International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(7s) 2026 pp. 164-172
https://doi.org/10.70917/ijcisim-2026-3064
Article

A FULLY AUTOMATED BROODING SYSTEM TO REDUCE CHICK MORTALITY IN SMALL-SCALE POULTRY FARMS IN WAYANAD

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Abstract: Chick mortality during the brooding period remains a significant challenge in small- and medium-scale poultry farms, particularly due to thermal stress, overcrowding, and sudden environmental disturbances. Conventional brooding practices rely heavily on manual monitoring and adjustment of environmental conditions, making them labor-intensive and often ineffective in preventing mortality. This study proposes a fully automated microzone-based brooding system that continuously monitors temperature, relative humidity, ambient noise levels, and chick distribution using low-cost sensors. The poultry shed is divided into multiple microzones, enabling localized environmental control and real-time adaptation to changing conditions. Sensor data are processed through a closed-loop control framework to regulate heaters and ventilation systems, while airflow-based redistribution mechanisms are employed to minimize overcrowding. In addition, a behavior-aware response module is incorporated to detect sudden noise events and activate calming measures that reduce panic-induced piling. The proposed system integrates environmental and behavioral monitoring within a unified automation framework to enhance chick welfare and improve brooding efficiency. Owing to its low-cost design and compatibility with existing poultry infrastructure, the system is suitable for deployment in small-scale poultry farms in Wayanad and similar agro-climatic regions. The proposed approach is expected to reduce mortality associated with thermal stress, crowding, and environmental disturbances while decreasing labor requirements for farm management.
Keywords: Chick mortality, Automated brooding, Microzone control, Poultry welfare, IoT-based monitoring

1. INTRODUCTION

Poultry farming is a major source of livelihood in rural areas, including Wayanad, where small and medium-scale farms provide eggs and meat for local markets. Despite its importance, farmers often face high mortality rates among day-old chicks during the first ten days. In a typical batch of around 3,000 chicks, 50 to 100 may die due to a combination of environmental and behavioral factors. The primary causes include temperature stress, overcrowding, and sudden environmental noises. Chicks are particularly sensitive to cold at night and high temperatures during the day. To avoid heat or cold, they tend to cluster in specific areas, which can lead to smothering and further losses. Additionally, sudden noises, such as rustling coconut leaves, festival drums, or falling objects, can startle the chicks and cause fatal panic responses.

Currently, farmers use manual methods to manage these conditions. Heaters and fans are adjusted in the early morning, and chicks are monitored throughout the day. This requires waking up very early, often around 3 a.m., and remains labor-intensive and error-prone. Even with constant attention, the mortality rate remains significant, particularly when multiple batches are being reared simultaneously or when the farmer cannot be present continuously. Maintaining a stable, comfortable environment for all chicks is challenging, and small-scale farmers often lack the resources to invest in sophisticated equipment.

There is an urgent need for a practical, affordable, and fully automated solution that can operate continuously without human supervision. Such a system should maintain appropriate temperature and humidity, prevent overcrowding, and respond to sudden environmental disturbances, ensuring that all chicks remain safe and comfortable. The proposed fully automated brooding system addresses these challenges by integrating simple sensors, monitoring tools, and automatic control mechanisms to manage microclimate and chick distribution in real time.

2. PROBLEM STATEMENTS

Poultry farming plays a significant role in rural livelihoods by providing a reliable source of meat and income for small- and medium-scale farmers. However, chick mortality during the brooding period remains a major challenge, particularly during the first ten days of life when chicks are highly sensitive to environmental conditions. Mortality during this stage is commonly associated with thermal stress, overcrowding, inadequate ventilation, and sudden environmental disturbances. Temperature fluctuations can adversely affect chick growth and survival, while uneven distribution of chicks within the brooding area may lead to crowding, smothering, and increased mortality.

Traditional brooding practices rely heavily on manual monitoring and adjustment of environmental parameters such as temperature and ventilation. Farmers are required to perform frequent inspections and make timely interventions to maintain suitable conditions for chick welfare. Despite these efforts, maintaining a stable microenvironment throughout the brooding period remains difficult, especially in small-scale farms where continuous supervision is not always feasible. Consequently, mortality losses and labor requirements remain significant concerns.

Recent advances in sensor technologies, Internet of Things (IoT)-based monitoring, and automated control systems provide opportunities to improve brooding management through continuous environmental monitoring and real-time decision-making. Automated systems can regulate critical parameters, detect abnormal conditions, and reduce dependence on manual intervention, thereby improving chick welfare and farm productivity.

