PERFORMANCE EVALUATION OF A 344-EGG AUTOMATIC INCUBATOR WITH TEMPERATURE-HUMIDITY REGULATION AND PERIODIC RACK TURNING

Soni Hestukoro[1], Marlon Tua Pangihutan Sibarani[2]
[1,2]Politeknik Negeri Medan, Jl. Almamater No. 1 Kampus USU Medan, North Sumatera 20155, Indonesia
sonihestukoro@polmed.ac.id

Abstract - This study evaluates an automatic poultry egg incubator designed for 344 chicken eggs. The prototype combines temperature regulation, humidity monitoring, and periodic rack turning to reduce manual handling during a 21-day incubation cycle. The operating temperature is maintained within 38-39 °C, while the humidity setting is 55-70%. A digital temperature sensor, hygrometer, Arduino Uno controller, relay module, heating lamp, ventilation fan, and DC rack-turning motor form the sensing-control-actuation chain. Hatching performance was assessed by classifying the 344 incubated eggs into normal hatch, defective hatch, dead embryo, and no-embryo outcomes. The test produced 327 normal chicks, 10 defective chicks, 5 dead embryos, and 2 eggs without embryos. The proportion of normal hatches was 95.06%, indicating that the incubator can sustain the environmental and mechanical conditions required for high-capacity chicken egg incubation. The study emphasizes integrated operation and outcome-based performance rather than only controller implementation.

Keywords - Automatic Incubator, Chicken Eggs, Temperature Control, Humidity Monitoring, Rack Turning.

I. INTRODUCTION

Chicken egg incubation requires a controlled environment because embryo development is sensitive to temperature, moisture, ventilation, egg quality, and the handling schedule. In conventional practice, operators frequently inspect environmental conditions and turn eggs manually. For a large batch, this repeated intervention increases workload and may introduce uneven treatment among trays. Previous work has therefore highlighted the importance of automated incubation systems and appropriate pre-incubation handling for improving hatchability [1], [2].

The prototype investigated in this study was developed as a 344-egg cabinet incubator with automatic rack movement and digital monitoring. The system uses an Arduino Uno as the main controller, supported by a temperature sensor, hygrometer, relay module, heating lamp, ventilation fan, and DC motor. The design target is to maintain the incubation chamber at 38-39 °C with a humidity setting of 55-70%, while the rack is moved periodically to distribute exposure and reduce manual egg turning. Arduino-based poultry incubators have been reported as practical low-cost control platforms for sensing and actuation [3].

This paper does not replicate the organization of a controller-only study. Instead, it reorganizes the original prototype work around system architecture, incubation protocol, measurable hatch outcomes, and machine effectiveness. The principal research question is whether the integrated 344-egg incubator can maintain the required operating conditions and achieve a high proportion of normal hatches during a complete chicken incubation cycle.

II. SIGNIFICANCE OF THE STUDY

A. Incubation Requirements

Successful incubation begins with appropriate egg selection. Eggs should have normal shape and weight, clean shells, a stable air cell, and no obvious defects such as cracks, abnormally rough surfaces, soft shells, or multiple yolks. Breeding conditions and the age of parent birds also influence the quality of eggs selected for hatching [4]-[6]. Before incubation, the source recommends cleaning with an appropriate disinfecting procedure and avoiding excessive storage time.

Temperature stability is critical because embryo development slows or stops when the thermal environment is outside the required range. Humidity is similarly important because moisture loss through shell pores affects embryo condition and hatchability [7]-[10]. Air circulation interacts with humidity and temperature distribution, while rack turning helps expose eggs more uniformly during early and middle incubation. For chicken eggs, the source protocol uses a 21-day cycle with rack rotation stopped on day 18.

B. Research Contribution

The main contribution of this work is the evaluation of a relatively high-capacity 344-egg incubator as an integrated machine rather than as an isolated controller. The study combines three operational functions: environmental sensing, automatic thermal switching, and periodic mechanical rack turning. Its performance is reported using complete batch outcomes, allowing the effectiveness of the machine to be expressed directly as the percentage of eggs that hatch normally.

C. Research Method

The research used a prototype development and experimental evaluation approach. The cabinet was assembled with multi-level egg racks, an enclosed chamber, a transparent access door, digital controls, and an automatic rack-turning mechanism. The control subsystem reads temperature and humidity, displays the measured condition, switches the heating device according to the temperature threshold, and operates the rack motor according to a timer setting.

