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Development of IoT Based Model for Monitoring and Optimizing Moisture Content in Rwanda School Feeding Maize Stores

A Case Study GS Cyeru

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Abstract: This study explores the development of an Internet of Things (IoT)-based Model to monitor and optimize the moisture content of maize storage in the context of a school feeding program at Groupe Scolaire Cyeru, Rwanda. The objective was to address the critical issue of moisture control in maize storage, which directly impacts the quality and safety of food distributed to students. Using a mixed-methods approach, the study employed both qualitative and quantitative techniques, including surveys, interviews, document analysis, and direct observation, to gather comprehensive data on the current state of maize storage practices. The research involved 318 respondents from various stakeholders, including students, teachers, cooks, and administrative staff. The findings revealed a significant gap in moisture monitoring within the existing storage system. Based on this, an IoT-based model was developed, incorporating temperature and moisture sensors, a microcontroller, and a GSM module for real-time data collection and remote alerts. Python programming and Google Colab were utilized for data collection, processing, and analysis, enabling seamless integration of the collected data into a central system for further insights. This system aimed to optimize storage conditions and prevent spoilage, thereby improving the efficiency and sustainability of the school feeding program. The study highlights the potential of IoT technology, Python, and Google Colab in transforming food storage management, particularly in educational settings with limited resources.

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I. INTRODUCTION

In Rwanda, the National School Feeding Programme (NSFP) is a critical initiative designed to support the health, nutrition, and educational development of students, particularly in rural regions. Since its nationwide expansion in 2024, the program has provided hot meals to over 4 million learners across approximately 4,800 schools. A cornerstone of this program is the "Home-Grown School Feeding" initiative, which sources food from local farmers, ensuring that meals are both nutritious and contribute to rural economic development. This initiative enhances food security, creates local markets for agricultural produce, and fosters sustainable livelihoods for farming communities.

Daily school meals have been shown to have a significant positive impact on children's education. Evidence suggests that such feeding programs improve attendance rates, cognitive function, and concentration in class—particularly in rural areas where children face greater challenges with food insecurity and limited access to education. In Rwanda, over 1.26 million primary school students benefit directly from this program, including 83,000 students in food-insecure districts.

However, the program faces challenges in maintaining food safety, especially in the **storage and preservation of maize**, a staple food used in many school meals. Traditional storage methods often struggle with pest infestation, contamination, and fluctuating moisture levels, which can compromise the safety and nutritional value of the maize. Furthermore, inadequate storage practices can result in post-harvest losses, undermining the effectiveness of the feeding program and wasting valuable resources. As maize is a primary component of these meals, ensuring its safe and efficient storage is essential to maintaining the quality of the meals provided to students.

This study focuses on maize storage as a case study, as it is a critical product in Rwanda's school feeding program. By integrating Internet of Things (IoT) technology, the study proposes a model to optimize moisture content and improve

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storage conditions for maize. IoT-based monitoring offers a real-time solution for tracking environmental factors such as humidity and temperature, providing data that can be used to adjust conditions and minimize risks like spoilage and contamination. This technological approach aims to reduce post-harvest losses, improve the quality of stored maize, and contribute to the overall sustainability of the school feeding program.

Through this research, the aim is to address a key gap in Rwanda's food security efforts by offering a practical solution for maize storage that could be scaled to other regions, further supporting the success of the National School Feeding Programme.

This chapter provides an overview of the study, including the background, problem statement, objectives, research questions, scope, significance, and organization of the study. By focusing on the specific challenges of maize storage, this research intends to contribute to the broader goal of ensuring the success and scalability of school feeding initiatives in Rwanda.

II. METHODOLOGY

➢ *Data Collection Methods and Instruments/ Tools*

Data collection is the process of acquiring information using predetermined methodologies in order to respond to the study's predetermined research topic. In this research, the researcher will use a questionnaire as the research instrument and examine secondary data. It has been stated that approaching people with questions is an obvious way to gather both quantitative and qualitative data from them. The survey method is used in this study to gather data. (Walliman, 2021).

- *Collaboratory of Google*

Available to use, Colab is a cloud-based Jupyter notebook environment. Most significantly, it doesn't need to be set up, and, like Google Docs pages, the notebooks you create can be edited simultaneously by members of your team. Colab supports a number of popular machine learning libraries that can be rapidly loaded into your notebook.

- *Python*

Python is a high-level, interpreted, general-purpose programming language. Its design philosophy prioritizes code readability and makes extensive use of indentation. Python is a dynamically typed, garbage-collected programming language. Because it is the simplest way of sampling participants are chosen based on their availability and desire to participate the study used convenience non-probability sampling. (Hope, 2021).

➢ *Data Analysis*

The process of discovering solutions through investigation and interpretation is known as data analysis. Understanding survey and administrative source results and presenting data information require data analysis. Data analysis is anticipated to provide light on the subject of the study and the respondents' perceptions, as well as to increase readers' understanding of the subject and pique their interest in this portion of the research. Google Collab will be used to analyze the data and present the results using data analysis tools used in scientific analysis. (Burns, 2022).

