Balut Production Convolutional Neural Network Egg Classifier

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***Abstract*— Some balut business owners worry about traditional production methods. Variable temperature and humidity, infrequent egg flipping, and poor ventilation demand constant monitoring. Low-quality eggs from other farms also affected the production of balut and penoy. Several factors determine how quickly chicken and duck eggs become abnoy baluts. In addition, embryo growth in the incubator isn't consistently monitored, which may cause some eggs to mature early. The deployed incubator must have reliable software and standardized hardware to meet criteria. This makes it a effective incubator and quality classifier.**

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

I. Introduction

Filipino cuisine and street food are well-known. Many people, especially those from other countries, have never had balut. Balut can be made with duck or chicken eggs, however duck eggs are preferred. Duck eggs taste better and have a lower infertility rate than chicken eggs. In the Philippines, street vendors serve boiled balut. 16-21 days must pass before a duck egg can be used in the kitchen. This delicacy is appealing since many tourists enjoy trying new things.

When duck or chicken eggs are collected on the farm, they are transported to the "Balutan," an incubator facility. A few fundamental classifications can be used to identify an egg's outer and inner quality without breaking it. "Balutan" owners can tell if a harvested egg is intact. In the past, eggs were wrapped with a blanket before being incubated in a jar or basket. In conventional incubation, the incubator's temperature is determined by the eggs' heat. Technological developments have made artificial incubators conceivable. These incubators can provide and develop incubation conditions, which improves efficiency. Ventilation, humidity, and temperature control, as well as egg rotation, are needed for embryo development. An artificial egg incubator mimics a mother hen's nest so the embryo can develop safely before hatching.

Modern technology allows for multiple egg-incubation processes. Despite this, artificial incubators still have challenges, which is to be expected given the advancement of technology. Unregulated circumstances result in immature duck eggs. Abnoys are inseminated ducks. Balut is an improperly fertilized duck whose egg contains a dead chick.

Researchers want to construct egg candling equipment and an egg quality classifier for the incubator to address abnoy baluts. These will be used to determine the ripeness of duck and chicken eggs to reduce balut farms' Abnoy balut production..

II. Related Review Of Literature

Balut is a two- to three-week-old hard-boiled duck egg served warm. Depending on how long the duck egg is incubated, a hatching embryo may have a beak or feathers. This duck's eggs yield "balut" and salted eggs. "Balut" means "wrapped" or "encased in bags during incubation," which was the practical procedure. The optimal time to incubate a balut is between 16 and 18 days, when the embryo is white-coated but not fully developed [1].

Balut makers, known as "mangbabalut," have consolidated information and skills. A nearby village had an abundance of "itik" ducks during that time. "Penoy" and "Balut" are two well-known products of duck eggs. These egg products were a delicacy in Vietnam were utilized in dishes and snacks. In Southern China, it's food and medicine. Due to lack of awareness and laws, Southeast Asian and other nations do not use these egg products [2].

According to the findings of a study, an incubator that is both cost-effective and efficient 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 [3].

In another study, Arduino, programmed using LabVIEW, controls the humidity and temperature of an incubation chamber. The research includes the candling procedure to identify fertilization using image analysis and the crank-rocker egg-turning device. User can record daily incubator conditions. The hatching rate was 69.44%, while the precision for identifying viable eggs was 91.43% [4].

Tolentino and his peers created an automated egg incubator with a camera-assisted candler to identify balut and penoy duck egg maturity. The incubator contains a heater, fan, and DHT11 sensors. DHT11 sensors interfaced with a Raspberry Pi 4 monitor incubator parameters. Per layer, roller-mounted trays hold 20 eggs. Fluorescent bulb trays with candlers. These rollers spin the trays every 8 hours for 5 minutes to turn the eggs during incubation. First, tenth, and eighteenth day candled eggs are photographed. The results will be displayed on a monitor with a user-friendly graphical user interface, which will help the vendor determine the eggs' state and maturity level. A region-based convolutional neural network (R-CNN) classified balut, penoy, and fresh eggs [5].

