Internet of things-based cricket environment system to maximize egg production and reduce mortality rate

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ABSTRACT

The deployment of Internet of things (IoT) technologies presents an opportunity to improve efficiency in cricket farming. This study investigates the implementation of an IoT-based system utilizing an ESP32 microcontroller, a suite of environmental sensors, and actuators. The system is supported by a ThingsBoard dashboard for data visualization and a Telegram bot for notifications. The setup was tested on a single cricket cage over a 28-day period and compared against a control group. Each cage contained 20 male and 100 female Cliring crickets. Key parameters analyzed included temperature, humidity, soil moisture, egg yield, food conversion ratio (FCR), and mortality rate. Findings show that the IoT-enabled cage consistently maintained optimal environmental conditions—temperature (20 to 32 °C), humidity (65% to 85%), and soil moisture (60% to 80%)—unlike the control, which experienced greater variability. The IoT cage yielded 87.28 grams of eggs, a 33.33% improvement over the control's 65.46 grams. Additionally, FCR improved from 2.53 to 2.01 grams per egg, and mortality rate dropped from 0.816 to 0.708. These results underscore the effectiveness of IoT systems in enhancing environmental stability, productivity, and survival rates in small- to medium-scale cricket farming operations.

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1. INTRODUCTION

Crickets have emerged as a vital and versatile resource in today’s world. Due to their high protein and nutrient density, they are widely used as a dietary component for companion animals, including reptiles, amphibians, avian species, and aquatic pets. More recently, crickets have been recognized as an eco-friendly protein alternative suitable for human diets, offering a solution to the environmental impacts of traditional meat production. They also continue to be valued in traditional medicine and as effective bait in fishing activities [1]–[3].

As the cricket farming industry continues to expand, it presents economic opportunities for small- and medium-scale entrepreneurs. However, ensuring consistent quality in production remains a significant barrier that can threaten business viability. One key challenge is maintaining uniform and nutritionally balanced feed, which is crucial for promoting healthy growth and optimal quality. Resource and logistical constraints often hinder this consistency [1], [4], [5]. Studies indicate that incorporating cassava and papaya leaves into feed enhances productivity due to their rich protein content [6]–[8].

Environmental variables, such as temperature, humidity, and soil moisture, significantly influence cricket development and reproductive success. Soil quality is especially important during oviposition, influencing egg viability and hatching outcomes [9]. Maintaining ideal soil conditions fosters successful reproduction, which is critical to sustaining population growth [9], [10]. Crickets flourish in environments with temperatures between 20–32°C, humidity between 65% to 85%, and soil moisture levels ranging from 60% to 80% [9], [11]. Their nocturnal nature also necessitates low-intensity lighting at night [12], [13]. Conversely, poor environmental management during growth phases can lead to increased mortality [14], [15].

IoT technologies provide farmers with tools to precisely monitor and manage such conditions. These systems enable real-time data exchange among interconnected devices, offering continuous updates and streamlining essential agricultural operations through automation [16]. Various areas in agriculture, such as irrigation [17], weather tracking [18], and insect farming [19], have already benefited from IoT applications. The integration of such systems not only minimizes manual labor but also enhances resource efficiency and yields. Innovations in precision agriculture have shown how IoT, combined with data analytics, can optimize inputs and boost productivity [20], [21].

The use of IoT in cricket farming enables the automation of systems like misting to maintain optimal temperature and humidity, as demonstrated in greenhouse environments [22]. Studies also emphasize the relevance of IoT in analyzing behavioral patterns in insect farming, highlighting its transformative impact [23]. Lessons from aquaculture, where IoT tools help monitor water parameters like pH and temperature, can be adapted to cricket farming [24] These approaches contribute to environmental stability, operational efficiency, and reduced mortality. Moreover, the scope of IoT in agriculture continues to grow, encompassing predictive analytics and system optimization to promote sustainability [25], [26].

This study introduces an IoT-integrated solution specifically developed for cricket farming, aiming to elevate productivity, sustainability, and operational efficiency. A primary contribution lies in the development and deployment of a tailored monitoring and control system that regulates key environmental variables—temperature, humidity, and soil moisture—to create optimal conditions for growth and reproduction. Automated mechanisms for feeding, misting, and climate regulation are incorporated to reduce labor dependency and enhance consistency.