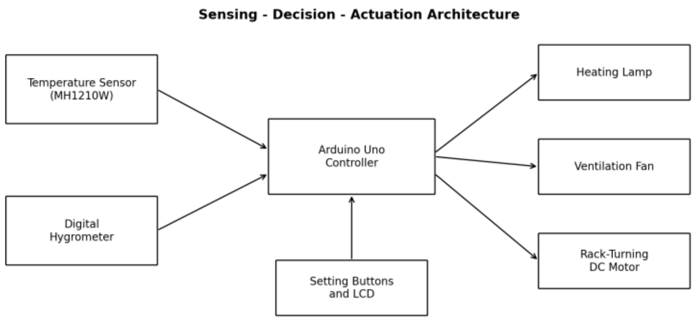

Figure 1. Functional architecture of the 344-egg incubator

Figure 1 summarizes the sensing-decision-actuation sequence. Temperature and humidity measurements are supplied to the Arduino Uno. User settings and current readings are shown on the LCD. Output control is sent through the relay module to the heating lamp, ventilation fan, and rack-turning motor. The resulting architecture separates low-voltage decision logic from the higher-power actuators.

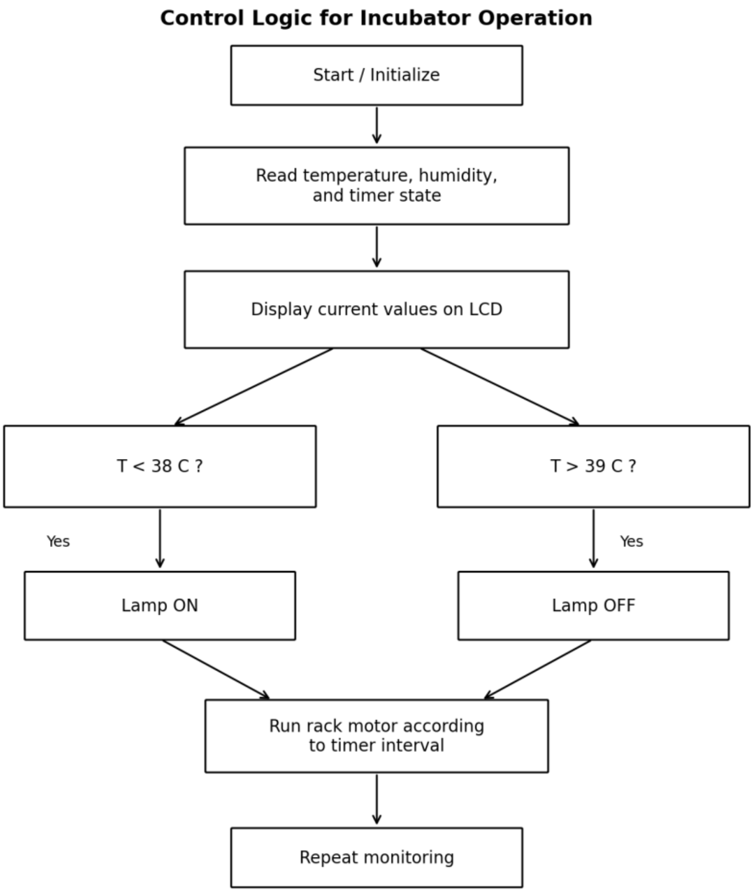

Figure 2. Temperature and rack-turning control logic

The temperature control logic uses the operating band stated in the source design. When the measured temperature falls below 38 °C, the heating lamp is activated. When it exceeds 39 °C, the heating lamp is deactivated. Between these limits, the system continues monitoring while the rack motor follows the timer schedule. This hysteresis-like operating band prevents continuous switching at a single temperature value.

TABLE I. DESIGN AND INCUBATION PARAMETERS

Parameter	Setting / Specification
Egg capacity	344 chicken eggs
Incubation period	21 days
Rack turning stop	Day 18
Temperature range	38-39 °C
Humidity setting	55-70%
Main controller	Arduino Uno
Temperature sensing	MH1210W digital temperature sensor
Humidity sensing	Digital hygrometer
Rack actuator	DC motor with timer-controlled operation

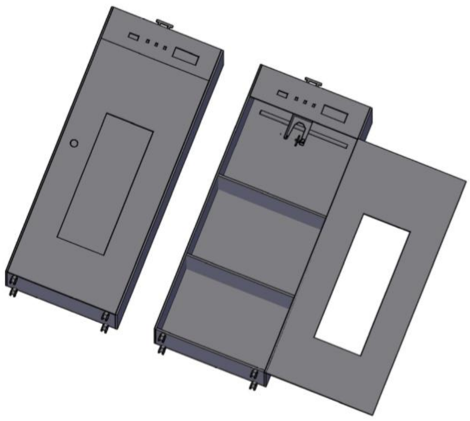

Figure 3. Mechanical configuration of the incubator cabinet

The mechanical model in Figure 3 shows a cabinet with several rack levels, a front access door, a viewing window, a top-mounted control area, and a rack-turning motor. This arrangement is intended to accommodate a large number of eggs while keeping the control interface accessible to the operator.