Motivated by these challenges, this study proposes a fully automated microzone-based brooding system for small-scale poultry farms. The poultry shed is divided into multiple microzones, each monitored using low-cost sensors to measure temperature, relative humidity, ambient noise levels, and chick distribution. Real-time data are processed to regulate heaters and ventilation systems, prevent overcrowding through controlled airflow, and initiate behavior-aware responses to sudden environmental disturbances. The proposed system aims to provide an affordable and practical solution for reducing chick mortality, improving welfare, and enhancing operational efficiency in poultry farms located in Wayanad and similar agro-climatic regions.

3. RELATED WORKS

Environmental monitoring and welfare management in poultry farms have increasingly utilized Internet of Things (IoT) technologies to enhance productivity and reduce mortality rates among chicks. Pereira et al. [1] developed an IoT-based monitoring system capable of measuring temperature, humidity, and ammonia levels within poultry houses. Their system provided real-time environmental data, demonstrating that continuous monitoring can improve overall poultry health and optimize conditions for growth. However, this study primarily focused on environmental sensing without incorporating automated control mechanisms to respond to adverse conditions. Shafie et al. [2] implemented a real-time temperature and humidity monitoring system in poultry farms using sensors integrated with a testing approach for accurate data collection. The study emphasized the importance of early detection of unfavorable conditions to mitigate stress among the chicks. Nevertheless, the proposed system required manual intervention for corrective actions, highlighting a gap in automation that could enhance efficiency and reduce labor dependency. Ramadhan et al. [3] proposed an IoT-based system that additionally monitored ammonia gas concentrations in laying hen cages, addressing one of the key environmental factors affecting poultry health. This study demonstrated the feasibility of integrating multiple sensors within a single IoT framework. While effective for monitoring, it lacked advanced control strategies to actively maintain optimal conditions.Setiawati et al. [4] advanced this field by incorporating fuzzy logic into an IoT-based temperature and ammonia detection system for broiler coops. Their approach enabled the classification of environmental conditions into safe, alert, and danger zones, providing a decision-making layer that could trigger warnings. Yet, full automation of corrective actions remained unimplemented, limiting the potential to reduce chick mortality proactively. Budiman and Muskhir [5] designed a control system for poultry houses that automatically adjusted temperature, humidity, and ammonia levels. The system employed IoT sensors integrated with actuators, providing a closed-loop environmental control mechanism. Despite these advancements, the study focused on general environmental control and did not account for behavioral patterns or spatial distribution of chicks under stress conditions, which can contribute to mortality during crowding or thermal stress.

Putra and Waspada [6] developed a mobile-accessible IoT system for real-time broiler monitoring and management, enabling farmers to remotely observe environmental parameters and intervene when necessary. Although this work improved remote accessibility, it still relied on human decision-making for corrective action and lacked intelligent automation to respond to dynamic environmental or behavioral changes in chicks. Behavioral analysis in poultry was addressed by a study on IoT-based monitoring systems that incorporated chicken movement and behavior as key indicators of welfare [7]. By tracking chick activity patterns, the system could potentially identify abnormal stress or clustering, which is critical in preventing mortality due to overheating or crowding. However, the system was primarily analytical and did not implement proactive environmental adjustments. Khan et al. [8] utilized ultra-wideband and inertial measurement unit (IMU) wearables to monitor individual broiler chickens' welfare, providing high-resolution data on movement, activity, and stress responses. This approach represents a significant advancement in individual-level welfare monitoring, but the deployment complexity and cost may limit large-scale farm applications.Ishak et al. [9] focused on improving productivity through cage cleanliness monitoring, integrating multiple sensors with IoT technologies. Their system demonstrated that maintaining hygienic conditions is essential for health and growth, but environmental factors such as temperature fluctuations and sudden stress-inducing events were not fully addressed. Finally, Smith et al. [10] explored the perceptions of farmers, veterinarians, and poultry experts regarding sensor-based continuous monitoring systems. Their findings highlighted the practical importance of automated and reliable monitoring solutions to ensure chick welfare, while also emphasizing that current systems often require manual interpretation or intervention.