Additionally, the integration of real-time data acquisition enables proactive management of environmental conditions, allowing farmers to identify and respond to risks more swiftly. The system's design also considers cost-effectiveness and scalability, making it accessible for small- and medium-sized operations that may not possess advanced technological infrastructure.

Lastly, the study presents a comparative evaluation between conventional and IoT-driven farming approaches, analyzing differences in growth rate, feed efficiency, and mortality. These findings provide valuable perspectives into the benefits of technology-driven innovation within insect farming practices. By addressing existing limitations in cricket farming through IoT integration, this study supports the progress of intelligent agricultural systems and provides a scalable model for future implementations [27]. The paper proceeds with a review of relevant literature in section 2, followed by system design in section 3, result evaluation in section 4, and conclusions and future work in section 5.

2. MATERIALS AND METHODS

This section outlines the materials utilized and the experimental design established to achieve the study's objectives. A comprehensive description of the cricket cages, the biological subjects, and the technological components involved is provided to ensure replicability and clarity in the research process.

2.1. Materials

Two identical cages, each measuring 60×30×60 cm, will house the crickets in this study. Each cage will contain 20 male and 100 female crickets of the Cliring species. Male and female crickets exhibit both common and unique behaviors. Agonistic behavior, such as threatening and displaying strength, is often observed in crickets when resources like food, shelter, or mates are limited. Male crickets, in particular, are known to engage in territorial fights and even cannibalism when housed together in close quarters, which can influence interactions within the cage and contribute to uneven outcomes in population dynamics and resource allocation [23]. We will equip one cage with a comprehensive internet of things (IoT) system, while the second cage will function as a control, without any IoT intervention.

The experimental setup's IoT infrastructure comprises multiple integrated components. The central processing unit will be an ESP32 microcontroller, which will collect data from various sensors and control the actuators. A DHT21 sensor will monitor temperature and humidity levels, while a capacitive soil moisture sensor will track soil moisture. To regulate these parameters, the system will use a relay to control actuators, including heating lamps to maintain temperature, a misting pump to adjust air temperature, humidity, and soil moisture, and an exhaust fan to expel excess humidity. Additionally, the system will send notifications to the user via a Telegram bot, reminding them to feed the crickets. The system will feed the crickets cassava leaves every two days, followed by concentrated feed every five days to ensure a balanced diet that promotes growth and productivity.

The control cage will have identical size and number of crickets to the test cage, but without IoT instrumentation or automated regulation mechanisms. This setup will enable a side-by-side evaluation to measure how IoT-driven environmental control affects cricket growth, productivity, and overall well-being.

2.2. Methods

The methodological approach in this research is structured into two separate stages to systematically evaluate the effectiveness of the IoT-based system. Phase 1 focuses on system development and configuration, while Phase 2 emphasizes implementation and performance assessment through controlled experimentation.

2.2.1. Phase 1

In phase 1, the focus will be on the creation and setup of the IoT system. The objective is to design an operational IoT setup that enables both observation and regulation of environmental variables within the cricket cage. The system will include the deployment of sensor modules—including a DHT21 for temperature and humidity readings, and a capacitive probe for soil moisture tracking, and actuators (heating lamp, misting pump, and exhaust fan) connected to an ESP32 microcontroller.

A ThingsBoard dashboard will display the data collected from the sensors, enabling real-time monitoring of environmental parameters. Users will be able to manually control the actuators via the dashboard. Additionally, a Telegram bot will integrate with the system to provide users with notifications and alerts about cage conditions, actuator status, and reminders to feed the crickets.

2.2.2. Phase 2

Phase 2 will see the implementation of the developed IoT system in the cricket cages, with the aim of evaluating their efficiency and impact against traditional manual methods. For this comparison, we will use two identical cages: one equipped with the IoT system and the other serving as a control without IoT intervention. During this phase, the focus will be on measuring the cage condition, including key variables like temperature levels, relative humidity, and soil moisture, and two key performance indicators, the food conversion ratio (FCR) and the mortality rate of the crickets. We will conduct the data collection process for 30 days. We will calculate the FCR using the following formula:

$$FCR = \frac{F}{E} \tag{1}$$

where F=total feed give (in grams), and E=total egg production (in grams).