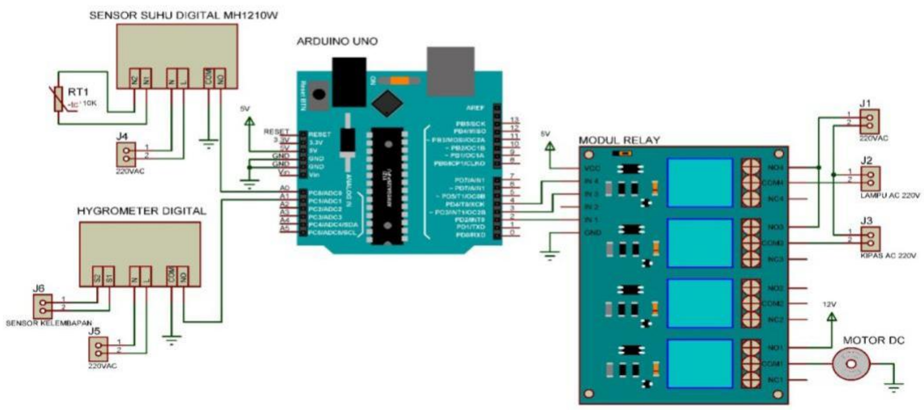

Figure 4. Automatic control circuit used in the prototype

The control circuit in Figure 4 connects the temperature and humidity instruments to the Arduino Uno and relay module. The relay outputs interface the controller with the electrical loads, including the heating and air-circulation devices, while the DC motor provides mechanical movement for the egg racks.

D. Experimental Procedure and Evaluation Metric

A batch of 344 chicken eggs was placed in the incubator and observed through the 21-day incubation period. On day 4, eggs were checked for embryo presence and infertile eggs could be removed. The rack-turning motor operated according to the timer through the active turning period. Additional embryo observations were carried out during incubation, rack movement was stopped on day 18, eggs were checked for shell cracks around day 20, and hatching was evaluated on day 21. Machine effectiveness was calculated using the ratio between eggs that hatched normally and the total number of eggs loaded into the incubator, as shown in Equation (1).

$$\text{Machine Effectiveness (\%)} = (\text{Normal Hatches} / \text{Total Eggs}) \times 100\% \qquad (1)$$

III. RESULTS AND DISCUSSION

A. Hatching Results

The complete outcome of the 344-egg test batch is summarized in Table II. The outcomes add up to the original loading capacity, allowing the batch performance to be evaluated without excluding the eggs that did not develop normally.

TABLE II. HATCHING OUTCOME OF 344 CHICKEN EGGS

Outcome	Number of Eggs	Percentage
Normal hatch	327	95.06%
Defective hatch	10	2.91%
Dead embryo	5	1.45%
No embryo	2	0.58%
Total	344	100.00%

Normal hatches accounted for 327 of 344 eggs. The remaining 17 eggs consisted of 10 defective hatches, 5 dead embryos, and 2 eggs without embryos. The low proportion of non-normal outcomes indicates that most eggs completed the incubation cycle successfully under the machine operating conditions.

Figure 5. Interior view of the loaded incubator

Figure 6. Prototype cabinet during testing

Figures 5 and 6 show the physical machine used for the experiment. The eggs are distributed across multiple rack levels inside the cabinet, while the control panel and door provide access for monitoring and inspection. The multi-level arrangement is consistent with the 344-egg capacity objective.

B. Incubation Sequence

The operational sequence follows embryo development over the complete 21-day period. After loading on day 1, the first inspection is carried out around day 4 to identify eggs without embryos. From days 5-11, periodic rack movement continues and embryo development is checked again. Rack turning is maintained through day 17 and stopped on day 18. Around day 20, shell cracking is observed as hatching approaches, and the final hatch condition is evaluated on day 21.

This sequence shows that the automatic function does not eliminate biological inspection. Instead, automation reduces repeated mechanical handling and maintains the environmental set points, while the operator remains responsible for candling or embryo observation and final hatch assessment. This division of functions is suitable for practical hatchery operation because it combines automatic control with necessary biological checks.

