

Optimizing Micro-Environment Conditions In Traditional Onion Storage Units Using Iot And Automation

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Abstract— The cultivation of onions is economically vital for Indian farmers, making effective storage essential to reduce financial losses. To address this issue, an IoT-based system was developed to monitor and regulate the storage environment for onions, thereby extending their shelf life. A thorough review of the research literature provided insights into onion properties, enabling the successful implementation of a real-time climate-monitoring solution. This system detects early signs of spoilage and alerts farmers via SMS. It includes temperature, humidity, and gas sensors for precise measurement of storage conditions, with data accessible via ThingSpeak. By utilizing this sensor data, the system can automatically engage exhaust fans and a dehumidifier to maintain optimal conditions. The selection of sensors and microcontrollers was such that the overall system design remains cost-effective and accurate in enhancing onion storage practices.

Keywords—Onion storage, IoT, Intelligent system, Agriculture, Small Unit etc.

I. INTRODUCTION

Onion cultivation is a significant crop for Indian farmers, with broad impacts on the national economy and the financial status of farmers and users. After harvesting, it is crucial to store onions properly to prevent them from rotting, which can result in substantial losses for farmers. Onions are grown in all three crop seasons, and their cultivation in India is steadily increasing, according to study of the ICAR - Directorate of Onion and Garlic Research [1]. The Indian climate's increasingly erratic nature during all seasons leads to unpredictable variations in temperature and humidity, making onions more susceptible to spoilage. This can result in bacterial rot, sprouting, and rooting caused by fungal growth. To prevent these losses, a study of various electronic devices was conducted, and a system was designed to prevent onion rotting [2]. This device can provide early warnings and send messages to the owner. By studying post-harvest losses in market storage sheds, needs to design and develop electronic circuitry to prevent onion rot. This work introduces an integrated system that offers the easiest way to reduce onion losses, operating on the principle of sensing the gases emitted by rotten onions and processing them to obtain the desired output. The emitted gases are sensed by rotten gas sensors, and their signals are then read and processed by the microcontroller ATmega 328P, which is programmed to send text messages to the farmer. Additionally, to control other parameters such as temperature and humidity, the system uses a DC exhaust fan along with sensors [3].

II. LITERATURE REVIEW

The application of IoT in agricultural storage has attracted considerable attention for

monitoring the storage system and improving preservation techniques. Many researchers have contributed to various aspects of smart storage monitoring and control systems for onions. To monitor onion storage, the literature reports many systems, such as the one introduced by Hina et al., which presents a real-time intelligent monitoring system (RT-IMNS) using IoT to monitor temperature, humidity, luminance, and rotten-gas concentration in cold storage. It uses artificial neural networks for decision support and achieves 99% accuracy in predicting commodities, outperforming previous models such as CS, ANB, XGBoost, and DM, which achieved 95.60%, 87.50%, 93.59%, and 90% accuracy, respectively [4].

Moreover, the author Muhammad et al. has implemented an internet-based autonomous control system in agriculture, creating an engineered microclimate. This enables real-time monitoring of variables using IoT, with a Node MCU ESP8266 and a DHT11 sensor to monitor temperature and humidity, and fuzzy-logic-based control of environmental conditions in onion storage. Air temperature fuzzification membership consists of 5 variables (Cold, Cool, Normal, Hot, and Very Hot), each with a single membership range. Air humidity fuzzification input membership consisting of 5 variables (Dry, Slightly Dry, Medium, Slightly Wet, and Wet) [5].

Also, the authors Akshay et al. have proposed a smart farming system for precise greenhouse monitoring that comprises four components: cloud, fog, edge, and gas sensors. Remotely controls and regulates CO₂, moisture, temperature, humidity, and light intensity with the help of DHT 11 temperature and humidity sensor, capacitive moisture sensor, and light-dependent register (LDR), and MQ 135 for Co₂ gas measurement. Sensor data is monitored using MQTT. An analytics system is implemented in fog using supervised machine-learning regression algorithms. The framework enhances presentation and achieves objectives [6].

Furthermore, Tharun et al. have studied and tested a custom-made gas sensor array to identify sour skin post-harvest disease in onions, a significant post-harvest issue. The array consisted of seven metal oxide semiconductor sensors, a microcontroller-based, fully automatic data-monitoring system, and two experimental trials: control and sour skin. The "relative response" characteristic was the strongest. The best performance (85%) was achieved using the Support Vector Machine (SVM) model when the data were gathered from an individual test experiment, and it was concluded that the gas sensor array detects sour skin-infected onions from the bulb of healthy onion storage [7].

Besides, authors Spurthi et al. propose a novel strategy to reduce agricultural waste by transforming onion storage and transportation facilities into smart warehouses using IoT and AI. The input sensors for this system are the DTH11 and MQ-2 gas sensors, which continuously collect real-time data needed to monitor the health status of onions. The ESP8266 uses this data to make decisions that carefully evaluate sensor inputs. The system monitors onion stock health, assists farmers, and improves onion detection with AI-powered image-processing sensors. Cameras are used to identify sprouted onions. The designed prototype achieves an excellent 87% efficiency in detecting sprouted onions using camera-based systems. The system can gather real-time data and send it to AWS Cloud for further analysis to improve efficiency in post-harvest decision-making [8].