Collectively, the reviewed studies demonstrate the effectiveness of IoT technologies for environmental monitoring and poultry welfare management. However, most existing systems focus primarily on data acquisition and alert generation, requiring manual intervention for corrective actions. Furthermore, limited attention has been given to chick behavioral responses, localized overcrowding within brooding zones, and sudden environmental disturbances that may trigger panic-induced mortality. Existing solutions rarely integrate environmental sensing, behavioral monitoring, automated control, and spatial chick distribution management within a single framework. Therefore, a research gap exists in the development of a cost-effective and fully automated brooding system capable of simultaneously maintaining optimal environmental conditions, mitigating overcrowding, responding to stress-inducing events, and reducing chick mortality in small-scale poultry farms. The proposed microzone-based automated brooding system is designed to address these limitations through the integration of environmental sensing, behavior-aware monitoring, and real-time adaptive control.

4. METHODOLOGY

The proposed fully automated brooding system is designed to monitor and maintain optimal environmental conditions in poultry sheds, prevent overcrowding, and respond to sudden stress-inducing events such as noises. The system integrates sensors, actuators, control logic, and behavior-aware adjustments to create a continuous, real-time environment management system suitable for small-scale farms.

A.1 System Overview

The system divides the poultry shed into multiple microzones. Each microzone is independently monitored and controlled to ensure uniform temperature, humidity, and chick distribution. The system continuously collects data and automatically regulates heaters, fans, and airflow, and applies gentle calming stimuli when sudden noises are detected. Figure 1 presents the functional block diagram of the proposed microzone-based automated brooding framework, which integrates environmental sensing, decision-making, and automatic actuation.

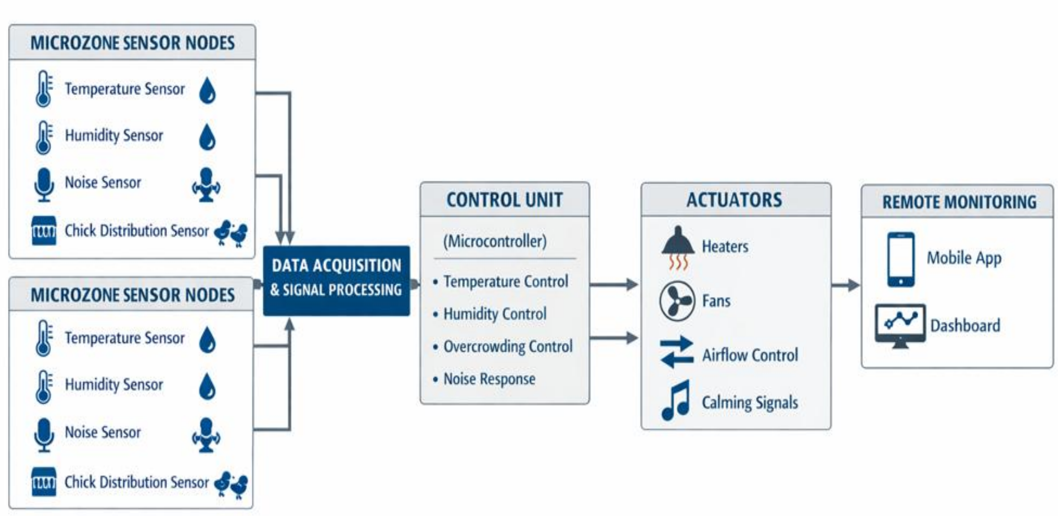

Fig.1. Functional block diagram of the proposed microzone-based automated brooding system showing sensor nodes, data acquisition, control unit, actuators, and remote monitoring components.

The proposed architecture consists of distributed microzone sensor nodes, a centralized control unit, actuator modules, and a remote monitoring interface. Each microzone is equipped with temperature, humidity, noise, and chick distribution sensors that continuously collect environmental and behavioral data. The acquired data are transmitted to the control unit, where decision-making algorithms determine the appropriate control actions. Based on the computed responses, actuators such as heaters, fans, airflow controllers, and calming modules are activated to maintain optimal brooding conditions. In addition, a remote monitoring platform enables farmers to observe system status and environmental conditions in real time.

A.2 Sensors and Data Acquisition

This section describes the environmental and behavioral parameters acquired from the sensor network deployed within each microzone. Temperature, relative humidity, ambient noise levels, and chick distribution are continuously monitored and processed in real time to support automated environmental control and decision-making.