Aldair explores IoT implementation (IoT). Two incubator sensors measure humidity and temperature. The microprocessor receives data and sends a signal to the controllers to adjust the temperature for setting eggs. Incubator motor tilts egg 45 degrees for four hours. Internet of Things allows users to adjust farm parameters via a web page. Every egg type is incubated [6].

Electric incubators that can use local materials. Incubator for hatch-proof chicken eggs. This study will help small and medium-sized chicken farms by developing a 540-egg hatchery. In this study, circumstances included 55% humidity and 37°C. This led to 387 viable eggs, 29 sterile eggs, 325 hatched eggs, and 84.06 percent reliability. The research integrates the hatchery and setter into a single system and shows its value to small-scale chicken growers [7].

Another study determined the impact of egg turning angle and frequency on hatchability and the occurrence of unhatched broiler embryos with heads at the narrower end of the egg. The study focuses on two trials, each with two tests, to evaluate if incubation eggs at an angle less than 45 degrees is desirable. Eggs were gathered from 51-61 week-old, 18-day-old flocks. First, eggs were exposed to 30, 40, and 45 degrees for 24 hours. The first experiment didn't affect hatchability, although malposition increased by 30 degrees. Experiment 2 also showed an increase in malposition at a 30 degree angle [8].

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) [9].

In a separate study, researchers describe the application and performance of poultry sensor technology. It identifies classic sensing techniques and evaluates novel performance-related technologies for manufacturing facilities. The poultry industry benefits from temperature, humidity, light, wind speed, and air quality. This list isn't comprehensive (in specific, CO_2 and NH_3 levels). The present industrial approach for evaluating these elements, as well as their impact on bird health and welfare, is examined, and technological advances are investigated and discussed [10].

Another study shows how the Raspberry Pi can be the PiBator's microcontroller. Raspberry Pi is a low-cost ARM-based computer designed for CS classrooms. During pregnancy, a safer, better-organized environment is created [11].

III. METHODOLOGY

For this research, we used eggs from viable hens and ducks. The egg will first go through an Egg Classifier to evaluate its quality. After incubation, it will be tested for maturity. The project requires a basic understanding of programming languages and IoT Technology, as well as the capacity to candle eggs using a convolutional neural network, the process of egg turning, and the proper way of incubation. Users can access the incubator through a website that uses Internet of Things technology and lets them change parameters. Candling determines whether an embryo is viable, and a convolutional neural network will evaluate camera images to identify egg maturation. Incubation helps the egg develop properly; egg turning prevents the embryo from sticking to the shell; candling determines the embryo's viability; and the convolutional neural network is utilized.

The project involves basic programming and IoT knowledge, as well as the ability to candle eggs using a convolutional neural network, egg turning, and incubation. The incubator's website leverages IoT technology and allows users alter parameters. Candling confirms if the embryo is alive, and the convolutional neural network determines if the eggs are mature. Convolutional neural networks are utilized for embryo candling. Incubation helps the egg develop, and spinning prevents embryo attachment. Microcontroller, Raspberry Pi, camera, and temperature and humidity sensors are included.

Placing the eggs in the container will determine their quality and fertility. Incubation involves turning the eggs every six minutes for nine hours. This process ensures that heat is evenly delivered and prevents embryos from clinging to egg shells. After 10 days, the eggs are candled to separate penoy from balut. After this phase, the eggs are incubated and a detection method is utilized to determine if they are ready to be harvested 18 days after being laid.