This measurement will help determine the efficiency of the automatic feeding system in the IoT-equipped cage. We will compare this to the manual feeding process in the control cage. We will measure the mortality rate using the following formula:

$$M = \frac{D}{N} \tag{2}$$

where M=mortality rate, D=number of dead crickets, and N=initial number of crickets.

This measurement will provide insights into the impact of the IoT-based monitoring and control system on cricket survival rates.

We will analyze the data collected from both cages to assess how the IoT system contributes to improvements in cricket farming operations. The comparison of results will highlight the potential benefits of adopting IoT technology, aiming to improve productivity, efficiency, and sustainability in small and medium-scale cricket farming operations.

3. RESULTS AND DISCUSSION

This section presents the outcomes of the IoT system development and its implementation in the cricket farming experiment. The discussion highlights the system's performance, functionality, and its potential impact compared to traditional manual methods.

3.1. Phase 1

The IoT system successfully integrated all of its components, including the ESP32 microcontroller, DHT21 sensor for temperature and humidity, and the capacitive soil moisture sensor. The ESP32 also successfully controlled the actuators, including the heating lamp, misting pump, exhaust fan, and servo motors for the automatic feeder. The previously created schematic design in Figure 1 guides the development of the IoT system.

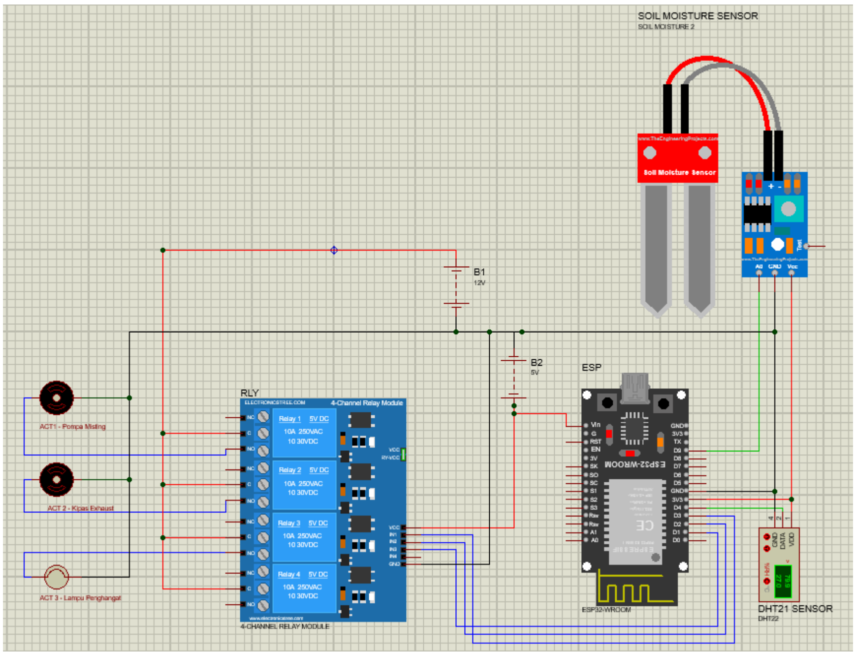

Figure 1. IoT system schematic design

Due to library limitations, Figure 1 shows a design that substitutes some components with alternatives. For instance, the DHT22 simulates the DHT21 sensor, and DC motors stand in for the misting pump and exhaust fan. The soil moisture sensor connects to the ESP32, with its VCC linked to the 3V3 pin to supply 3.3V, GND to the GND pin for grounding, and the AO pin connected to pin D9 to transmit soil moisture data. As illustrated in Figure 1, the ESP32 interfaces with the DHT21 sensor, similarly, connecting its VCC to 3V3, GND to GND, and the data pin to pin D4 for temperature and humidity data. The relay (RLY) controls three actuators: it links IN1 to pin D3 on the ESP32 to regulate the misting pump (ACT1), IN2 to pin D2 for the exhaust fan (ACT2), and IN3 to pin D1 for the heating lamp (ACT3). A 5V supply powers the ESP32 through its VIN pin, while the actuators (ACT1 to ACT5) draw power from a 12V source, with a shared ground ensuring stable operation.

Figure 2 demonstrates how the ThingsBoard dashboard accurately displayed data from the sensors, enabling real-time monitoring of both the cage conditions and the actuator status. The Telegram bot effectively delivered notifications and alerts, providing updates on cage conditions and reminders to feed the crickets.