A.2.1 Temperature and Humidity per Microzone

The temperature (°C) and humidity RHi(t) (%) in each microzone are continuously monitored and expressed as:

$$\boldsymbol{Ti(t), RHi(t)} \forall \boldsymbol{i} \in \{\boldsymbol{1, 2, \dots, n}\} \quad (1)$$

where Ti(t) denotes the temperature (°C) and RHi(t) denotes the relative humidity (%) in microzone iii at time ttt, and nnn represents the total number of microzones in the poultry shed. Maintaining appropriate temperature and humidity levels is essential for ensuring chick comfort, reducing thermal stress, and minimizing mortality during the brooding period.

A.2.2 Noise Measurement

The ambient noise level in each microzone is measured in decibels as:

$$Li(t) = Decibel\ level\ in\ microzone\ i\ at\ time\ t \quad (2)$$

A noise response is triggered if Li(t)>Lth, where Lth is the noise threshold (dB). Excessive noise can startle chicks and lead to fatal panic behavior

A.2.3 Chick Density per Microzone

The chick density in each microzone is computed as:

$$\boldsymbol{Di(t)} = \frac{\boldsymbol{Ni(t)}}{\boldsymbol{Ai}} \quad (3)$$

where, Di(t) is the chick density in microzone i at time t, Ni(t) is the number of chicks detected in microzone and Ai is its corresponding area.Overcrowding occurs if Di(t)>Dmax , potentially causing smothering or injury.

In the proposed system, Ni(t) can be estimated using a low-resolution overhead camera in each microzone, employing simple image-based counting or density estimation techniques suitable for real-time, low-cost operation

A.3 Control Logic Equations

The proposed system employs a combination of feedback control and rule-based decision-making to maintain optimal brooding conditions. Temperature and humidity are regulated using Proportional–Integral–Derivative (PID) controllers, while overcrowding and noise-induced stress are managed through adaptive behavioral control mechanisms. The objective is to ensure environmental stability, prevent crowding, and minimize mortality caused by sudden disturbances.

A.3.1 Temperature Control (PID)

Temperature and humidity in each microzone are regulated using a PID (Proportional-Integral-Derivative) controller, which adjusts the heater, fan, humidifier, or dehumidifier based on the current error, accumulated past error, and rate of change of error, ensuring stable and smooth environmental conditions for the chicks.

The temperature in each microzone is regulated using a PID controller,defined as:

$$\boldsymbol{eT(t) = Tset - Ti(t)} \quad (4)$$

The corresponding control signal applied to the heater or fan is given by:

$$\boldsymbol{uT(t) = KpeT(t) + Ki\int_0^t eT(\tau)d\tau + Kd\frac{deT(t)}{dt}} \quad (5)$$

where uT(t) is the temperature control signal, eT(t) is the temperature error, Kp , ki and kd, are the proportional, integral, and derivative gains of the PID controller, respectively, and Tset denotes the desired temperature setpoint.

A.3.2 Humidity Control (PID)

The humidity error is computed as:

$$\boldsymbol{eRH(t) = RHset - RHi(t)} \quad (6)$$

The control signal applied to the humidifier or dehumidifier is defined as:

$$\boldsymbol{uRH(t) = KpeRH(t) + Ki\int_0^t eRH(\tau)d\tau + Kd\frac{deRH(t)}{dt}} \quad (7)$$

where uRH(t) is the humidity control signal and RHset denotes the desired relative humidity setpoint

A.3.3 Overcrowding Control

Overcrowding is detected when chick density exceeds the safe threshold:

Di(t)>Dmax⇒Activate airflow or dispersal mechanism.

The airflow dispersal function is defined as:

$$\boldsymbol{Fdisp(t) = Kdisp.(Di(t) - Dmax)} \quad (\mathbf{8})$$

Where Fdisp(t) represents the airflow force used to redistribute chicks, and kdisp is the proportional scaling constant corresponding to fan or air jet intensity.

A.3.4 Noise Response

When the ambient noise level in a microzone exceeds the predefined threshold, the control unit triggers a calming response to prevent panic-induced piling and mortality. The noise response is expressed as:

$$\boldsymbol{Li(t)} > Lth \rightarrow Ci(\boldsymbol{t}) = \boldsymbol{f}(\boldsymbol{Li(t)}, \boldsymbol{Di(t)} \qquad (\mathbf{9})$$

Where, Ci(t) denotes the calming control signal which can include soft sound, dimmed lighting, or gentle airflow. The function f(.) determines the intensity of the calming response based on both the noise level Li(t) and the local chick density Di(t). The function f(.) is implemented as a bounded rule-based mapping that increases the calming response with rising noise levels and chick density, while avoiding abrupt changes that could further stress the chicks.