➢ *Research Design*

A research design is a plan or blueprint which shows how data required for the solution of the problem that the researcher will focus on, the procedure and methods for data collection and analysis, will answer the research questions. In these lines the research herein the present study, researcher would employ a combination of descriptive and correlation research design to describe the characteristics of a population under investigation and carefully examine the impact of INTER-HOSPITALS data management system on health services provided. (Hardt,2016).

III. CONCEPTUAL FRAMEWORK

A conceptual framework was a flexible analytical tool that could be used in a variety of situations. It was employed to arrange concepts and draw conceptual distinctions. It offered a broad depiction of how various elements related to one another in a particular phenomenon. It embodied the precise path that needed to be followed when conducting the research. Robust conceptual frameworks effectively conveyed a real idea in a way that was simple to recall and implement. (Bas, 2015)

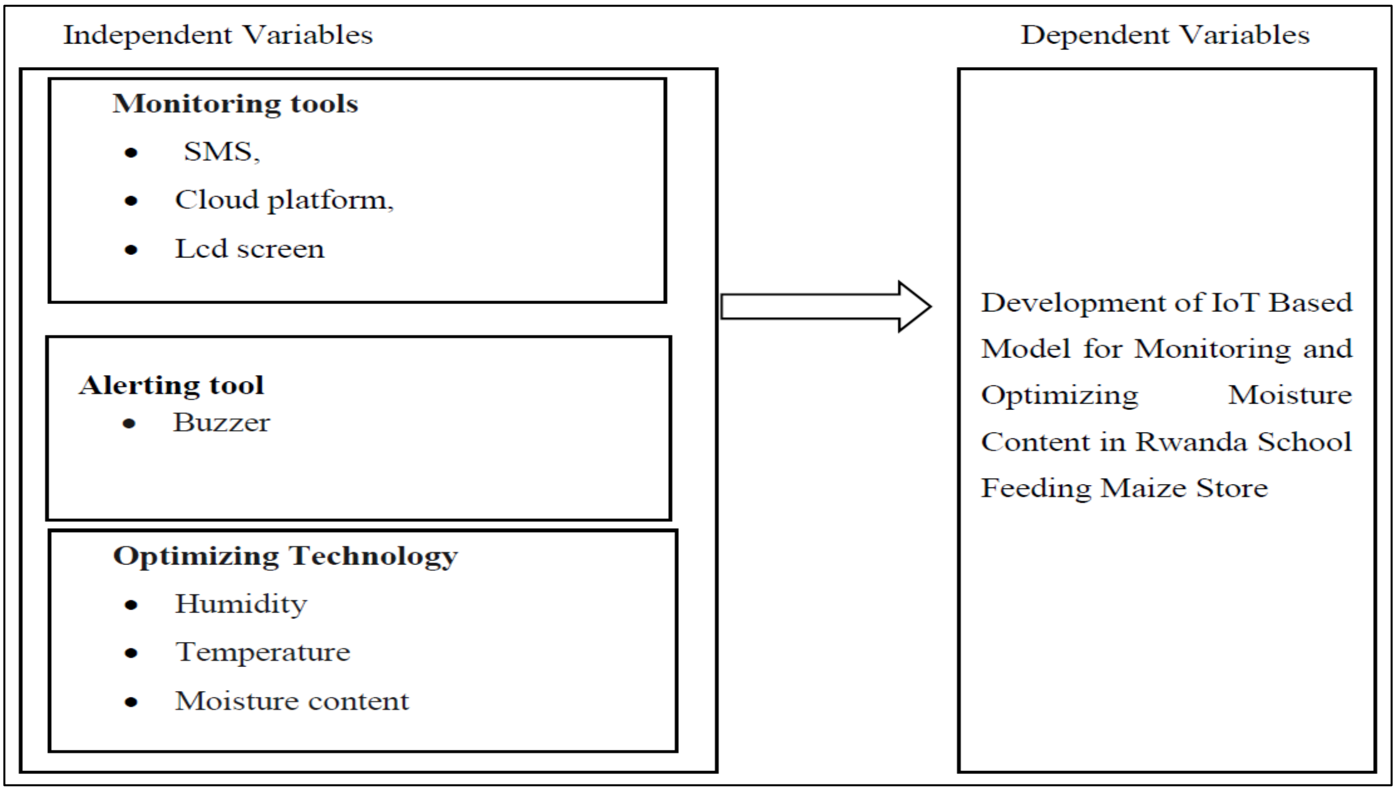

Fig 1 Independent Variable and Dependent Variable

IV. PRESENTATION, ANALYSIS AND INTERPRETATION OF FINDING

➢ *Introduction*

This chapter presents, analyzes, and interprets the findings of the study on the IoT-based model for monitoring and optimizing moisture content in maize storage at Groupe Scolaire Cyeru (GS Cyeru). The data collected from questionnaires, interviews, observations, and secondary sources are organized and interpreted according to the research objectives. The findings are discussed in relation to the research questions and in comparison, to existing literature reviewed in Chapter 2.

➢ *Demographic Characteristics of the Respondents*

This section provides an overview of the demographic profile of the respondents. The sample consisted of 318 individuals from various categories: teachers, cooks, storage keeper, administrative staff, and students. The following table summarizes the demographic characteristics of the respondents:

Table 1 Demographic Profile of Respondents

Category	Frequency	Percentage (%)
Teachers	20	6.29
Cooks	4	1.26
Storage Keeper	1	0.31
Students	289	90.89
Administrative Staff	4	1.26
Total	**318**	**100**

From the above table, it is evident that the majority of the respondents were students (90.89%), followed by teachers (6.29%). Cooks, storage keeper, and administrative staff represented smaller proportions of the sample.