3.2. Phase 2

During this stage, we measured the temperature, humidity, and soil moisture in both cages. We measured the FCR and mortality rate of the crickets in Cage 1 (with an IoT system) and Cage 2 (without an IoT system) for 28 days. Analyzing these environmental parameters will provide insights into how they influence the efficiency and health of the cricket farming system.

Figures 3 to 5 show the temperature, humidity, and soil moisture level in cage 1 can maintain the ideal cage condition for cricket breeding, which is 20-32 °C for temperature, 65% to 85% for humidity, and 60% to 80% for soil moisture. In contrast, the cage condition in Cage 2 is unstable. Cage 2 frequently experiences temperature, humidity, and soil moisture fluctuations, causing the cage condition to fall outside the ideal range.

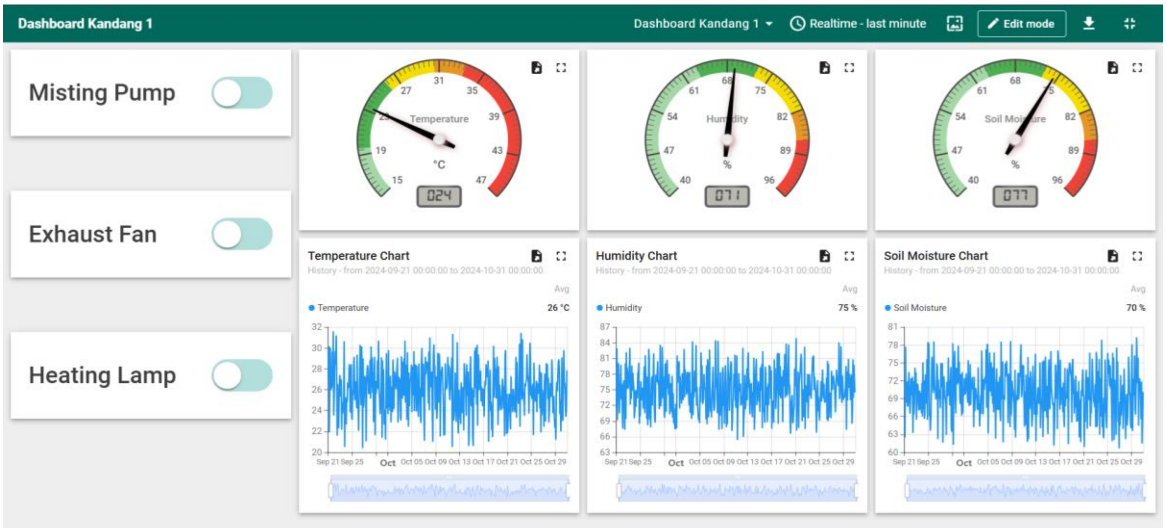

Figure 2. Dashboard

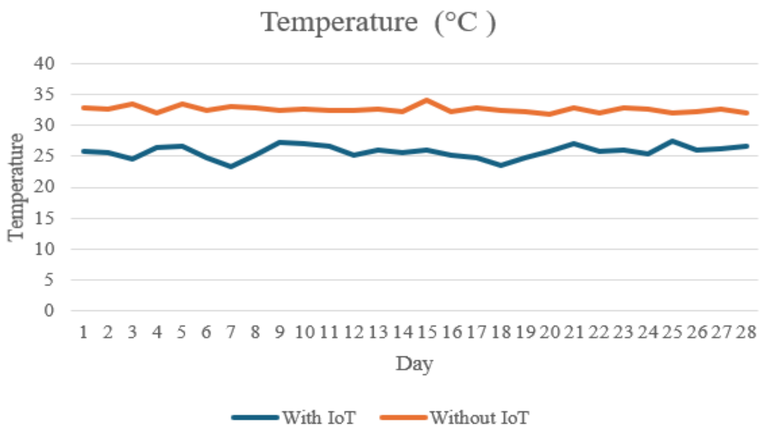

Figure 3. Temperature measurements

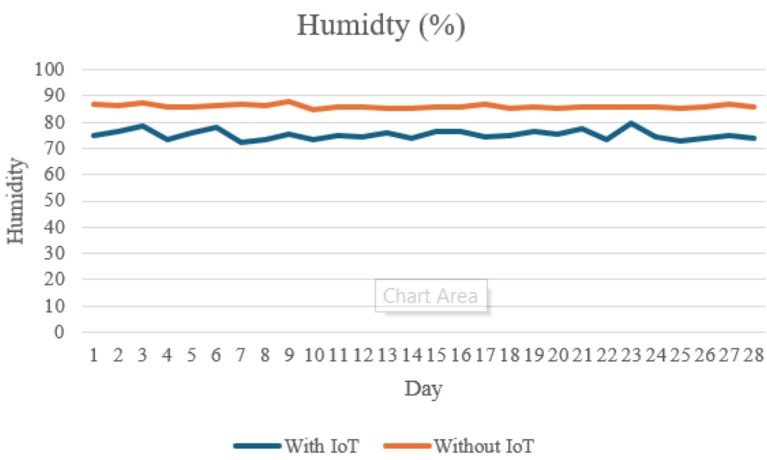