Additionally, the authors Kadam et al. have monitored sensor data on the Think Speak cloud platform for temperature and ethylene gas levels in onion storage, which affect onion quality. The sensors in this system include the DTH22 and MQ-135 gas sensors, which continuously collect real-time data needed to monitor onion health. Use of Thing

Speak's built-in MATLAB-based analytics tools to collect and analyze the incoming data from sensors. The system dynamically controls fan state to improve storage conditions based on sensor inputs, reducing energy usage and supporting sustainable agricultural practices. This automated, data-driven strategy could reduce waste and improve the effectiveness of onion storage [9].

The review of literature discusses the benefits of IoT for monitoring temperature, humidity, and rotten gas in the onion storage system to detect spoilage and rot while optimizing storage conditions. The proposed system also aims to minimize post-harvest losses and maximize onion shelf life by adopting temperature and humidity sensors, gas sensors, and an environmental control system.

III. SYSTEM OVERVIEW

The research methodology involves designing and implementing a cloud platform, along with an Internet of Things (IoT)-based sensor system for small-scale units, known as the Smart Onion Storage System. As illustrated in Fig. 1, the schematic circular onion storage unit typically measures between 1.2 meters in height and 0.76 meters in diameter. This section outlines the sequential steps involved, including system setup, data acquisition, processing, and control execution based on sensor inputs, all aimed at achieving an optimized storage environment for onions.

A. Block Diagram:

Fig 2 shows a block diagram of an Internet of Things (IoT) sensor-based Smart Onion Storage System. The proposed system is a comprehensive environmental control solution that integrates a master unit and a slave unit with various components, including sensors for real-time monitoring of temperature and humidity, a microcontroller (PIC18F4520) as the master unit, and an Arduino UNO for the slave unit. The slave unit is used for data processing and decision-making, and a GSM module for remote communication and alerts. Thing Speak's built-in MATLAB-based data analytics tool connects to a cloud platform for data logging and analysis, providing users with access to historical trends and insights. Additionally, an actuator exhaust fan for air ventilation enables automated responses to ensure optimal conditions by adjusting the environment as needed. This system guarantees continuous monitoring and automatic intervention when thresholds are reached, enhancing safety and efficiency in various applications.

Hence, a developed system has a cost-effective solution for monitoring onion storage. The block diagram of a low-cost monitoring and controlling system is shown in Fig 2. The developed system has defined threshold levels for temperature, humidity, and CO₂ from repeated experiments over 3 months in both controlled and natural environments. We found that the CO₂ gas sensor delivers more accurate onion-quality monitoring results than other gas sensors. In addition, to minimize costs, we have introduced a system in which data transmission from the CO₂, temperature, and humidity sensors occurs only when the onion starts to rot [10].

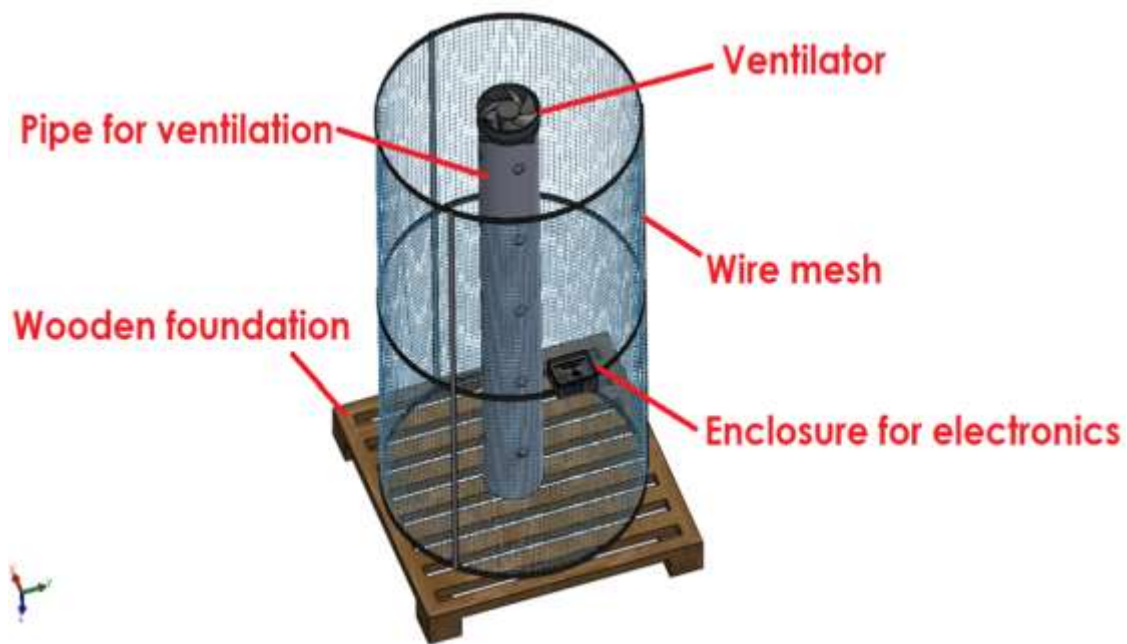
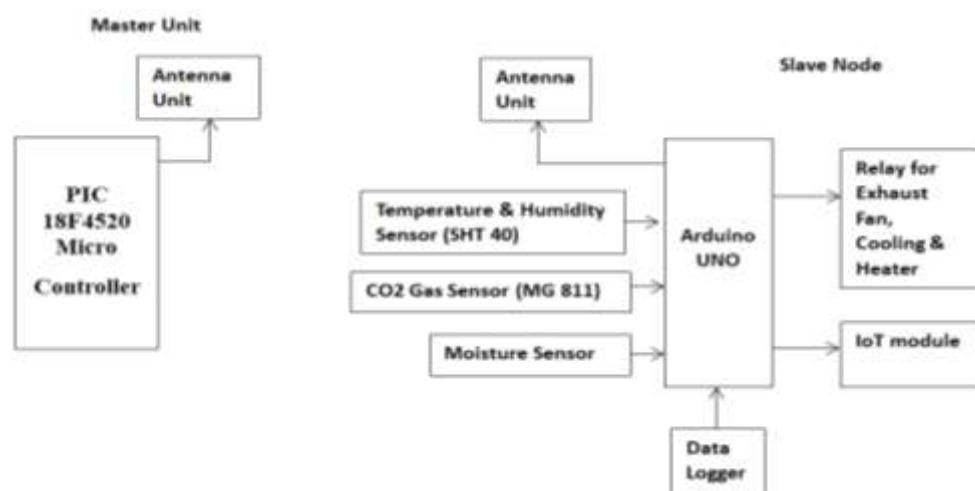