A. Research Process Flow

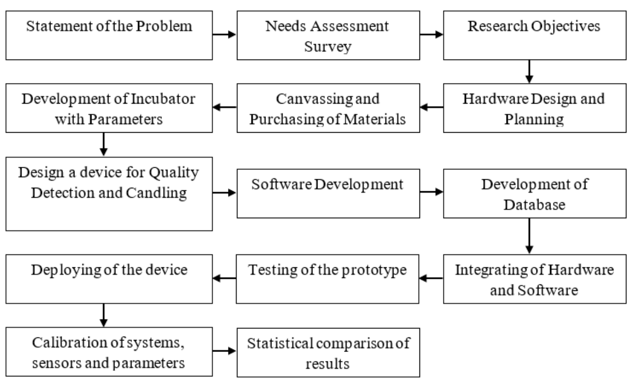


Fig. 1. Research Process

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 1.

B. *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

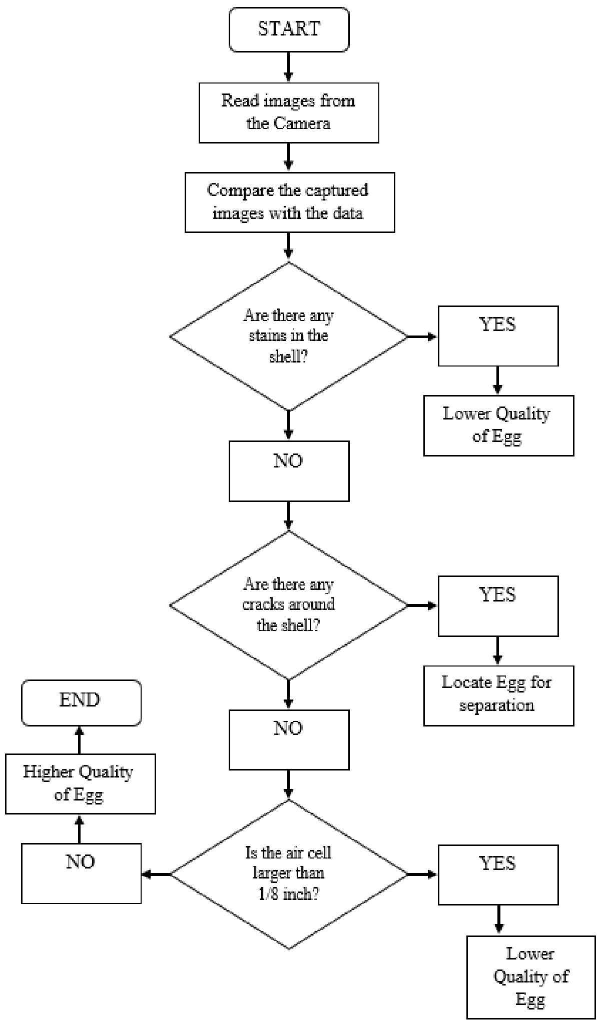


Fig. 2. Quality Detection Flowchart

As shown in Figure 2, 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

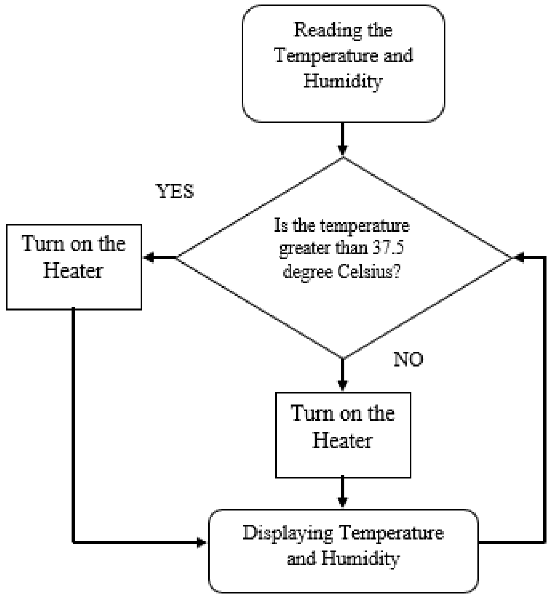


Fig. 3. Temperature and Humidity Control Flowchart

The Temperature and Humidity control flowchart depicted in Figure 3 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.