Figure 4. Humidity measurements

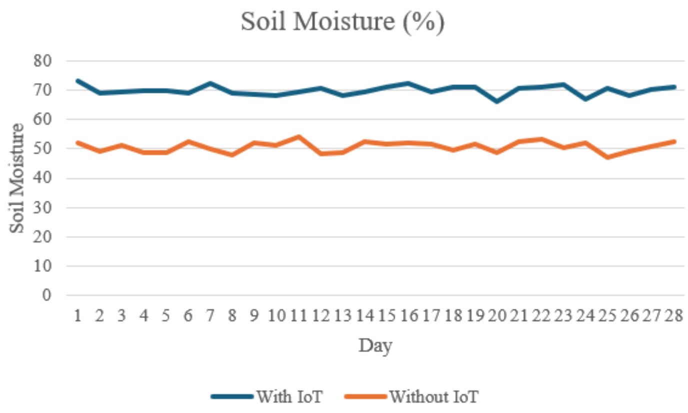

Figure 5. Soil moisture measurements

Based on Figure 6, the enclosure utilizing the IoT system produced 87.28 grams of eggs, while the enclosure without the IoT system only produced 65.46 grams. In terms of percentage, the increase in egg production in the IoT-enabled enclosure compared to the non-IoT enclosure reached approximately 33.33%.

Figure 7 illustrates the food conversion ratio (FCR) over the 28-day period for both Cage 1, equipped with the IoT system, and Cage 2, which lacks the IoT system. Throughout the study period, each cage received a total of 165.6 grams of feed, and we took weekly FCR measurements to ensure consistent monitoring. Figure 7 shows that Cage 1's FCR was 2.01 grams/egg, lower than Cage 2's FCR of 2.53 grams/egg. This indicates that the enclosure with the IoT system required less feed to produce a single egg, thus demonstrating more efficient feed utilization.