➢ *Current Practices in Maize Storage and Food Safety*

The study explored the existing food safety practices employed in managing maize storage. According to responses from participants directly involved in maize storage and management, it was found that the school relied on traditional food safety practices, which included manual monitoring of storage conditions. However, these methods had significant limitations, particularly in ensuring the safety and quality of the food provided to students.

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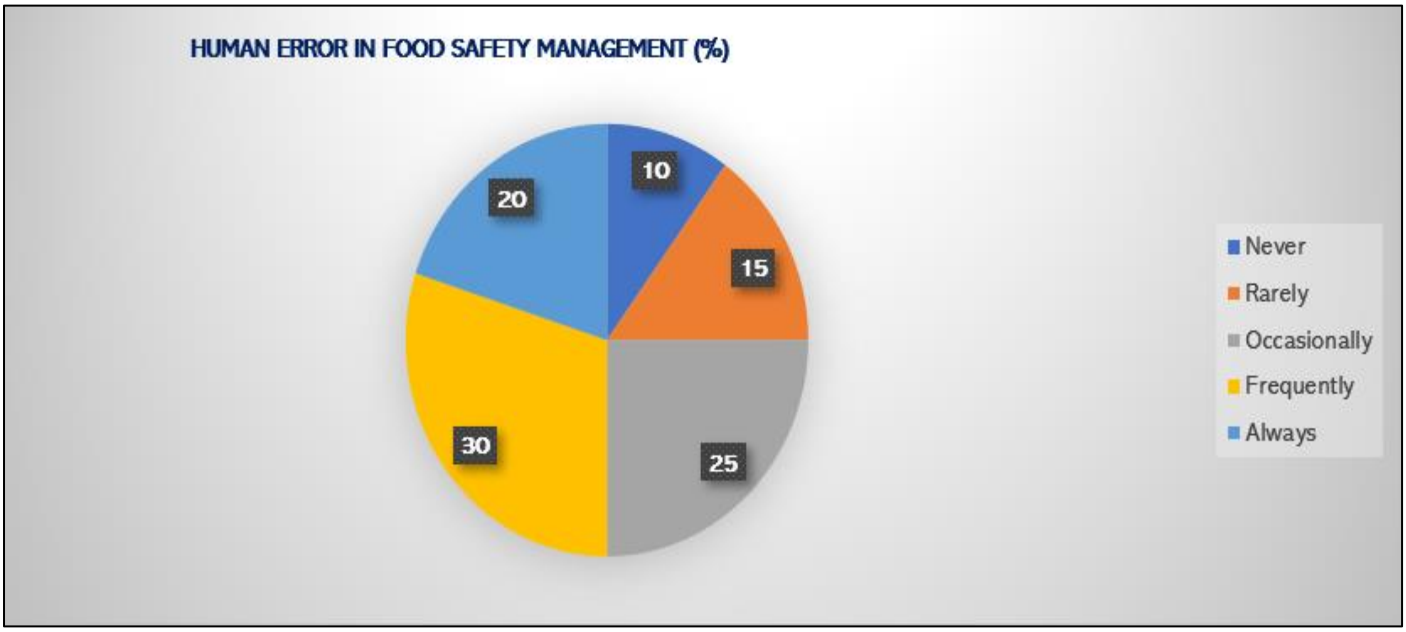
- *Sample Image of Maize.*

Fig 2 Maize Image in Good Condition

A sample of maize in good condition is defined by its storage under optimal environmental conditions to prevent spoilage and contamination. Key characteristics include low moisture content, typically between 13–14%, which minimizes the risk of mold growth and aflatoxin contamination. The maize must be free from visible damage, discoloration, or signs of mold and should emit a fresh, clean odor. Proper storage involves maintaining a cool, dry, and well-ventilated environment, as this preserves both the nutritional value and integrity of the maize. These conditions are critical in preventing foodborne illnesses and ensuring the safety and suitability of maize for school feeding programs. Failure to meet these conditions can lead to nutritional degradation, increased contamination risks, and adverse health effects on students. This study's IoT-based monitoring model addresses these challenges by providing real-time data on key parameters such as moisture and temperature, enabling proactive management of maize storage conditions.

