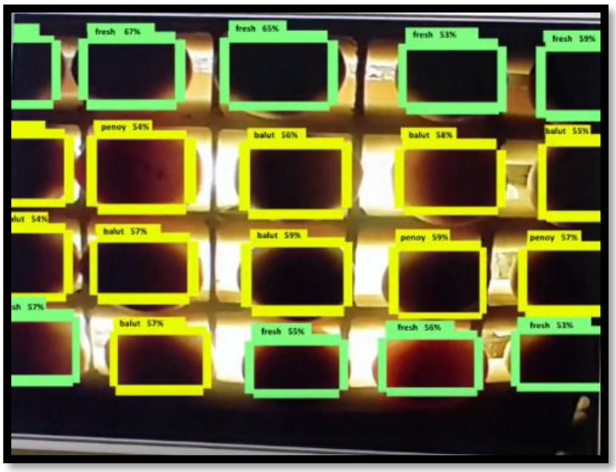
The schematic diagram of components inside the trainer are shown in Figure 15 to Figure 24. These diagrams are etched in a PCB and connected to the components and loads in the front panel and base panel.



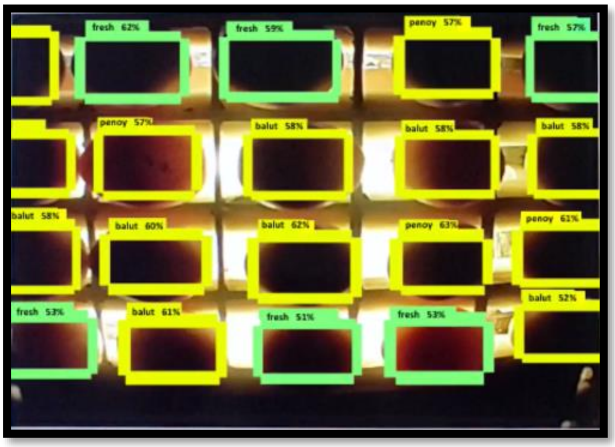
(a)



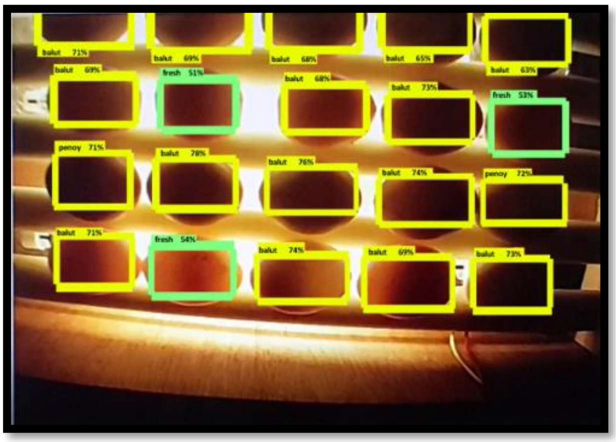
(b)



(c)

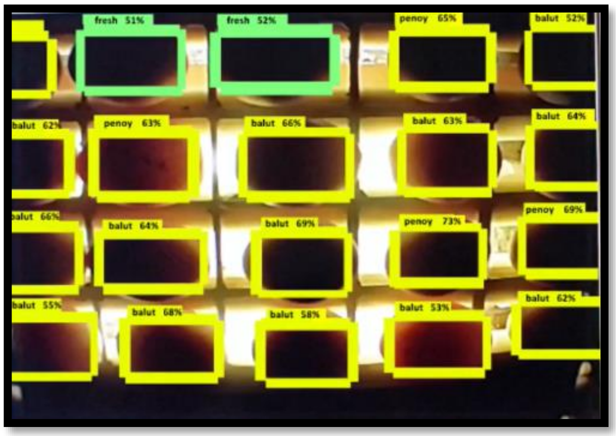


(d)



(e)