Figure 1: Schematic of prototype

**Figure 2: Block diagram of the onion storage system**

However, when the CO₂ level exceeds the threshold signaling the onset of onion decay, both sensors, including CO₂ and SHT40, are activated. This offers an in-depth understanding of the root scope and characteristics, enabling the implementation of suitable control measures. In addition, when 3-month trials are conducted in a controlled environment, the temperature range should be kept between 25° C and 30° C, relative humidity between 60% to 70%, and the CO₂ range should be less than 800 ppm to reduce the weight loss of onion by up to 10% than traditional onion storage environment [11].

B. Hardware Details

The proposed system is designed to provide robust environmental control by integrating various components that work seamlessly together.

1. Sensor

At its core, the system features an array of sensors that continuously monitor parameters such as temperature and humidity, ensuring the environment remains within predefined thresholds.

1. Temperature sensor and Humidity sensor (SHT 40):

In the onion storage monitoring system, a temperature sensor and a humidity sensor, specifically the SHT 40, are utilized to ensure optimal storage conditions for the onions. The SHT 40 sensor is known for its high accuracy and reliability in measuring both temperature and humidity levels. The SHT04 Digital Humidity and Temperature Sensor Probe is a high-precision sensor designed to provide precise readings of temperature and humidity. It has a capacitive polymer sensor that delivers 1.8% RH accuracy for humidity, making it an excellent choice for applications requiring accurate measurements. The sensor also has a 16-bit resolution, allowing it to measure temperatures ranging from -40 °C to 125 °C and relative humidity from 0% to 100%.

2. Gas sensor (MG811): The MG811 gas sensor, which detects carbon dioxide (CO₂), is used in onion storage monitoring systems to detect the onset of spoilage. As onions decay, they release CO₂, and the MG811 sensor can detect the increase in CO₂ levels, triggering alerts and potentially activating ventilation systems to prevent further spoilage. The device has dimensions of 32 mm in length, 22 mm in width, and 30 mm in height. It offers two types of signal outputs: an analog output and a TTL-level output. The TTL output produces a legitimate low-level signal, which permits direct connection to a microcontroller. The analog output can be configured to operate within a range of 0 to 2V or 0 to 4V, with a customizable default voltage output of 0 to 2V. Notably, this instrument demonstrates high sensitivity and selectivity for carbon dioxide detection, as well as rapid response and recovery characteristics [12].

3. Moisture Sensor: Capacitive moisture sensor detects the water content in the storage environment by changing the dielectric constants of the sensor with add-on benefits like corrosion resistance and low power utilization. The capacitive moisture sensor operates at 3.3-5.5V, draws ~5 mA, and provides an analog output (0-3V).