- *Human Error and Adverse Weather Conditions in Food Safety Management*



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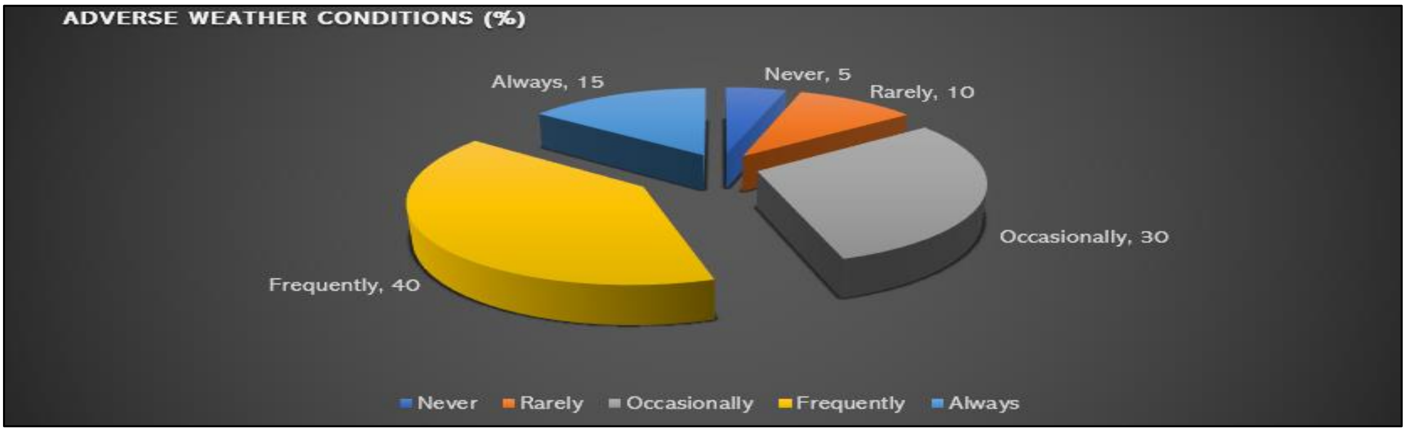

Fig 3 Human Error and Diverse Whether Condition

'Human Error and Adverse Weather Conditions in Food Safety Management' aligns with the data presented in the chart, emphasizing the significant role these factors play in maize storage inefficiencies. The chart visually demonstrates how human error and adverse weather conditions contribute to challenges in food safety, highlighting the critical need for enhanced monitoring and management practices. This underscores the importance of adopting innovative solutions, such as an IoT-based system, to mitigate these risks and ensure the safety and quality of food in school feeding programs.

➢ *Responses to Questionnaire on Food Safety Practices in Maize Storage*

The responses from the questionnaire on food safety practices in maize storage at GS Cyeru. The demographic section shows the diversity of participants, with varying lengths of experience in food safety management. Human errors, such as inaccurate measurement and miscommunication, were identified as frequent contributors to inefficiencies in food safety management, highlighting the need for better training or automated systems. Adverse weather conditions, particularly during the rainy season, were also seen as a significant risk, with moisture accumulation and aflatoxin contamination being common concerns. Real-time monitoring issues were identified as the leading cause of delayed responses, underlining the importance of implementing real-time monitoring systems like IoT to improve food safety practices. Finally, a strong majority of participants expressed support for the implementation of an IoT-based system to Support for the implementation of an IoT-based system to automate the monitoring and control of storage conditions, reduce human error, and provide real-time alerts, thereby ensuring better management of moisture levels and preventing contamination, which would ultimately enhance the safety and quality of the maize used in the school feeding program.