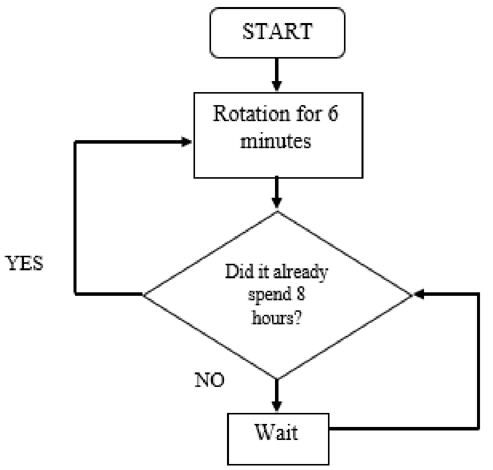


Fig. 4. Egg Turning Control Flowchart

Figure 4 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

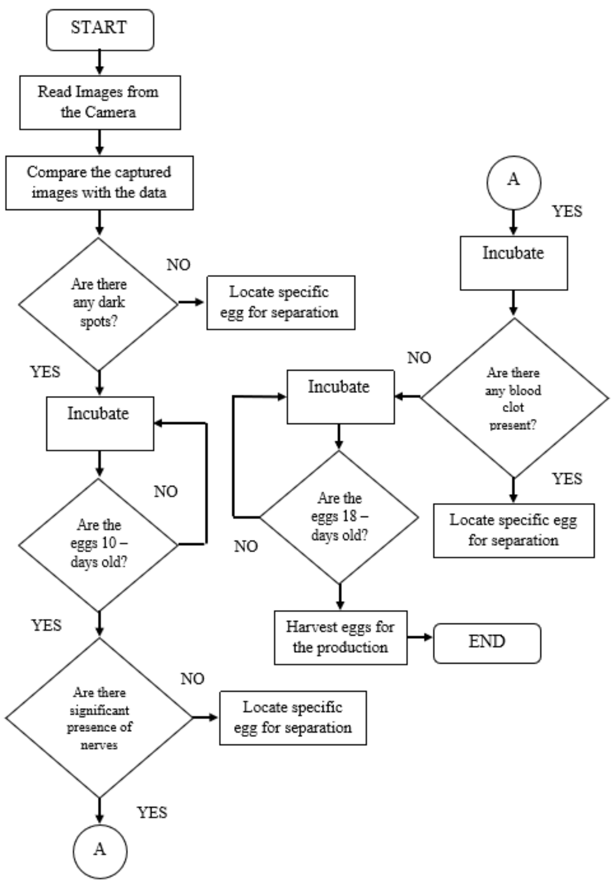


Fig. 5. Fertility and Maturity Detection Flowchart

Candling, which is helped by a camera, was used to execute the maturity and fertility detection program, and Figure 5 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.

C. 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.

D. 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.

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

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. *Temperature and Humidity Data*

TABLE I. 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

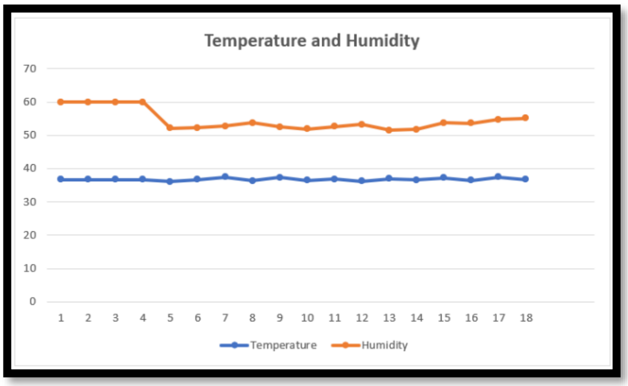
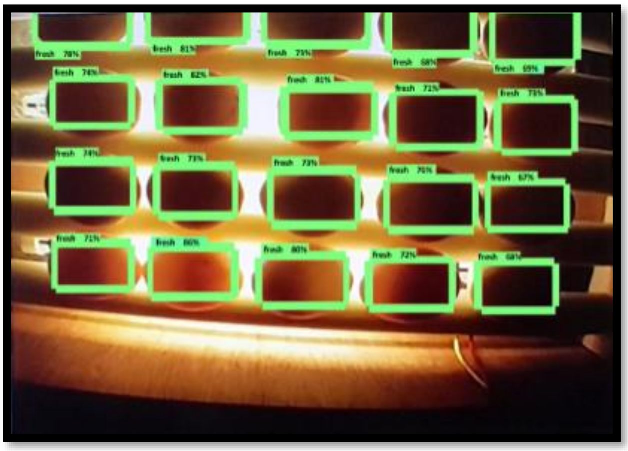