C. Machine Effectiveness

Using Equation (1), the machine effectiveness is calculated from the number of normal hatches:

$$\textbf{Effectiveness} = (327 / 344) \times 100\% = 95.06\%$$

The calculated value is slightly above 95%, consistent with the original experimental conclusion. This percentage should be interpreted as the proportion of the full loaded batch that produced normal chicks. Because two eggs were classified as having no embryo, the final result reflects both machine operation and the biological quality of the starting batch.

D. Discussion

The observed performance suggests that the combined regulation of temperature, humidity, air circulation, and rack movement provided a stable incubation environment for most eggs. The temperature band of 38-39 °C and the stated humidity range were maintained as the operating references, while automated rack movement reduced the need for manual turning. These factors correspond with the incubation requirements described in earlier studies on egg hatchability and incubator development [1], [2].

Compared with a design description that focuses mainly on Arduino implementation, the present analysis emphasizes the 344-egg machine as a complete hatchery system and reports the distribution of biological outcomes. The largest non-normal category was defective hatch (2.91%), followed by dead embryos (1.45%) and eggs without embryos (0.58%). These categories provide a more informative view than reporting only a single success percentage because they separate developmental failure from initial infertility.

Figure 7. Hatched chicks from the incubation test

Figure 8. Additional hatch outcome documentation

The photographs in Figures 7 and 8 provide visual documentation that a substantial number of chicks emerged from the test batch. However, the source data do not provide repeated experimental batches, time-series sensor logs, energy consumption, or tray-by-tray temperature and humidity distributions. Therefore, the reported 95.06% value should be treated as the outcome of the documented batch rather than as a statistical estimate across repeated trials.

IV. CONCLUSION

A 344-egg automatic incubator integrating temperature control, humidity monitoring, air circulation, and periodic rack turning was evaluated using a complete 21-day chicken egg incubation cycle. From 344 eggs, 327 hatched normally, 10 produced defective hatches, 5 contained dead embryos, and 2 had no embryos. The normal-hatch effectiveness was 95.06%. The result indicates that the prototype can support high-capacity incubation while reducing manual rack handling. Future evaluation should include repeated batches, continuous temperature-humidity logging, uniformity measurements at different rack positions, and power-consumption analysis to establish repeatability and operational efficiency more rigorously.

REFERENCES

[1] T. A. Adegbulugbe, A. O. Atere, and O. G. Fasanmi, “Development of an automatic electric egg incubator,” International Journal of Scientific & Engineering Research, vol. 4, no. 9, pp. 914-918, 2013.

[2] H. Bergoug et al., “Effect of pre-incubation and incubation conditions on hatchability, hatch time and hatch window, and effect of post-hatch handling on chick quality at placement,” World’s Poultry Science Journal, vol. 69, no. 2, pp. 313-334, 2013.

[3] A. Faroqi et al., “Design of Arduino Uno Based Duck Egg Hatching Machine With Sensor DHT22 and PIR Sensor,” in 2020 6th International Conference on Wireless and Telematics (ICWT), IEEE, 2020, pp. 1-4.

[4] J. E. Fulton, “Genomic selection for poultry breeding,” Animal Frontiers, vol. 2, no. 1, pp. 30-36, 2012.

[5] I. Ismoyowati et al., “Sexual dimorphism and identification of single nucleotide polymorphism of growth hormone gene in Muscovy duck,” Journal of Indonesian Tropical Animal Agriculture, vol. 42, no. 3, pp. 167-174, 2017.

[6] S. Johari, N. D. Kusumadani, and E. Kurnianto, “Multivariate analysis of the morphological traits of female duck, muscovy-duck and mule-duck,” Journal of the Indonesian Tropical Animal Agriculture, vol. 38, no. 3, pp. 143-148, 2013.

[7] Lourens A, Brand HVD, Meijerhof R, Kemp B. Effect of eggshell temperature during incubation on embryo development, hatchability, and posthatch development.. *Poultry science.* 2005;84 6: 914-20 . doi:10.1093/ps/84.6.914

[8] Kingori AM. Review of the Factors That Influence Egg Fertility and Hatchabilty in Poultry. *International Journal of Poultry Science.* 2011;10:483-492. doi:10.3923/ijps.2011.483.492

[9] Tona K, Voemesse K, N’nanlé O, et al. Chicken Incubation Conditions: Role in Embryo Development, Physiology and Adaptation to the Post-Hatch Environment. *Frontiers in Physiology.* 2022;13. doi:10.3389/fphys.2022.895854

[10] Nowaczewski S, Kontecka H, Rosiński A. Effect of Japanese quail eggs location in the setter on their weight loss and eggshell temperature during incubation as well as hatchability results. *European Poultry Science.* 2012. doi:10.1016/s0003-9098(25)00730-1