- *Flowchart of IoT-Based Maize Storage Management System*

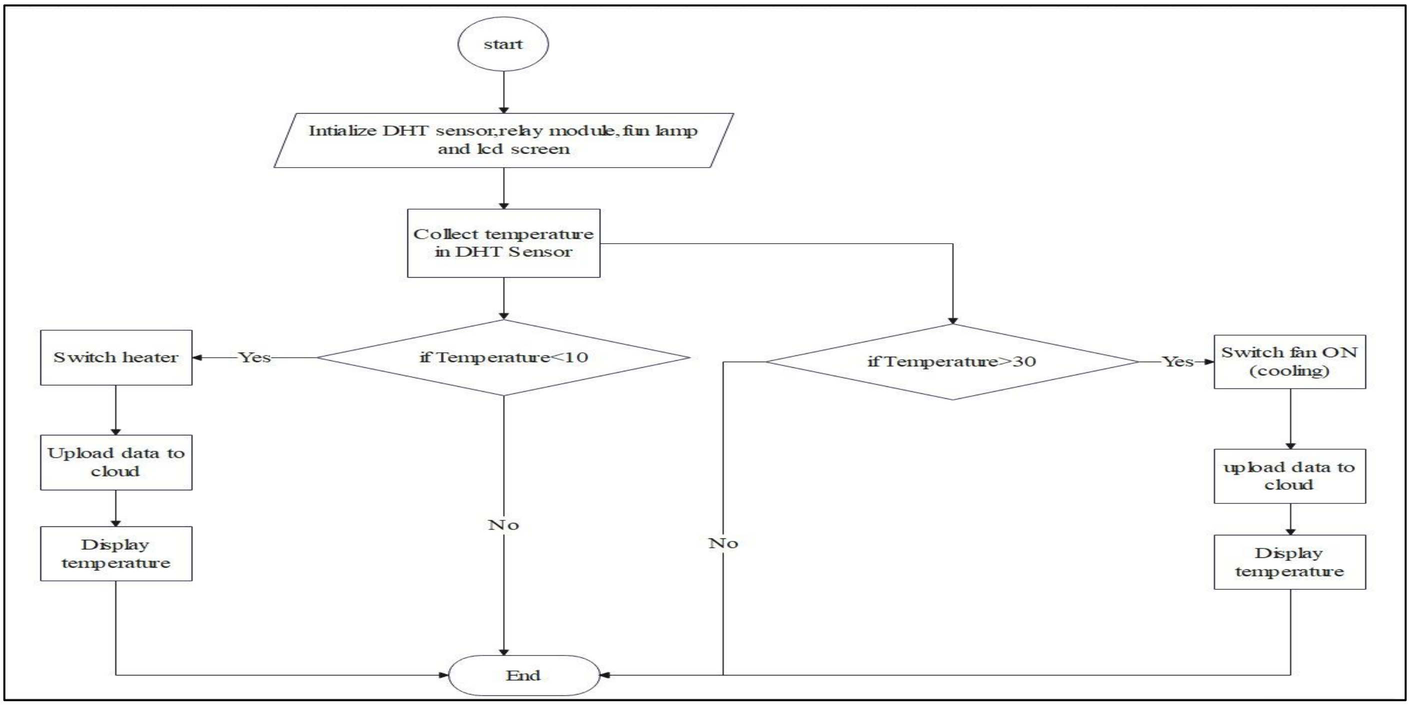

Fig 4 Flowchart of IoT-Based Maize Storage Management System

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This flowchart illustrates the operational process of the IoT-based maize storage management system, designed to optimize storage conditions for maize used in school feeding programs. The system initializes key components, including the NodeMCU microcontroller, DHT11 sensor, and relay controls for cooling and heating. It continuously collects real-time data on temperature and humidity from the sensor. If the temperature falls below 10°C, the system activates the heater, and if the temperature exceeds 30°C, the cooling fan is turned on. After collecting the data, the system uploads it to the cloud for remote monitoring and displays the current temperature and humidity on an LCD screen. If any parameter falls outside the defined range, the system triggers an alert via a buzzer. This integration ensures that the maize storage conditions remain optimized, enhancing the quality and safety of the food provided to students.

- *Code Implementation for Real-Time Temperature and Humidity Monitoring in Maize Storage*

```
LiquidCrystal_I2C lcd(0x27, 16, 2);
DHT dht(DHTPIN, DHTTYPE);

void setup() {
LCD
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Food Store Mon");

  dht.begin();

  pinMode(FAN_PIN, OUTPUT);
  pinMode(HEATER_PIN, OUTPUT);

  digitalWrite(FAN_PIN, LOW);
  digitalWrite(HEATER_PIN, LOW);

  // Start Blynk
  Blynk.begin(auth, ssid, pass);

  delay(2000);
}

void loop() {
  Blynk.run();

  float temperature = dht.readTemperature();
  float hum = dht.readHumidity();

  // Error handling
```

Fig 5 Code Implementation for Real-Time Temperature and Humidity Monitoring in Maize Storage

This code is written in C++ for an ESP8266 microcontroller and Arduino IDE uses libraries like LiquidCrystal_I2C, DHT, and BlynkSimpleEsp8266 to create a food monitoring system. It reads temperature and humidity from a DHT22 sensor, controls a fan and heater based on the temperature, and displays the data on an LCD screen. The system also sends the temperature and humidity readings to the Blynk app for remote monitoring. The code connects to Wi-Fi and interacts with Blynk using the provided authentication token, allowing you to monitor and control the system via the Blynk mobile interface.

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- *System Architecture for Optimizing Maize Storage Conditions in School Feeding Programs*