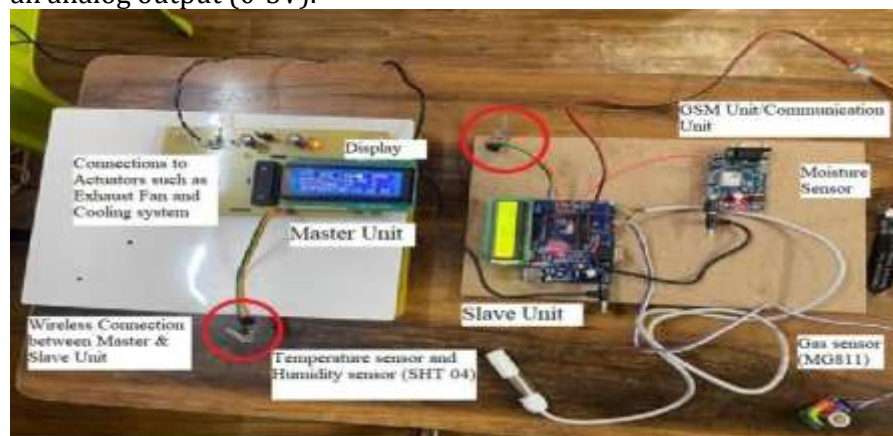


Figure 3: Actual hardware of the Onion quality monitoring system

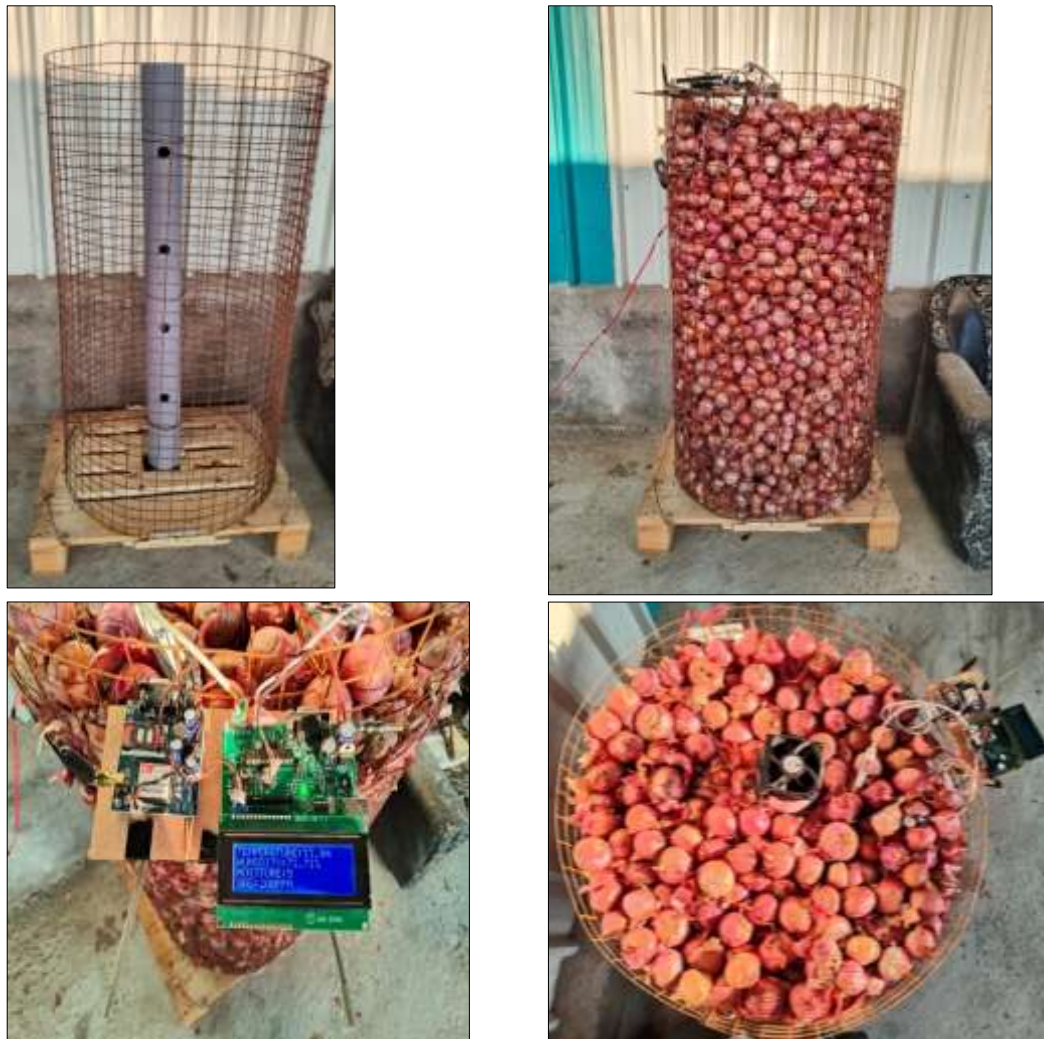


Figure 4: Prototype of onion storage

II. Processing Unit:

Central to the system's operation is a microcontroller, specifically the PIC18F4520, which serves as the brain. This microcontroller processes sensor data in real time, enabling quick decision-making and action. Its versatile capabilities enable the handling of multiple inputs and outputs, ensuring efficient operation of the entire system. The PIC18F4520 serves as the main master control unit in the onion storage monitoring system, while the Arduino Uno acts as the slave unit. The Arduino UNO is connected to various sensors, including temperature, humidity, and gas sensors, as well as actuators such as exhaust fans and cooling systems [13].

III. Control System

In addition to the microcontroller and sensors, a GSM module is incorporated to facilitate remote communication. This allows users to receive alerts and notifications on their mobile devices when environmental conditions deviate from the set thresholds. The GSM module adds a layer of convenience by enabling remote access and control of the system, making it easier to manage the environment from anywhere. To further enhance functionality, the system is connected to a cloud platform. This

connection enables data logging, analysis, and machine-learning algorithms to improve response strategies over time. Users can access historical data and trends through an intuitive dashboard, gaining insights to further optimize the system. Finally, the inclusion of actuators for cooling and heating ensures that the system can respond dynamically to changing conditions. When the sensors detect that temperatures are too high or too low, the actuators will automatically adjust the heating or cooling systems to maintain the desired environment. This automation not only improves efficiency but also prevents potential damage to sensitive equipment or materials. Overall, this comprehensive system ensures continuous monitoring and automated responses, creating a controlled environment that enhances safety and efficiency across various applications. Its ability to integrate multiple technologies makes it a versatile solution for modern environmental management challenges [14].

C. Software details

Onion storage monitoring systems use a variety of software and hardware components to monitor environmental conditions and ensure optimal storage conditions. Key software includes Arduino IDE for programming microcontrollers, cloud platforms like Think Speak for data visualization and remote monitoring, and potentially machine learning algorithms for predictive analysis and automation. Specialized software may also be used for data logging, alert management, and integration with other systems, such as SMS gateways for notifications [15].