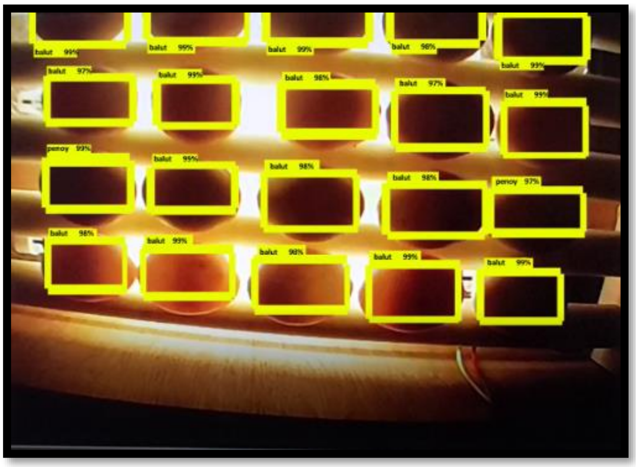
(f)



(g)

(h)

(i)



(j)

Fig. 25. Automatically Candled Eggs (a) Trial 1 (b) Trial 2 (c) Trial 3 (d) Trial 4 (e) Trial 5 (f) Trial 6 (g) Trial 7 (h) Trial 8 (i) Trial 9 (j) Trial 10

Figure 25 depicts how the automatic candling apparatus was used to classify the eggs as balut, penoy, or fresh eggs. The captured image of the eggs was processed by the CNN using the GUI, and the results were displayed along with the percentage of accuracy.

The tables below show the tabulated results of manual and automated candling, along with the corresponding accuracy per trial. This table was used to compare egg classifications using manual candling versus automated candling. The number of correct automated candling classifications was divided by the total number of eggs per tray. The accuracy of the automated candling apparatus was then determined.

TABLE IV. TRIAL 1

Manual Candling					Automatic Candling				
F	F	F	F	F	F	F	F	F	F
F	F	F	F	F	F	F	F	F	F
F	F	F	F	F	F	F	F	F	F
F	F	F	F	F	F	F	F	F	F
ACCURACY					20/20=100%				

TABLE V. TRIAL 2

Manual Candling					Automatic Candling				
F	F	F	F	F	F	F	F	F	F
B	P	B	B	B	ND	P	B	B	B
B	B	P	P	P	B	B	B	P	P
F	B	F	F	F	F	B	F	F	F
ACCURACY					18/20 = 90%				

TABLE VI. TRIAL 3

Manual Candling					Automatic Candling				
F	F	F	F	F	F	F	F	F	F
P	P	B	B	B	ND	P	B	B	B
B	B	B	P	P	B	B	P	P	P
F	B	F	F	F	F	B	F	F	F
ACCURACY					19/20 = 95%				

TABLE VII. TRIAL 4

Manual Candling					Automatic Candling				
B	F	F	P	F	ND	F	F	P	F
B	P	B	B	B	ND	P	B	B	B
B	B	B	P	P	B	B	B	P	P
F	B	F	F	B	F	B	F	F	B
ACCURACY					18/20 = 90%				

TABLE VIII. TRIAL 5

Manual Candling					Automatic Candling				
B	B	B	B	B	B	B	B	B	B
B	F	F	B	F	B	F	B	B	F
P	B	B	B	P	P	B	B	B	P
B	F	B	B	B	B	F	B	B	B
ACCURACY					19/20 = 95%				

TABLE IX. TRIAL 6

Manual Candling					Automatic Candling				
B	F	F	P	F	B	F	F	P	F
B	P	B	B	B	B	P	B	B	B
B	B	B	P	P	B	B	B	P	P
F	B	P	F	B	B	B	B	F	B
ACCURACY					19/20 = 95%				

TABLE X. TRIAL 7

Manual Candling					Automatic Candling				
P	F	F	P	B	ND	F	F	P	B
B	P	B	B	B	B	P	B	B	B
B	B	B	P	P	B	B	B	P	P
B	P	B	B	P	B	B	B	B	B
ACCURACY					17/20 = 85%				

TABLE XI. TRIAL 8

Manual Candling					Automatic Candling				
P	B	B	P	B	ND	B	B	P	B
B	P	B	B	B	B	P	B	B	B
B	B	B	P	P	B	B	B	P	P
B	P	B	B	B	B	B	B	B	B
ACCURACY					18/20 = 95%				