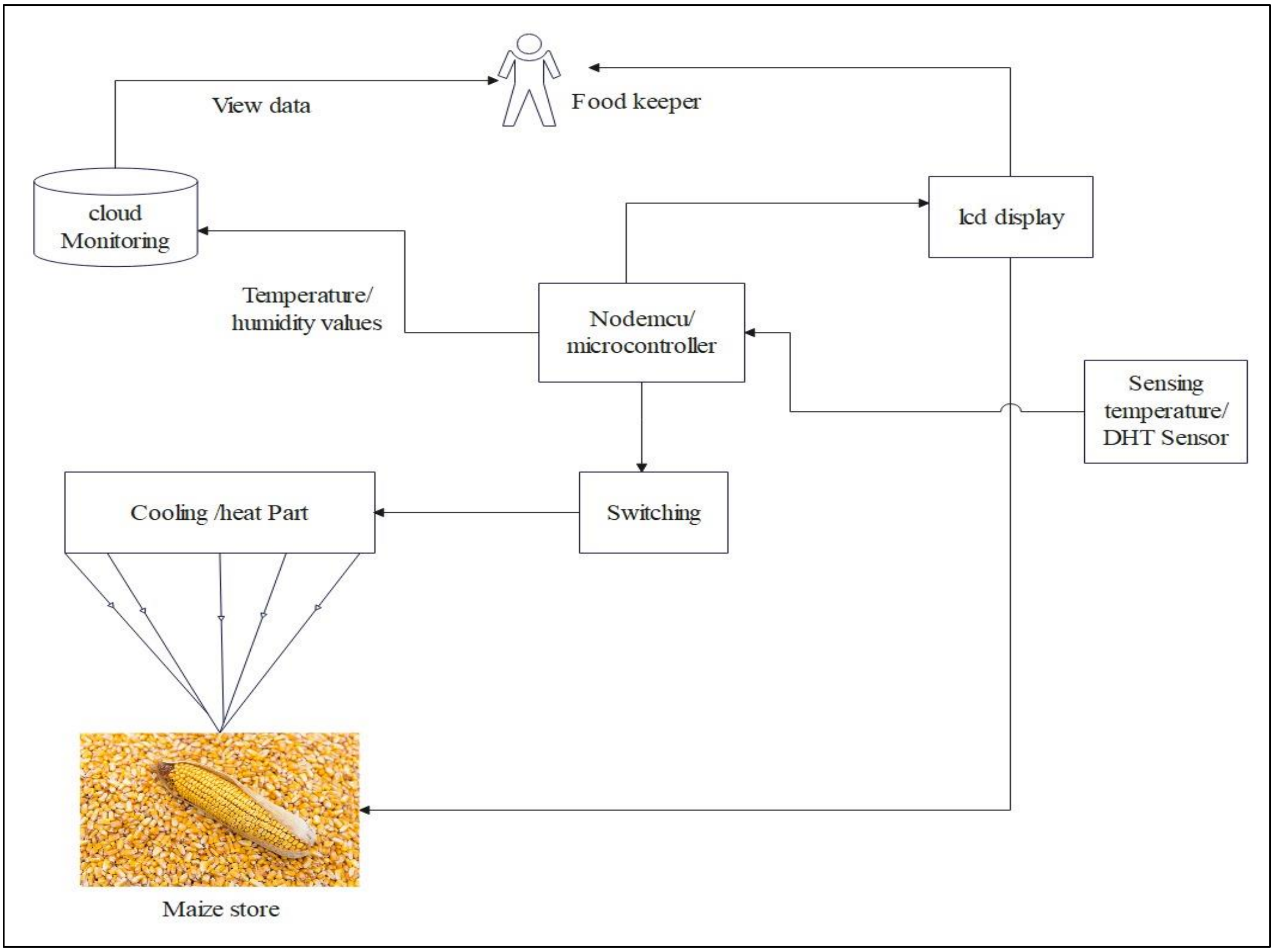

Fig 6 System Architecture for Optimizing Maize Storage

The system integrates key components to optimize maize storage conditions. The **Cloud Monitoring** collects and analyzes data from the **NodeMCU/Microcontroller**, which gathers sensor data (temperature and humidity) and sends it to the cloud for long-term tracking. The **Cooling/Heating Part** regulates temperature within the maize storage area, with fresh air cycling in and out. The system adjusts cooling or heating as needed to maintain optimal conditions, and the **foodkeeper** oversees operations. An **LCD Display** provides real-time local feedback on conditions, while the **DHT Sensor** monitors temperature and humidity levels. The **Switching Mechanism** activates corrective actions like cooling or heating based on sensor data. Together, these components ensure efficient and safe maize storage, with both immediate and remote monitoring capabilities.

- *LCD Screen for Local Monitoring*

Fig 7 LCD Screen

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The LCD screen is integrated into the maize storage system for real-time, on-site monitoring of temperature and humidity levels. It provides immediate feedback to the storage keeper, displaying the current environmental conditions, such as the temperature, humidity, and system status (whether the fan or heater is active). This visual display ensures that staff can quickly assess the storage conditions without needing remote access, helping to maintain optimal conditions for preserving the maize. The clear and accessible layout of the LCD screen supports efficient decision-making and quick corrective actions when necessary.