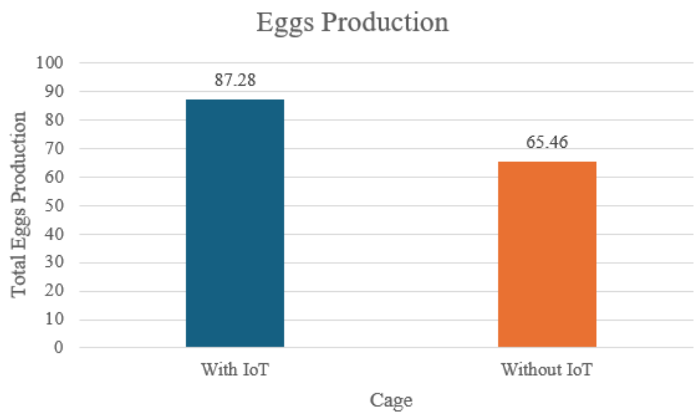

Figure 6. Egg production

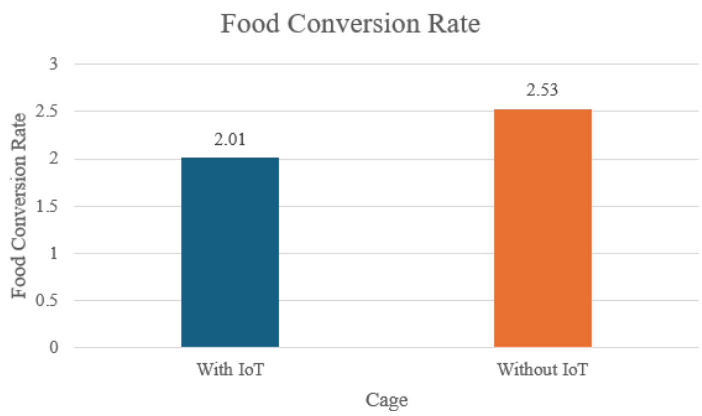

Figure 7. Food conversion rate

The stable temperature, humidity, and soil moisture levels maintained by the IoT system in Cage 1 likely created optimal conditions for cricket growth, reducing stress and improving the conversion of feed into body mass. Research on Grillus Mitratus crickets compared three types of feed combinations: green mustard, concentrate, and rice bran (P0); green mustard and concentrate (P1); and young cassava stems with concentrate (P2) [3]. The results showed FCR values of 2.92 (P0), 2.93 (P1), and 3.27 (P2). This comparison further highlights that the IoT-controlled environment significantly enhances feed efficiency, thereby increasing egg production in crickets.

Figure 8 presents the mortality rate of crickets in both cages over the same 28-day period, with weekly measurements. Based on Figure 8, the mortality rate in Cage 1, which utilizes the IoT system, was 0.708, significantly lower than the 0.816 recorded in Cage 2 without the IoT system. This demonstrates that the controlled environmental conditions provided by the IoT system in Cage 1 can effectively reduce the mortality rate during the egg-laying period by maintaining stable conditions.

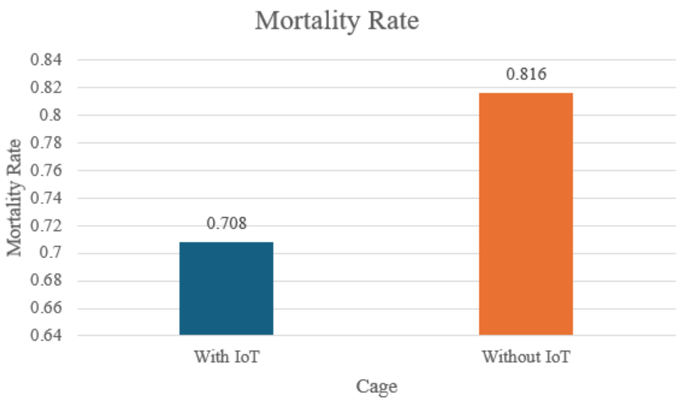

Figure 8. Mortality rate

Research on crickets (*Acheta domesticus*) fed on wild flowering plants revealed that the diet composition had a substantial impact on survival outcomes. Crickets provided with common nettle, rough comfrey, and gypsophila as dietary inputs experienced over 80% mortality within the initial week, leading to the removal of these feeds from the trial after 14 days. In contrast, those fed with white nettle and control feed showed a survival rate of 59% after 28 days, albeit with slower weight gain compared to the control group. These findings indicate that IoT-based environmental regulation in cricket pens can contribute to reduced mortality. This is because the IoT system kept the conditions stable, which worked better than just changing the food. While unsuitable feed types led to high mortality rates, IoT systems optimized environmental control, reducing mortality rates throughout the crickets' growth period [9].

4. CONCLUSION

This study demonstrates the significant benefits of integrating an IoT-based environmental control system in cricket farming. Cage 1, equipped with the IoT system, achieved stable environmental conditions that enhanced egg production, feed efficiency, and survival rates compared to Cage 2, which lacked IoT intervention.

Key findings include a 33.33% increase in egg production, improved FCR (2.01 vs. 2.53 grams per egg), and a reduced mortality rate (0.708 vs. 0.816). These results highlight the potential of IoT technology to optimize small- and medium-scale cricket farming practices by ensuring stable and controlled environmental conditions.

Future work should focus on long-term studies to assess the broader applicability of the IoT system, testing it across various species and conditions. Incorporating additional features such as light intensity control, predictive optimization through machine learning, and automation in feeding and waste management could further enhance system effectiveness and sustainability.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Suryadiputra Liawatimena	✓	✓		✓						✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no known financial, personal, or professional conflicts of interest that could have appeared to influence the work reported in this manuscript. All contributions were made with full academic independence and integrity.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, DMT. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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