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IoT Based Onion Storage System

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ABSTRACT: Post-harvest loss of onions is a significant challenge, with 40–50% spoilage occurring in India due to improper storage conditions. Inadequate temperature and humidity control, combined with insufficient monitoring of weight loss, results in rot, sprouting, and microbial damage. This study presents a cost-effective IoT-based smart onion storage system that integrates temperature, humidity, and weight sensors with automated fan and alternative light/heat units. The system monitors environmental conditions in real-time, sends mobile alerts to farmers when thresholds are breached, and predicts weight-loss trends to prevent spoilage. Solar power ensures sustainability for rural and off-grid deployment. The proposed system demonstrates improved shelf life, reduced post-harvest losses, and provides actionable guidance to farmers, offering a practical and scalable solution for medium and small-scale onion storage operations.

KEYWORDS: IoT, Smart Storage System, Onion Storage, Temperature Monitoring, Humidity Control, Weight Monitoring, ESP32, DHT22 Sensor, Load Cell, Automated Climate Control, Post-Harvest Loss Reduction, Solar-Powered System.

I. INTRODUCTION

Onion is one of the most important commercial vegetable crops in India, widely used in daily cooking and contributing significantly to the agricultural economy. Despite its high production, a major portion of harvested onions is lost during storage due to poor post-harvest management practices. Small and medium-scale farmers, in particular, rely on traditional storage structures that lack proper ventilation, insulation, and environmental control mechanisms. As a result, onions are highly susceptible to spoilage caused by excessive moisture, temperature fluctuations, sprouting, and microbial infections. These factors not only reduce the shelf life but also decrease the market quality and economic value of the produce.

Maintaining optimal storage conditions is essential to minimize these losses. Research indicates that onions require a controlled environment with temperatures ranging between 35–50°C and relative humidity levels of 65–70% to prevent sprouting and decay. However, continuous manual monitoring of these parameters is labor-intensive, inaccurate, and often impractical for farmers. While cold storage facilities can effectively control environmental conditions, their high installation and operational costs make them inaccessible for many rural farmers.

In recent years, the advancement of Internet of Things (IoT) technology has opened new possibilities in agriculture by enabling real-time monitoring, automation, and remote control. IoT-based systems can continuously collect environmental data, analyze it, and automatically take corrective actions without human intervention. This project focuses on developing a smart onion storage system that leverages IoT technology to address the limitations of traditional storage methods. By integrating temperature and humidity sensing, automated climate control using fans and heating elements, real-time weight monitoring, and mobile-based alert systems, the proposed solution ensures optimal storage conditions. This not only reduces post-harvest losses but also empowers farmers with timely information and decision-making support, making the system efficient, affordable, and practical for real-world applications.

II. LITERATURE REVIEW

1. Wakchaure & Pawase (2025) emphasized the importance of real-time temperature and humidity monitoring in onion storage. Their study proved that maintaining stable environmental parameters significantly increases shelf life and reduces sprouting losses. However, their work mainly focused on monitoring rather than automated control.

2. Kadam et al. (2024) proposed structural improvements in traditional onion storage systems by integrating sensors. Their research highlighted how ventilation design combined with sensing technology can improve storage efficiency, but automation features were limited.

3. Mokshi et al. (2019) developed a GSM-enabled alert system that sends notifications to farmers when environmental parameters cross safe limits. This approach improved remote monitoring capability, though it did not include integrated weight-based quality analysis.

4. Gawade et al. (2025) introduced gas-sensing techniques for early spoilage detection. Their system focused on detecting harmful gases released during decay, which helps in identifying spoilage at an early stage.

5. Godase et al. (2025) discussed IoT-driven storage optimization models aimed at improving farmer profitability and supply-chain stability. Their study highlighted the economic benefits of smart storage systems.