Fig. 6. Temperature and Humidity Chart

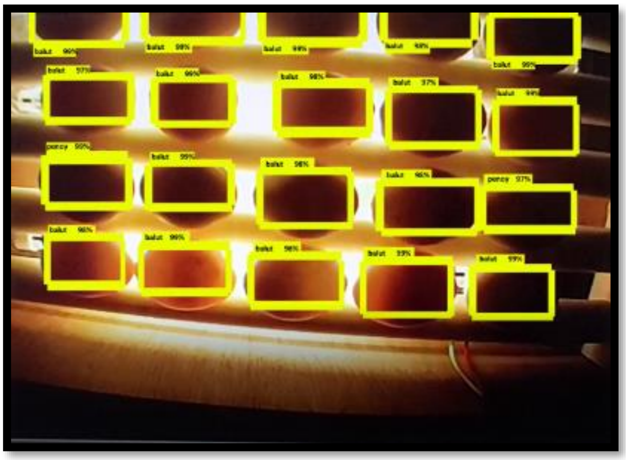
The chart depicts temperature and humidity readings during one incubation cycle. The data show that the incubator was able to keep the temperature between 36 and 38 degrees Celsius and the humidity between 51 and 60 percent, which is very good for an incubator.

B. *Candling Progression*



(a)

(b)



(c)

Fig. 7. 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.

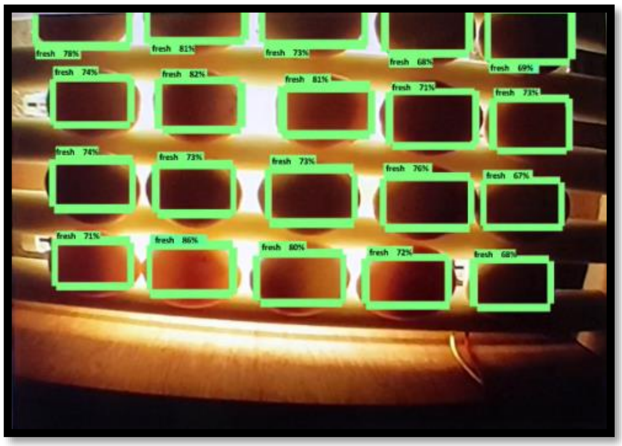
TABLE II. CANDLING TIME COMPARISON

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

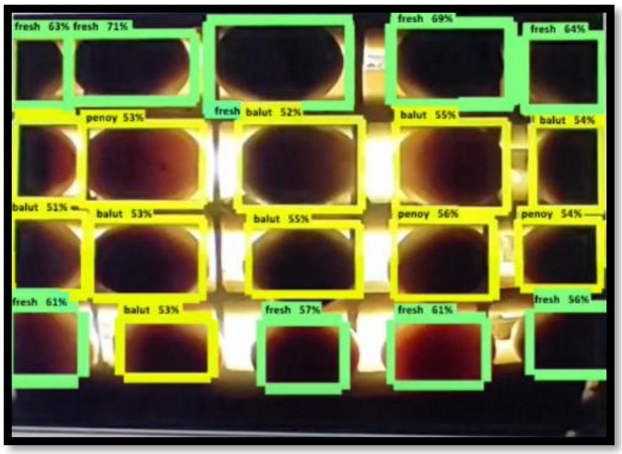
Table III compares the speed of candling with traditional candling and automatic candling.