I. Arduino IDE and MP lab:

This is the primary software used to program microcontrollers such as Arduino and PIC18F4520, which are often used to collect data from sensors (temperature, humidity, and gas).

II. Cloud Platforms Think Speak:

These platforms receive data from the microcontrollers, allowing for remote monitoring, data visualization (charts and graphs), and potentially remote control of the storage environment.

III. Visual Studio Code:

The Visual Studio platform is used to draw graphs of recorded temperature, humidity, and rotten gas readings. Jupyter Notebook and Python extensions are installed to analyze data collected from ThingSpeak.

VI. System Workflow

To prevent onion rotting, IoT and AI are being used to detect it early during storage. Continuously collecting data from hardware components and given to advanced machine learning algorithms. This system's sensors consist of SHT40 and MG 811, which always capture real-time data important for monitoring the health status of onions. The PIC18F4520 uses this data to guide a decision-making mechanism that evaluates the sensor inputs in detail. Its main purpose is to reduce the spoiling and early detection of the sprouting of onions, which rot away [12].

The flow of the proposed system is shown in Figure 4. Onion is stored in the storage, where the sensor measures temperature, humidity, and CO₂ levels. CO₂ gas is the most effective gas for detecting onion quality and is thus used as a primary indicator. Then, the SHT40 and MG 811 readings are compared against their thresholds to assess the health and onset of rot in the emitted onion emissions.

If the onion begins to decay, both sensors are activated, and control actions such as the exhaust fan are triggered. The sensor's readings are then sent to

the cloud. The GSM module facilitates communication between the device and the cloud platform (e.g., Think Speak) by sending data over the cellular network. The GSM module establishes communication to the cell network, enabling data transmission even in remote locations. It uses a SIM to access the network [16].

Bluetooth modules are used to connect the slave unit to the master unit. This setup allows real-time information to be provided to farmers. It leverages Think-Speak Cloud with an SQL database for data storage and continuous monitoring to minimize waste and enhance efficiency. The software design monitors temperature and makes necessary changes to the ON/OFF fan, while also checking humidity and adjusting the ON/OFF exhaust fan to alert farmers about the actions taken [17].

The controllers use sensor inputs to process data and deliver it to a server. The server compares the data to threshold values and warns farmers to prevent onions from spoiling, sprouting, or rotting. Farmers may remotely monitor onions to ensure their quality throughout storage. This helps reduce post-production losses.

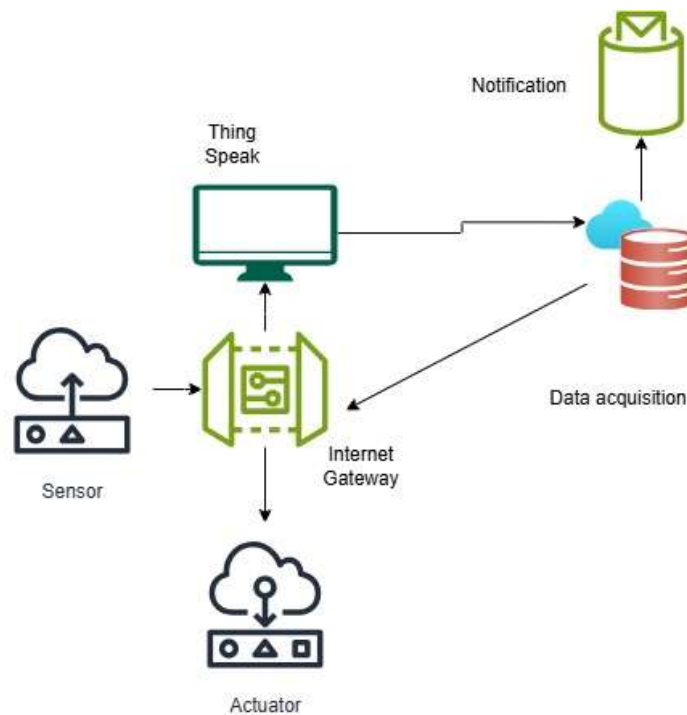


Figure 4: Flow of the system

IV. RESULTS AND DISCUSSION

Detection of onion wastage during storage using IoT and AI involves monitoring environmental conditions in the storage facility. This is achieved using SHT04 temperature and humidity sensors and MG 811 carbon dioxide gas sensors during both

storage and transportation. Data is analyzed to obtain information on temperature, humidity, and gas levels in the storage. The system uses ThingSpeak to analyze data gathered from all sensors. This method enables the detection of gas emitted by rotten onions. A detection program categorizes onions as either healthy, moderately healthy, or rotting based on real-time sensor data and previous datasets.