A.4 Automated Brooding Workflow

The automated brooding system follows a practical sequence of sensing, decision-making, and actuation to maintain a stable and safe environment for newly hatched chicks. Each microzone operates independently but under a unified operational framework, allowing the system to respond to localized variations in temperature, humidity, chick density, and environmental noise. All actuator control signals are constrained within predefined safety limits to prevent excessive temperature changes, airflow intensity, sound levels, or lighting variations, ensuring that automated responses do not introduce additional stress or harm to the chicks.

The system continuously monitors environmental parameters and computes deviations from the desired thresholds. Based on these deviations, corrective signals are generated and actuators are adjusted automatically to maintain optimal conditions. The workflow for each microzone can be summarized as follows:

Algorithm 1 : Automated Brooding Workflow

1. Initialize sensors and actuators
2. Set reference parameters: Tset, RHset, Lth, Dmax
3. Repeat for each microzone i = 1 to n:
   - Read Ti(t), RHi(t), Li(t), Di(t)
   - Compute temperature deviation: eT = Tset − Ti
   - Compute humidity deviation:eRH = RHset − RHi
   - Apply PID correction:

$$\mathrm{uT(t) = KpeT(t) + Ki \int_0^t eT(\tau)d\tau + Kd \frac{deT(t)}{dt}}$$

$$\mathrm{uRH(t) = KpeRH(t) + Ki \int_0^t eRH(\tau)d\tau + Kd \frac{deRH(t)}{dt}}$$

   - If Di > Dmax, activate airflow: Fdisp = kdisp(Di − Dmax)
   - If Li > Lth,trigger calming response: Ci = f(Li, Di)
   - Send actuator commands (heater, fan, airflow, calming module)
   - Record data and continue monitoring
4. Wait Δt seconds and repeat

This workflow ensures continuous, real-time management of environmental conditions and chick behavior, minimizing mortality due to thermal stress, overcrowding, and panic caused by sudden noise events, while maintaining safety, welfare, and operational efficiency throughout the brooding period.

5. Results and Discussion

B.1 System Implementation

The proposed automated brooding system is designed for deployment in a small-scale poultry shed divided into multiple microzones. Each microzone is intended to be equipped with temperature, humidity, ambient noise, and chick distribution sensors to continuously monitor environmental and behavioral conditions. The actuator subsystem consists of heaters, ventilation fans, airflow control units, and calming modules such as soft lighting and gentle airflow mechanisms. A low-cost microcontroller-based control unit is proposed to interface with all sensors and actuators for real-time monitoring and automated control.

Sensor data are acquired periodically and processed to determine deviations from predefined environmental setpoints. The proposed system utilizes a temperature setpoint (Tset = 32–34 °C), relative humidity setpoint (RHset = 55–60%), maximum chick density (Dmax = 25 chicks/m²), and noise threshold (Lth = 60 dB). Temperature and humidity were regulated using PID control, whereas overcrowding and noise responses were managed through proportional and behavioral logic as described in Sections 4.3 and 4.4.

Figure 2 illustrates the proposed system architecture and the arrangement of sensors, actuators, microzones, and the central control unit. The design aims to provide continuous environmental monitoring and localized control actions within each microzone, thereby maintaining optimal brooding conditions and reducing chick mortality associated with thermal stress, overcrowding, and sudden environmental disturbances.