III. STEP-BY-STEP ALGORITHM

Step 1: Initialize system
Step 2: Read Temperature (T)
Step 3: Read Humidity (H)
Step 4: Read Weight (W)
Step 5: If $T < T_{min}$ → Turn ON Heater
Else → Turn OFF Heater
Step 6: If $T > T_{max}$ → Turn ON Exhaust Fan
Else → Turn OFF Fan
Step 7: If $H > H_{max}$ → Turn ON Fan
Step 8: Calculate Weight Loss = $W_{initial} - W$
Step 9: If Weight Loss > Threshold → Display "Moisture Loss Warning"
Step 10: Log Data
Step 11: Repeat Process (Continuous Loop)

IV. MATERIALS

4. 1. DHT22 Sensor:
The DHT22 sensor is used to measure both temperature and relative humidity inside the storage unit. It provides digital output, which can be directly read by the ESP32 microcontroller. The sensor has a temperature measurement range of -40°C to 80°C with good accuracy, making it suitable for various environmental conditions. It also measures humidity in the range of 0% to 100% relative humidity. The sensor continuously monitors these parameters and sends real-time data to the controller. This data is used to maintain optimal storage conditions and prevent spoilage. Its wide range and reliable performance make it ideal for agricultural applications like onion storage.

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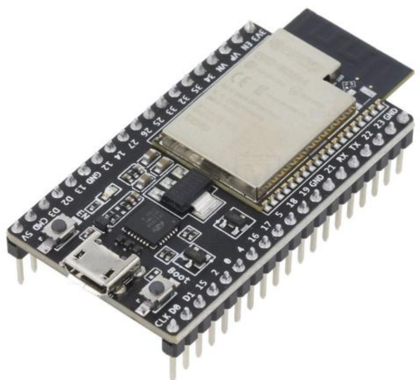
4.2. Load Cell with HX711 Module:

The load cell is used to measure the weight of the stored onions and plays an important role in detecting spoilage. In this project, a 5 kg load cell is used, which means it can accurately measure weight up to 5 kilograms. It converts the applied weight into a small electrical signal, which is then amplified by the HX711 module for accurate digital output. The ESP32 reads this data and monitors changes in weight over time. Gradual weight loss indicates moisture loss, while sudden drops may indicate damage or spoilage. This helps farmers take early action. The 5 kg capacity is suitable for small-scale storage monitoring.

4.3. ESP32 Microcontroller:

The ESP32 microcontroller acts as the brain of the system, controlling all operations and data processing. It operates at 3.3V and includes multiple GPIO pins for connecting sensors and output devices. It reads data from the DHT22 sensor and load cell, processes it based on predefined threshold values, and controls the fan and heating system accordingly. The ESP32 also has built-in Wi-Fi capability, which allows it to send real-time data to cloud platforms and mobile applications. It supports fast processing and efficient communication. This makes the system smart and fully automated. Its compact design and performance make it suitable for IoT applications.



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4.4. Cooling Fan:

The cooling fan is used to regulate temperature and humidity inside the storage unit. It typically operates at 5V or 12V depending on the model used. The fan is activated when the temperature or humidity exceeds the predefined limits set in the system. It helps in removing excess heat and moisture by improving air circulation. This prevents fungal growth and spoilage of onions. The operation of the fan is controlled by the ESP32 through a relay module. It ensures proper ventilation and maintains a stable environment inside the storage.

4.5.4-Channel Relay Module:

The relay module is used to control high-voltage devices using low-voltage signals from the ESP32. It usually operates at 5V and can control multiple devices through its four channels. Each channel can switch devices like fans, lights, or heaters ON or OFF. The relay provides electrical isolation between the control circuit and the load circuit, ensuring safety. It receives signals from the ESP32 and performs switching operations accordingly. This makes it possible to automate the system efficiently. It is an essential component for controlling external devices.

4.6. Light / Heating Element:

The light or heating element is used to maintain the required temperature inside the storage unit. It operates on electrical power and is activated when the temperature falls below the set threshold. This helps in preventing excessive cooling and moisture buildup. The heating element works in coordination with the fan to maintain a balanced environment. It is controlled by the ESP32 through the relay module. This ensures automatic temperature regulation. It improves storage efficiency and prevents spoilage.

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4.7.LCD Display

The LCD display is used to provide real-time visual information about the system's operation. It typically displays parameters such as temperature, humidity, and weight, allowing users to monitor conditions directly. The display is connected to the ESP32 and updates continuously as new data is received. It is especially useful in situations where internet access is limited, as it provides on-site monitoring capability. The LCD enhances user interaction and makes the system more user-friendly. It also helps in quick verification of system performance without the need for external devices. Thus, it improves the overall usability of the project.