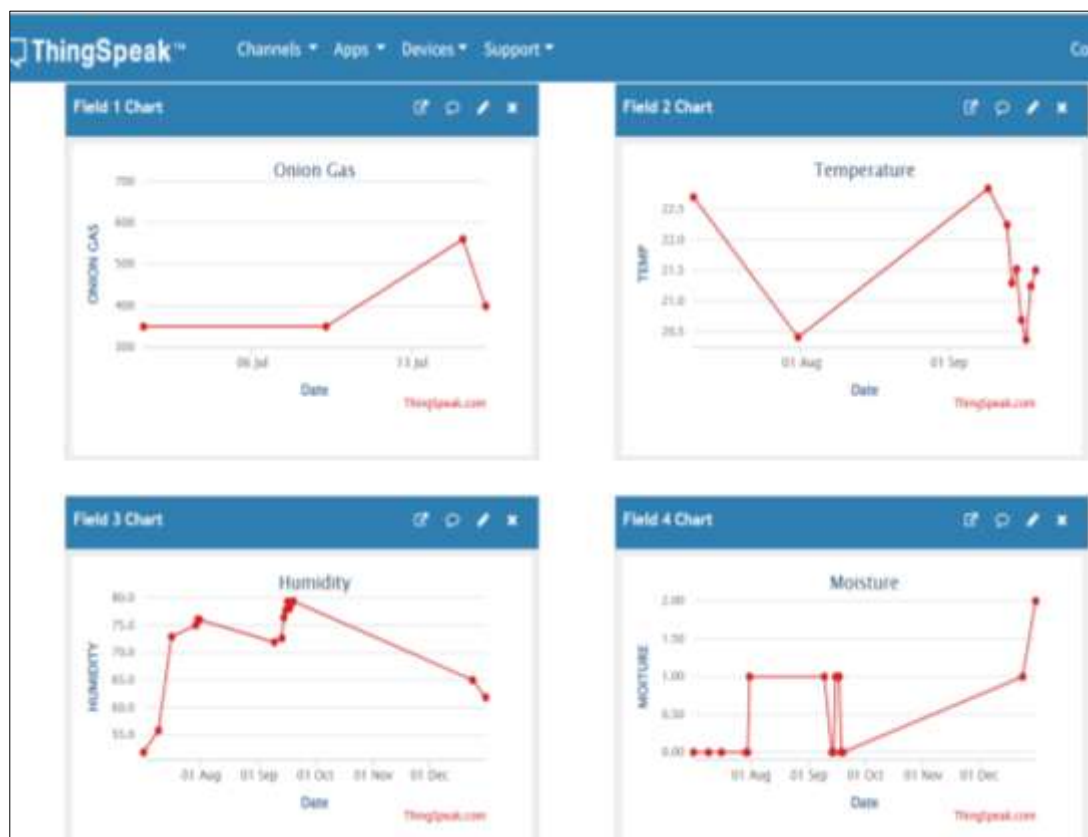
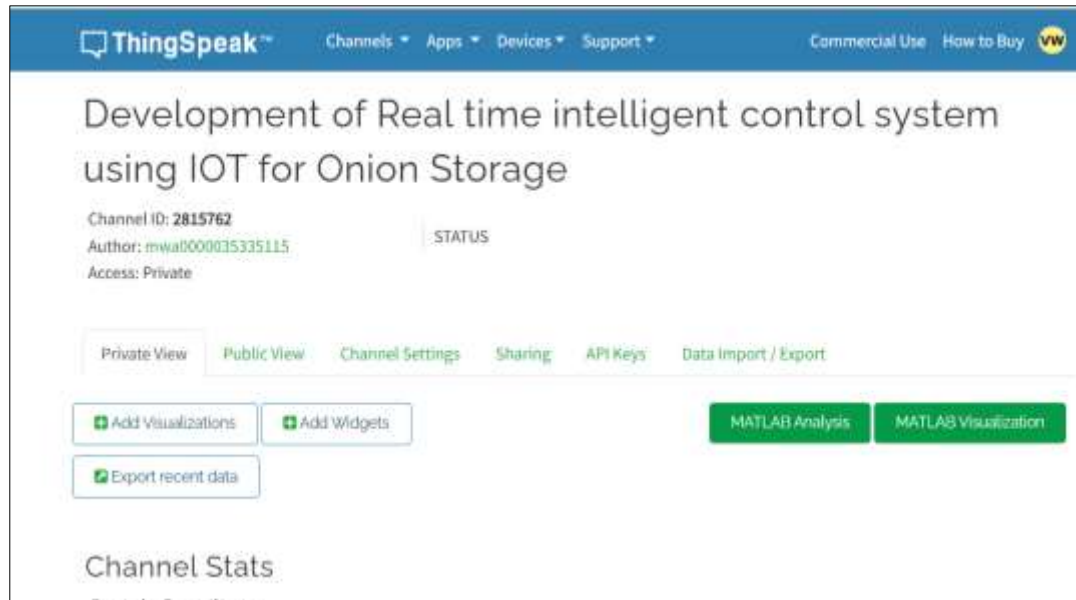


Figure 5: Data Collected at ThingSpeak

The onion monitoring system collected data for approximately three months, from March to May 2025. We gathered hourly readings of the minimum and maximum temperatures, humidity, and the amount of rotten gas emitted by onions.

Collected data is then analyzed in MATLAB and in ThingSpeak itself against the threshold levels for the sensing parameters. A MATLAB script is run every 1 hour under the TimeControl tab, and SMS notifications are sent via the ThingHTTP features, with control of the exhaust fan under the TalkBack tab. This data is presented in the following figures 6 (a), 6 (b), 6 (c) are drawn using VS Code:

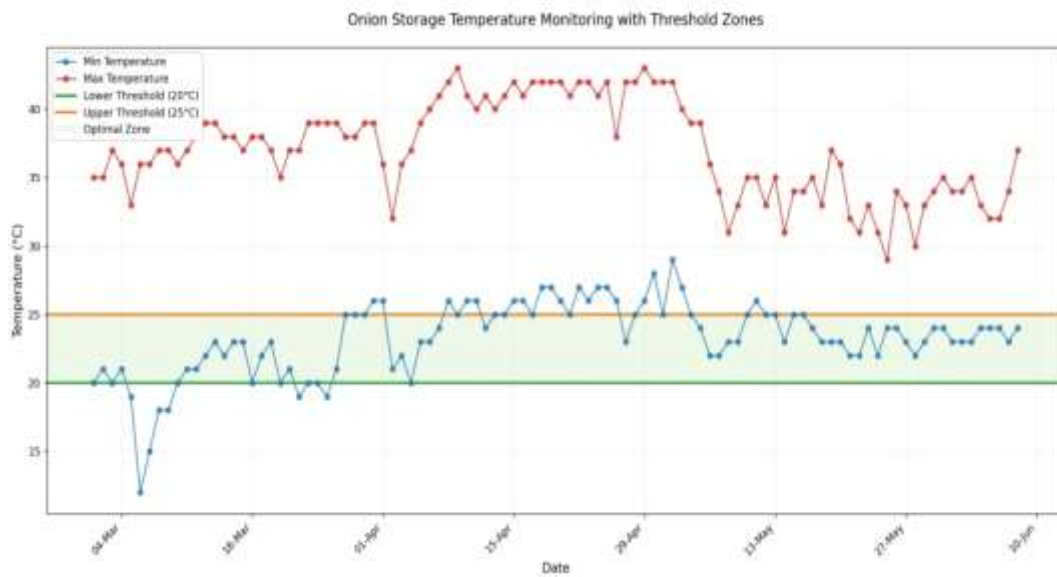


Figure 6(a) Minimum and Maximum temperature recorded by the sensor from 1st March to 8th July 2025, with a threshold of 20° C to 25° C

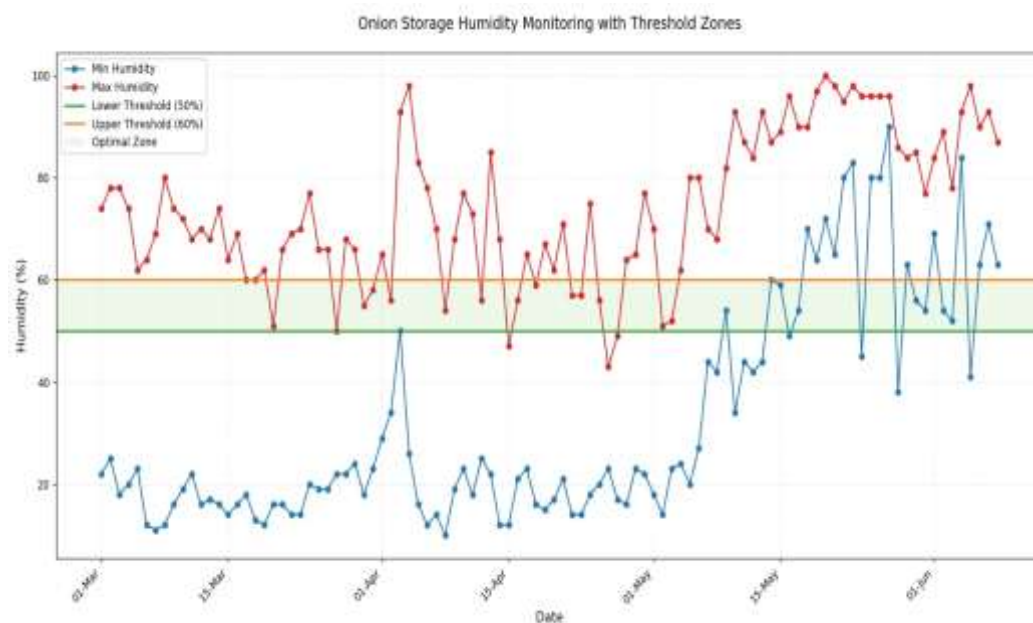


Figure 6(b) Minimum and Maximum Relative Humidity recorded by the sensor from 1st March to 8th July 2025, with a threshold of 50 % to 60 %.

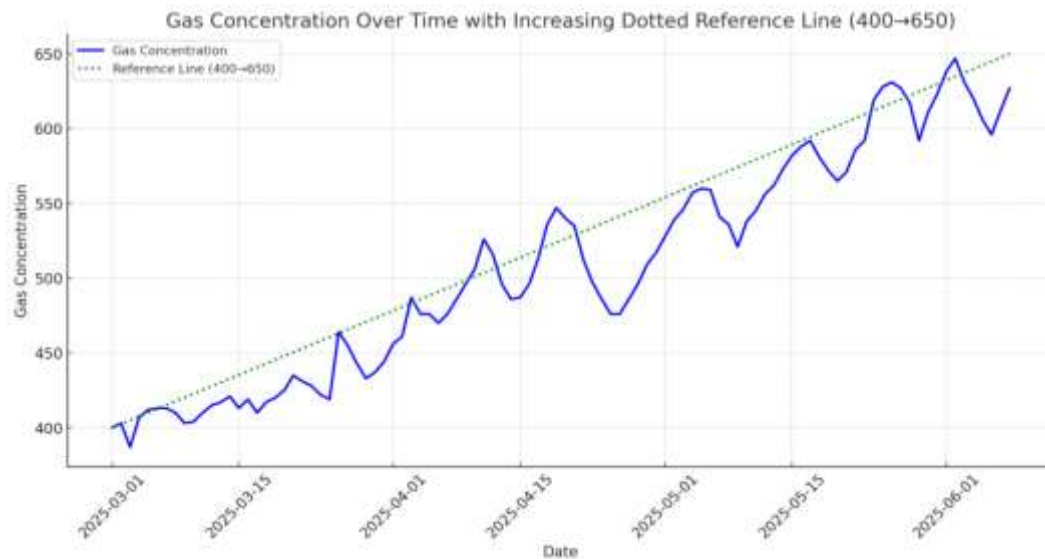


Figure 6(c) CO₂ gas recorded by the sensor from 1st March to 8th July 2025, in the onion storage.