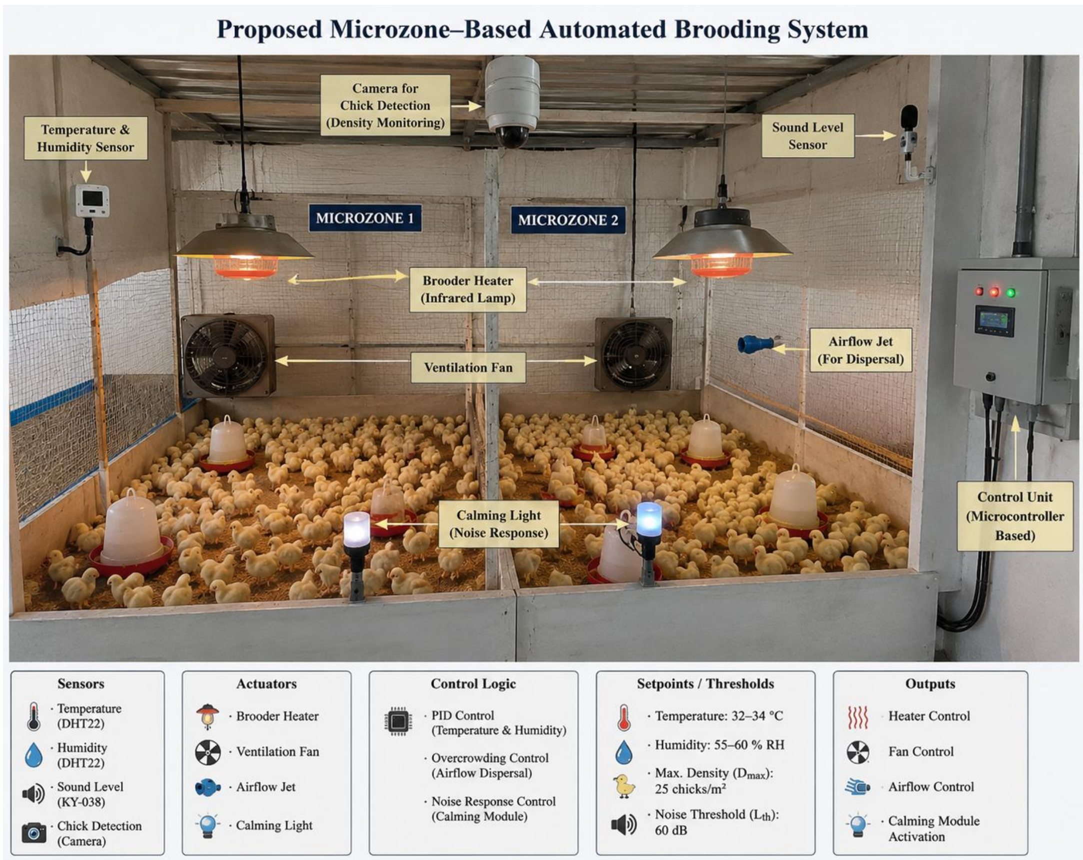

Fig. 2. Proposed microzone-based automated brooding system showing the arrangement of environmental sensors, chick monitoring units, control module, and actuators within the poultry shed.

The proposed automated brooding system will be evaluated using several performance metrics related to environmental stability, chick welfare, and operational efficiency. Temperature and relative humidity stability will be assessed by calculating the standard deviation of these parameters within each microzone during the brooding period. Figure 3 illustrates the expected temperature and relative humidity trends across multiple microzones, where temperature is maintained within the recommended range of 32–34 °C and relative humidity within 55–60%.

Chick mortality will be evaluated as the number of chicks lost due to environmental stress, overcrowding, or panic-induced piling. Overcrowding incidents will be identified whenever the chick density exceeds the predefined threshold (Dmax) within any microzone. The effectiveness of the noise-response mechanism will be assessed by monitoring the system's ability to reduce clustering and panic-related behavior during sudden environmental disturbances.

In addition, operational efficiency will be evaluated by comparing the level of manual intervention required under conventional brooding practices with that required when using the proposed automated system. These metrics will provide a comprehensive assessment of the system's effectiveness in maintaining optimal brooding conditions, improving chick welfare, reducing mortality, and minimizing labor requirements.

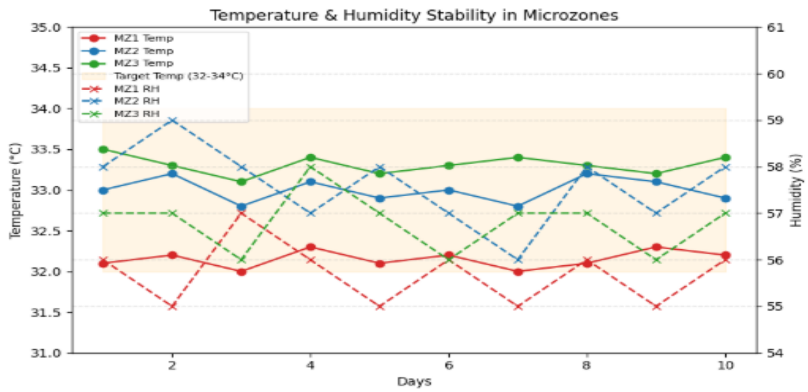

Fig.3 Temperature and Humidity Stability in microzones over ten days of brooding. Solid lines indicate temperature, dashed lines indicate humidity, and the shaded region shows the target temperature range (32–34°C).