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.

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



(a)



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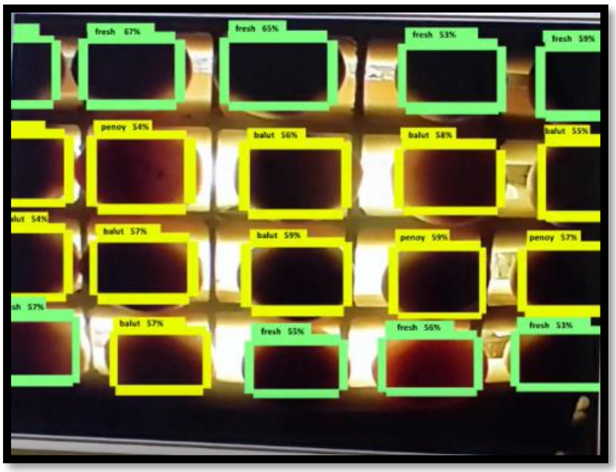

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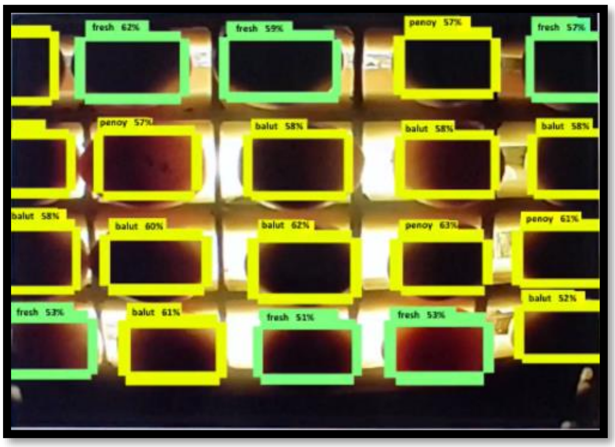

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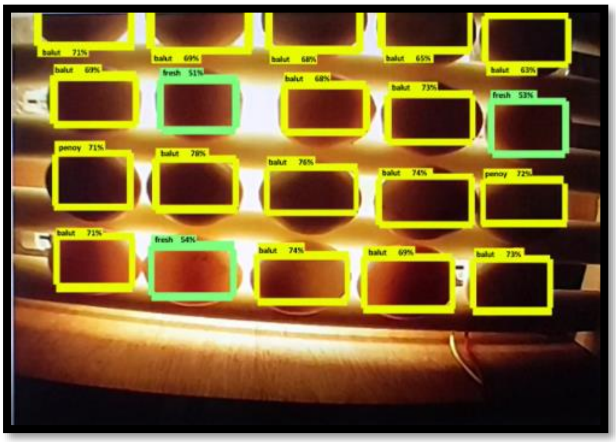
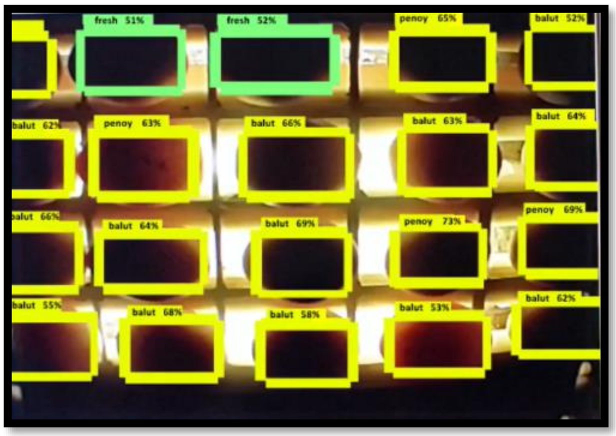