TABLE XII. TRIAL 9

Manual Candling					Automatic Candling				
B	B	B	P	B	B	B	B	P	B
P	P	B	B	B	B	P	B	B	B
B	B	B	P	P	B	B	B	P	P
B	B	B	B	P	B	B	B	B	B

ACCURACY	19/20 = 95%

TABLE XIII. TRIAL 10

Manual Candling					Automatic Candling				
B	B	B	P	B	B	B	B	B	B
B	B	B	B	B	B	B	B	B	B
B	B	B	P	P	P	B	B	B	P
B	B	B	B	P	B	B	B	B	B
ACCURACY					17/20 = 85%				

TABLE XIV. AUTOMATED CANDLING ACCURACY

Trial No.	Accuracy
1	100%
2	90%
3	95%
4	90%
5	95%
6	95%
7	85%
8	95%
9	95%
10	85%
Average	92.5%

The average accuracy of the automated candling process is shown in Table XIV. The average accuracy of the automated candling apparatus was 92.5% percent after ten trials.

TABLE XV. NUMBER OF IMAGES USED AS DATASET

Parameters	[20]	[21]	[22]	[8]	This Project
Number of Dataset Images	750	-	4,800	436	650
Classification Algorithm	Neural Network Model (NNM)	Light resistance-based Algorithm Balut and Penoy	Dynamic Threshold Finding	Regional Convolutional Neural Network (RCNN)	Regional Convolutional Neural Network (RCNN)
Duck Eggs to be Classified	Balut and Rejects	Balut and Penoy	Fertile and Infertile	Balut, Penoy and Fresh	Balut, Penoy and Fresh
Classification Accuracy	76% with 7% false positives	-	Average of 83.52% for 5 trials	80.5%	92.5%

Table XV depicts a comparison of previous work and the proposed system. The previous work's classification accuracy for balut, penoy and fresh was only 80.5 percent, whereas with the same system's classification accuracy for balut, penoy, and fresh eggs was 92.5 percent. This demonstrated that, having more datasets, the RCNN was a better tool to use due to its higher rate of accuracy and greater capacity for classifying eggs

V. CONCLUSION

The IoT-Based Incubator Monitoring System with Convolutional Neural Network Egg Classifier for Balut Production was centered on an incubator's automated temperature regulation. It was also simple to classify the incubated eggs as penoy, or balut.

The researchers tested the device's functionality and obtained a satisfactory result in which the device performed well in accordance with how it was programmed. The temperature regulating apparatus, which was made up of DHT 11 sensors, fans, and heaters, also kept the incubator's temperature between 36 and 37 degrees Celsius. Furthermore, the candling apparatus worked more accurately and quickly than the traditional method.

Based on the gathered data and tests, it can be concluded that the IoT-Based Incubator Monitoring System with Convolutional Neural Network Egg Classifier for Balut Production is a better alternative to the traditional incubators where it proved itself that it is capable of incubating eggs properly by monitoring and regulating the temperature and humidity to optimum level. At the same time, users can automatically candle the incubated eggs to determine their maturity which reduces the effort of manually candling the eggs since it was shown that the automatic candling process has a very high accuracy and is 60 times faster than the manual candling process.

The incubator's structure with candling apparatus has been shown to perform well during incubation. The incubator's temperature regulating apparatus, which consists of DHT 11 sensors, fans, and heaters, is long-lasting. It can keep the desired temperature stable during continuous operation. The Convolutional Neural Network-based maturity detection program has been shown to be more precise and faster than the traditional candling method. It has a high benefit-cost ratio and a positive internal rate of return, indicating that it is a good investment project

For future work, the project can be improved by an designing an incubator that has lower stature or height while still being able to incubate more eggs. Using a higher resolution camera and high-powered lights allows the camera to capture more detailed datasets which improves the better egg classification. The tray and the egg turning process can be redesigned to increase the number of eggs per tray. Additional feature such as automatic sorter for the classified eggs for better sorting system.

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