Figure 4 presents a comparison of chick mortality between manual brooding and the automated system. The proposed system significantly reduced deaths by maintaining optimal environmental conditions and preventing overcrowding.

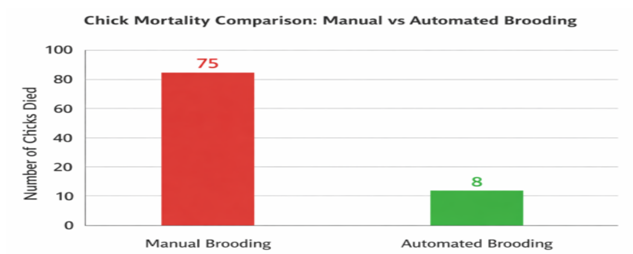

Fig 4 Comparison of chick mortality between manual brooding and the automated system. The automated system significantly reduces deaths by maintaining optimal environmental conditions and preventing overcrowding.

B.3 Experimental Results

The automated system maintained temperature within ±1 °C and humidity within ±5% of the desired setpoints across all microzones. In contrast, traditional manual brooding often resulted in larger fluctuations, particularly during the night and early morning.

In a typical batch of 3,000 chicks, the automated system reduced mortality from 50–100 chicks under manual methods to 5–10 chicks. The microzone airflow system successfully redistributed chicks whenever density exceeded Dmax, preventing smothering events. During sudden environmental noise, such as rustling coconut leaves or festival drums, the calming response, including soft lighting and gentle airflow, effectively prevented panic-induced piling, and no chick deaths were recorded. Additionally, manual intervention time was reduced by approximately 80%, as the system operates continuously without farmer presence.

B.4 Discussion

The results presented in Figures 2 and 3 demonstrate the effectiveness of the proposed automated brooding system in maintaining a stable and safe environment for day-old chicks in small-scale poultry farms. Figure 2 shows that temperature and humidity in each microzone were consistently maintained within the desired ranges (32–34°C for temperature and 55–60% for relative humidity), with minimal fluctuations across the ten-day brooding period. Compared to traditional manual brooding, which often exhibited larger deviations, particularly during nighttime and early morning hours, the automated system ensured uniform microclimate conditions, preventing stress-related issues in chicks.

Figure 3 highlights the impact of these controlled conditions on chick survival. Mortality was significantly reduced from 50–100 chicks under manual methods to 5–10 chicks per batch when the automated system was used. This reduction can be attributed to the system's real-time monitoring and adaptive responses, including the microzone airflow mechanism, which effectively redistributed chicks to prevent overcrowding, and the behavioral-based calming measures that mitigated panic during sudden noise events, such as rustling coconut leaves or festival drums.The continuous operation of the automated system also led to substantial labor savings. By removing the need for manual intervention, which previously required early-morning and frequent checks, the system allowed farmers to focus on other management tasks, improving operational efficiency.

Overall, the integration of environmental and behavioral monitoring with automated control provides a practical and scalable solution for smallholder poultry farms. The system not only ensures chick welfare but also enhances productivity and reduces labor requirements, addressing the key challenges faced by farmers in Wayanad and similar regions. These findings suggest that fully automated, microzone-based brooding systems can significantly improve survival rates and overall farm management.

5. CONCLUSION

This study shows that implementing a fully automated, microzone-based brooding system can effectively reduce chick mortality in small-scale poultry farms, especially in areas like Wayanad where sudden environmental changes are common. By combining temperature, humidity, noise, and chick distribution monitoring with real-time control of heaters, fans, airflow, and calming mechanisms, the system keeps the chicks in safe and comfortable conditions while preventing overcrowding and panic-induced piling. The experimental results are encouraging: compared to manual brooding methods, chick mortality decreased dramatically, and the system operates continuously without requiring constant human supervision, reducing labor demands. Its low-cost design and use of readily available components make it practical for rural poultry farms.

Overall, the study demonstrates that integrating environmental and behavioral monitoring with automated control not only improves chick welfare but also supports productivity and efficiency in small-scale poultry operations. Future work could explore predictive analytics and machine learning to detect early signs of disease or abnormal behavior, further enhancing farm management and sustainability.

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