- *Blynk Cloud Monitoring for Maize Storage*

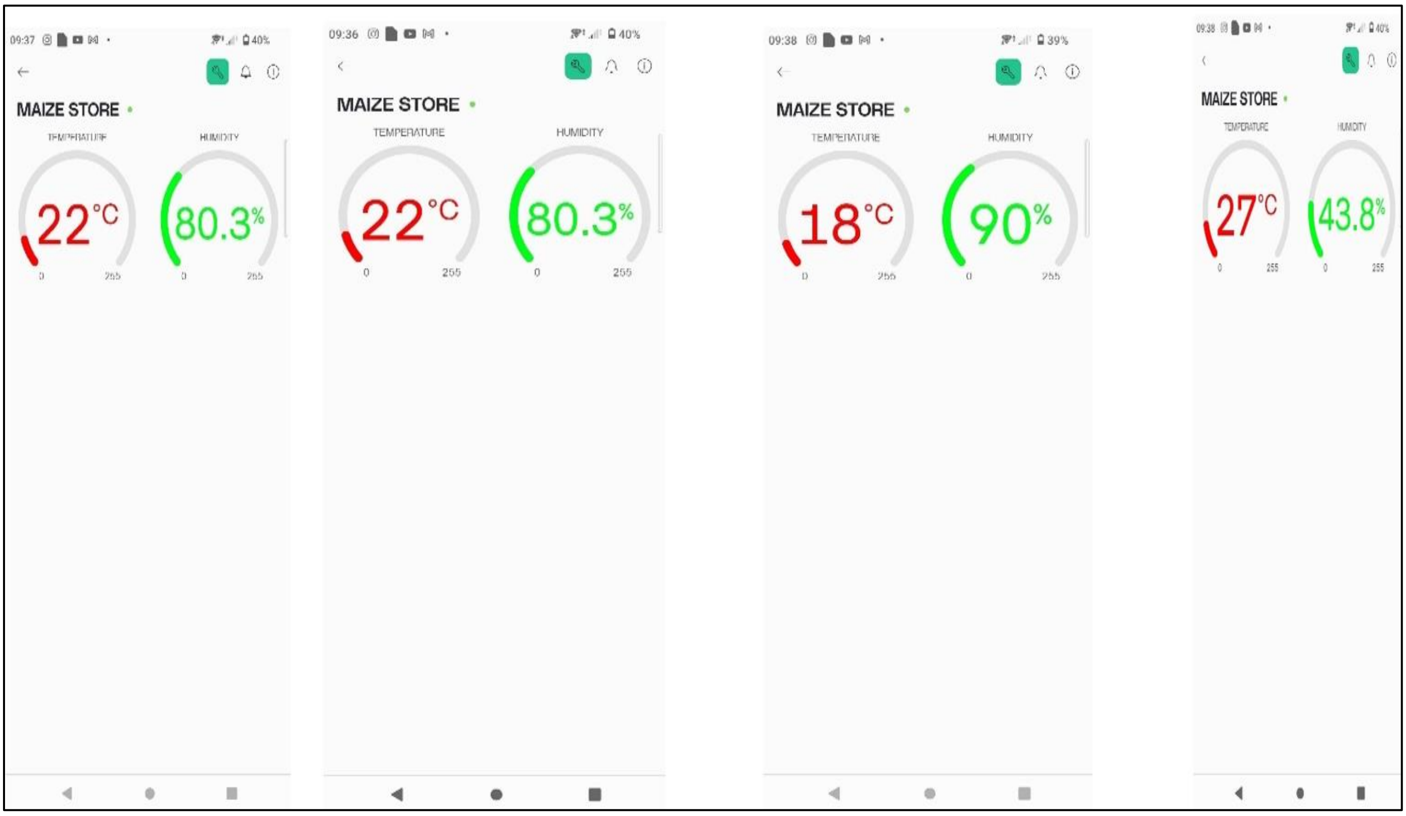
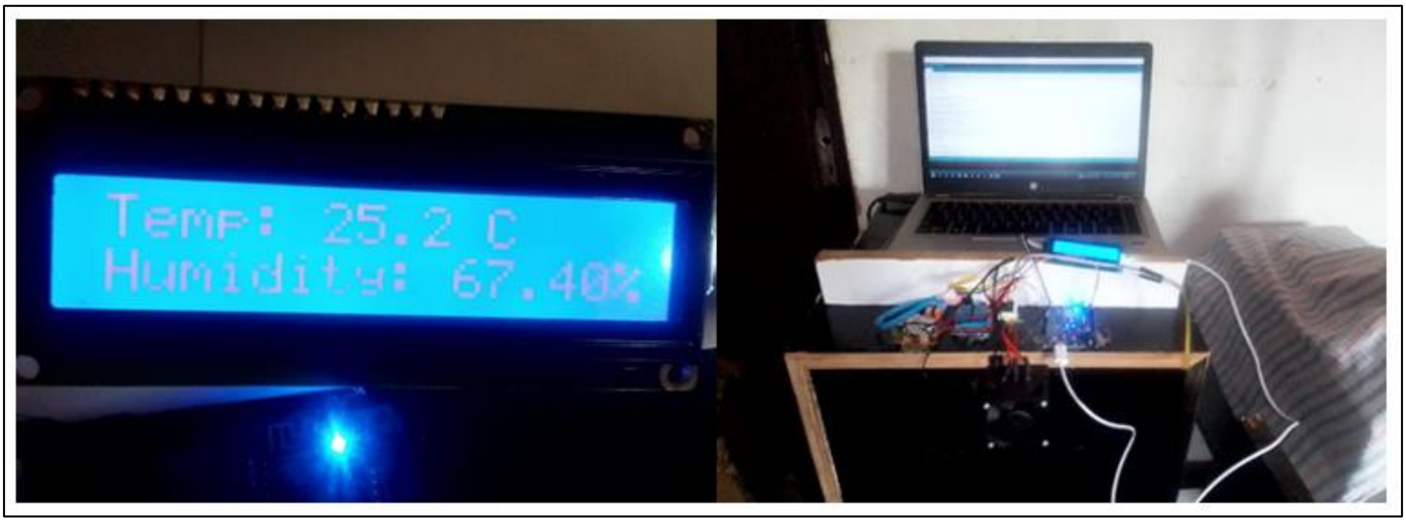


Fig 8 Cloud Monitoring

The Blynk platform is used to remotely monitor and manage the maize storage conditions, allowing real-time tracking of temperature and humidity levels. Through the integration of Blynk's cloud services, the system can send sensor data from the maize storage environment directly to the app. This enables instant notifications, visualization, and remote adjustments to optimize storage conditions. The Blynk interface includes various widgets, such as gauges and value displays, to monitor the system's performance, ensuring the maize remains in good condition for the school feeding program.