All this data was input into a regression algorithm in MATLAB, using the Machine Learning Analysis tab in ThingSpeak, to predict when the rooting process would begin. This prediction helps determine the optimal time to market the onions shown in Figure 7.

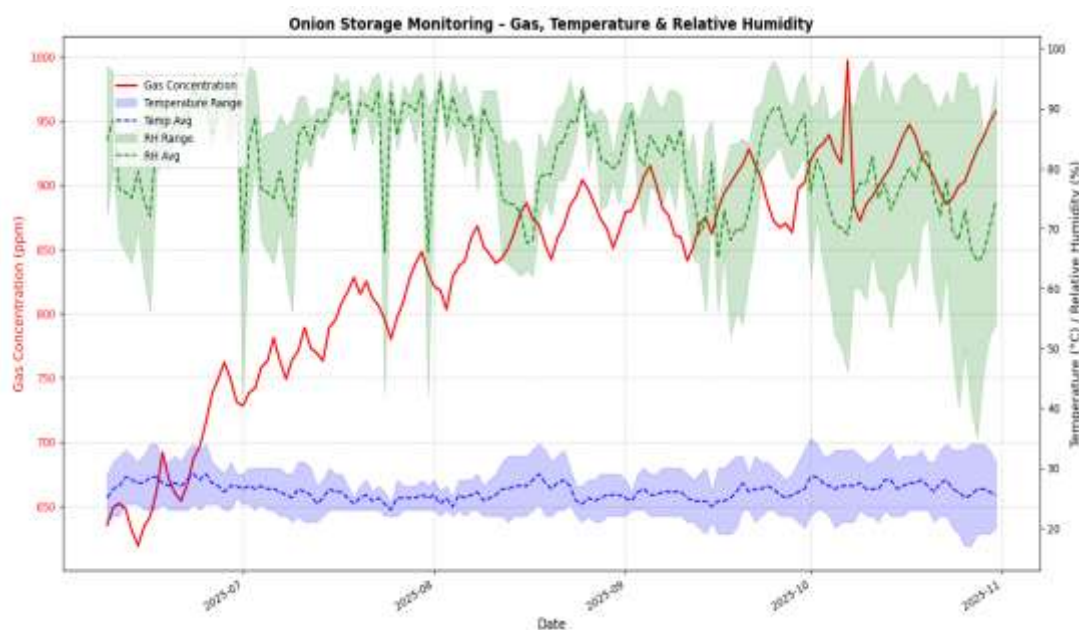


Figure 7: Presents all the parameters for prediction

To maintain a healthy environment for the onions, it is essential to keep the temperature between 20° C to 25° C and the humidity between 50 % and 60 %. Additionally, the emitted gas should remain in the range of 700 ppm to 800 ppm. To control these parameters within the lower and upper thresholds, exhaust fans, cooling, and heating systems will be activated through relays.

If the system identifies low-quality onions or changes in storage conditions, it will send alert notifications. These alerts will be sent to farmers' designated cellphones via SMS, and the system will also update the status on a webpage.

Proposed system: Activating MG 811, SHT40 Sensors When Onions are in Good Condition and MG 811, SHT40 Sensors When Onions Begin to rot (CO₂ exceeds a specific threshold).

Table 1 displays the approximate detection ranges for sensors, indicating the healthy emission, the start time of emission, and the rotted emission from onions. It provides information on CO₂, temperature, and humidity ranges for three stages of onion quality: healthy onions, onions at the start of rotting, and fully rotted onions. The experimentation is carried out at various times for three different categories of onion, i.e., healthy, medium-level rotted, and high-level rotted onion.

Table 1: Detection Ranges

Parameter	Healthy Emission	Rotting Start time	Rotted Emission
CO ₂	700ppm to 800ppm	800 ppm to 2000ppm	2000ppm to 5000ppm
Temperature	0°C to 25°C	25° C to 40°C	40°C to 55°C
Humidity	50% to 60%	60% to 70%,	70% to 90%

V. CONCLUSION & FURTHER WORK

This paper presents a cost-effective solution for monitoring onions in a Small Unit using CO₂ gas sensors, along with temperature and humidity sensors such as the SHT40. CO₂ has been identified as the most accurate gas for assessing onion quality. To optimize cost, basic sensors are used; moreover, the proposed system is scalable, portable, small in size, and low-power operated. Multiple devices can be deployed in large warehouses without changing their design. Predictions for all parameters are made in VS Code.

In the future, maintaining a healthy environment for onions will be supported by cloud technology. All relevant data will be collected and stored using Think Speak. This data will then be automatically analysed through ANN algorithms, followed by filtering processes in Python. Intelligent decisions will be made using algorithms, and these decisions will be communicated to the onion storage via an IoT platform. As a result, the environment for the onions will be maintained automatically, ensuring optimal growing conditions with the help of a cooler, heater, humidifier, and dehumidifier. For future design prediction, forecasts of all parameters are made using ANN algorithms.

Declarations: All authors declare that they have no conflicts of interest.

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