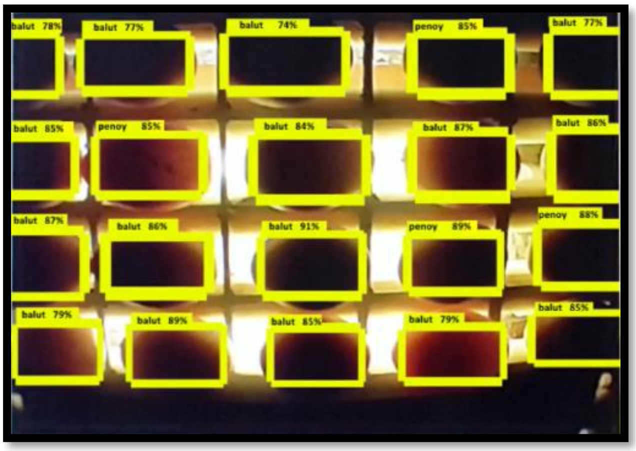
(e)

(f)

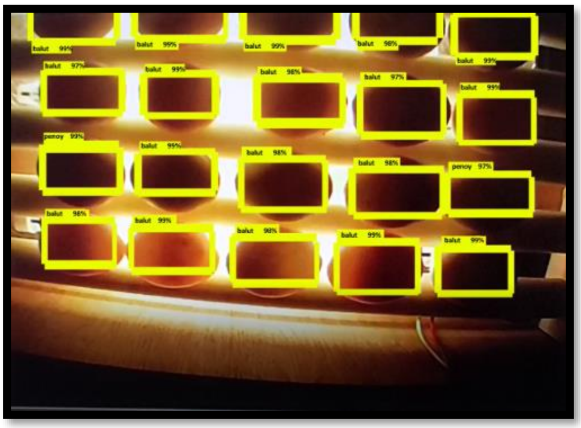


(g)

(h)



(i)



(j)

Fig. 8. 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 8 shows how the automatic candling device classified balut, penoy, and fresh eggs. CNN processed the egg image using the GUI and provided the results and accuracy.

The tables below compare manual and automated candling accuracy per trial. This table compares manual and automated egg classifications. The number of proper candling categories per tray was divided. The candling machine's accuracy was tested.

TABLE III. 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 IV. 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 V. 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 VI. 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 VII. 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 VIII. 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 IX. 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 X. 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 XI. 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 XII. 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 XIII. 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 XIII. The average accuracy of the automated candling apparatus was 92.5% percent after ten trials.

TABLE XIV. NUMBER OF IMAGES USED AS DATASET

Parameters	[5]	This Project
Number of Dataset Images	436	650
Classification Algorithm	Regional Convolutional Neural Network (RCNN)	Regional Convolutional Neural Network (RCNN)
Duck Eggs to be Classified	Balut, Penoy and Fresh	Balut, Penoy and Fresh
Classification Accuracy	80.5%	92.5%

Table XIV compares old and new work. Previous work's classification accuracy for balut, penoy, and fresh was 80.5%; with the same system, it was 92.55%. Due to its superior accuracy and capacity for categorizing eggs, the RCNN was a better tool with more datasets.

V. CONCLUSION

The IoT-Based Incubator Monitoring System with Convolutional Neural Network Egg Classifier for Balut Production monitored an incubator's temperature. Incubated eggs were easily classified as penoy or balut.

Based on the 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 traditional incubators because it properly incubates eggs by monitoring and regulating temperature and humidity. Users can also automatically candle incubated eggs to identify their maturity, which lowers the work of manually candling the eggs since the automatic method is 60 times faster and more accurate.

For future work, YOLOv5 object detection might produce faster and accurate result in egg candling. Compact type for the incubator to increase it's portability.

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