➢ *Screenshoot and Photos of the Running Project in the Store*



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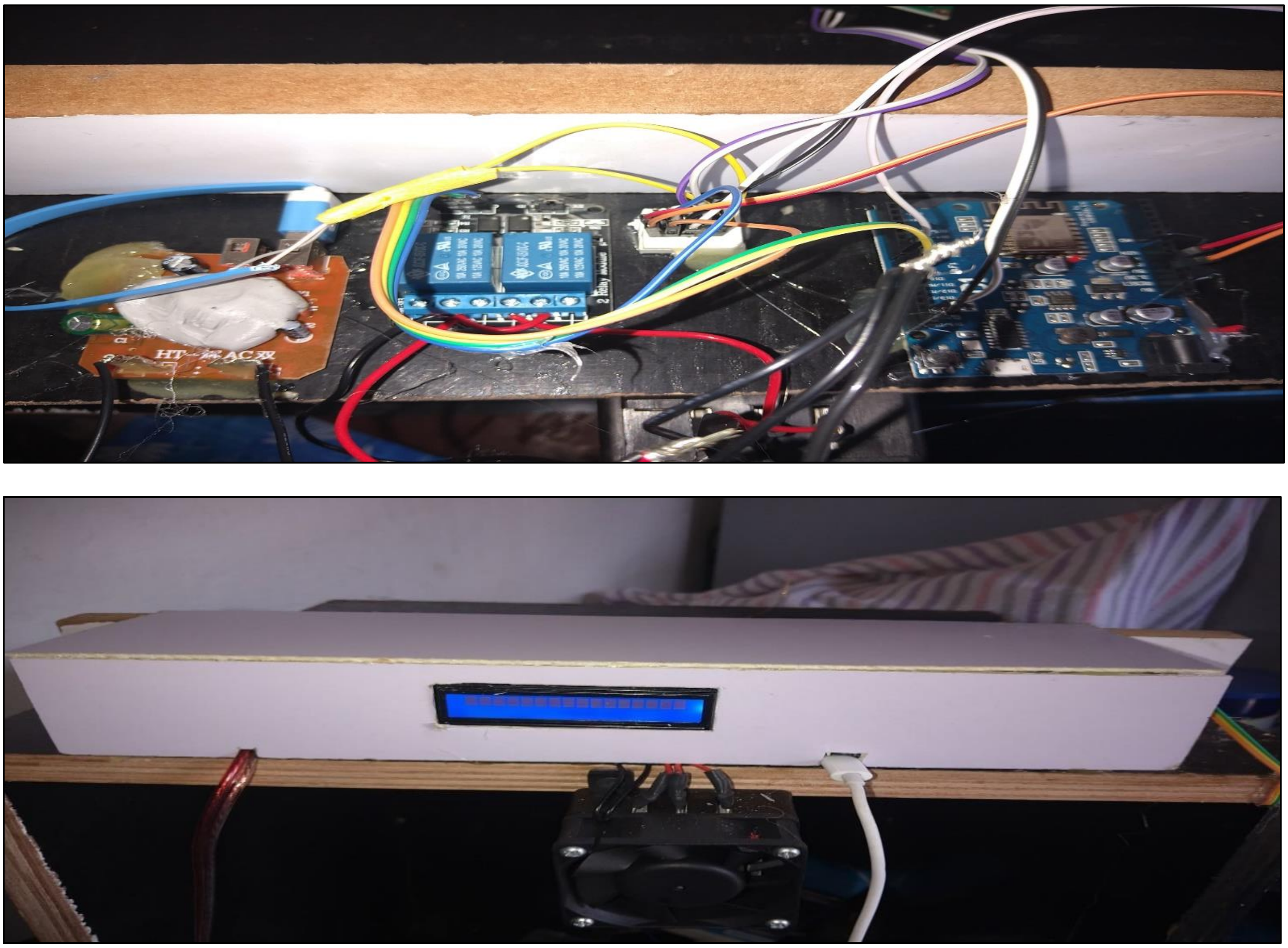

Fig 9 Screenshoot and Photos of the Running Project in the Store

V. CONCLUSION

The IoT-based monitoring and control system proved to be an effective solution for optimizing maize storage conditions at **GS Cyeru**. By continuously monitoring temperature and humidity, and automating corrective actions (cooling or heating), the system addresses the main issues identified in the questionnaire, such as human error and adverse weather conditions. Cloud connectivity enables remote monitoring, ensuring that the storage environment remains in optimal condition even when the staff is not physically present. The system not only improves food safety by reducing the risks of spoilage and contamination but also supports the long-term success of the school feeding program at **GS Cyeru**. Despite some challenges, such as technical limitations and sensor accuracy, the project demonstrated the significant potential of IoT in managing food safety and storage in **GS Cyeru**.

RECOMMENDATIONS

- **System Improvement**: Future iterations of the system could improve sensor accuracy and address potential issues such as data reading errors or connectivity disruptions. Additional sensors, such as moisture level detectors, could further optimize the storage environment.
- **Wider Adoption**: The IoT-based system should be scaled and implemented in other schools and institutions involved in food storage management to improve overall food safety practices and reduce risks of contamination in maize storage.
- **Training and Maintenance**: It is recommended that school staff at **GS Cyeru** and other similar institutions receive proper training on how to operate and maintain the IoT-based system to ensure its continued effectiveness and reliability in the long term.
- **Future Research**: Further research could explore the use of AI or machine learning models to predict storage conditions based on historical data or the integration of solar-powered systems for locations with limited access to electricity. Additionally, expanding the system's capabilities to monitor other factors like air quality or pest control could further enhance food safety.

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