4.8 .Jumper Wires

Jumper wires are used to establish electrical connections between different components in the circuit. They are flexible wires that help in transferring signals and power between the ESP32, sensors, relay, and other devices. These wires come in different types such as male-to-male, male-to-female, and female-to-female, depending on the connection requirements. Jumper wires make the setup easy to assemble and modify during testing. They eliminate the need for permanent soldering, which is beneficial during the development stage. Their flexibility and ease of use make them an essential part of prototyping. Overall, they ensure smooth connectivity within the system.

4.9. Breadboard

The breadboard is a solderless prototyping platform used to assemble and test electronic circuits. It contains a network of interconnected holes that allow components to be inserted and connected easily. The breadboard enables quick circuit construction and modification without damaging components. It is especially useful for beginners and for testing different configurations. All components such as sensors, ESP32, and jumper wires are connected using the breadboard. It helps in organizing the circuit neatly and reduces wiring complexity. Thus, the breadboard plays a key role in developing and testing the system efficiently.

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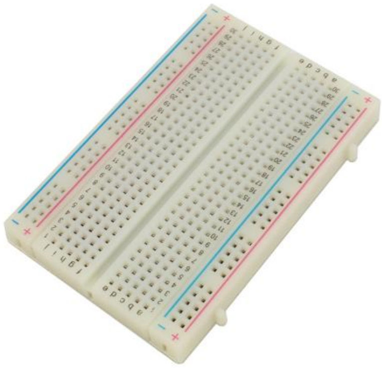

4.10. Connector Block

The connector block is used to provide secure and organized electrical connections between wires. It helps in joining multiple wires safely and ensures proper current flow without loose connections. These blocks are especially useful for connecting power supply lines and high-current components. They improve safety by reducing the risk of short circuits and accidental disconnections. The connector block also makes maintenance and troubleshooting easier. It provides a clean and professional wiring setup. Hence, it is an important component for reliable system integration.

4.11. Switch and Socket

The switch is used to manually control the power supply of the system, allowing users to turn it ON or OFF when required. The socket is used to connect external electrical devices and power sources. Together, they provide convenience and safety in operating the system. The switch ensures that the system can be controlled easily without disconnecting wires. The socket allows proper connection of power inputs. These components are essential for user-friendly operation and electrical safety. They also help in protecting the system from improper handling.

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4.12. Battery

The battery acts as an energy storage device that supplies power to the system when required. It stores electrical energy generated by the solar panel and provides a continuous power supply during night time or low sunlight conditions. This ensures uninterrupted operation of the system. The battery is essential for maintaining system reliability, especially in rural areas with unstable electricity. It also helps in reducing dependency on external power sources. Thus, it plays a crucial role in ensuring continuous monitoring and automation.

4.13.Solar Panel

The solar panel is used to generate electrical energy from sunlight and serves as a renewable power source for the system. It converts solar energy into electrical energy, which is then stored in the battery. This makes the system energy-efficient and environmentally friendly. The use of solar power is especially beneficial in rural and off-grid areas where electricity supply is limited. It reduces operational costs and ensures sustainability. The solar panel enables continuous functioning of the system without relying on conventional power sources. Hence, it is an important component for long-term operation.

4.14. ThingSpeak

The web server provided by ThingSpeak™ was used. Free service of the server was used for the prototype. ThingSpeak is an IoT analytics platform service that allows users to aggregate, visualize and analyse live data streams in the cloud (Nasution et al., 2019). ThingSpeak provides instant visualizations of data posted by the devices to ThingSpeak. It can also execute MATLAB® code. ThingSpeak was used to communicate the data to web server and to analyse and visualize the data.

V. COST ESTIMATION

Component	Quantity-	Cost (INR)
ESP32	1-	700
DHT22 Sensor	1-	600
Load Cell (5kg) + HX711	1-	550
Relay Module (4-channel)	1-	400
Cooling	1-	500

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Light / Heater	1-	400
LCD Display	1-	300
Breadboard & Jumper Wires	1-	400
Connector Block, Switch, Socket	1-	450
Battery	1-	1200
Solar Panel	1-	1800
Miscellaneous (casing, wiring, setup)		700
Total Estimated Cost-		₹9000 (Approx.)

VI. BLOCK DIAGRAM

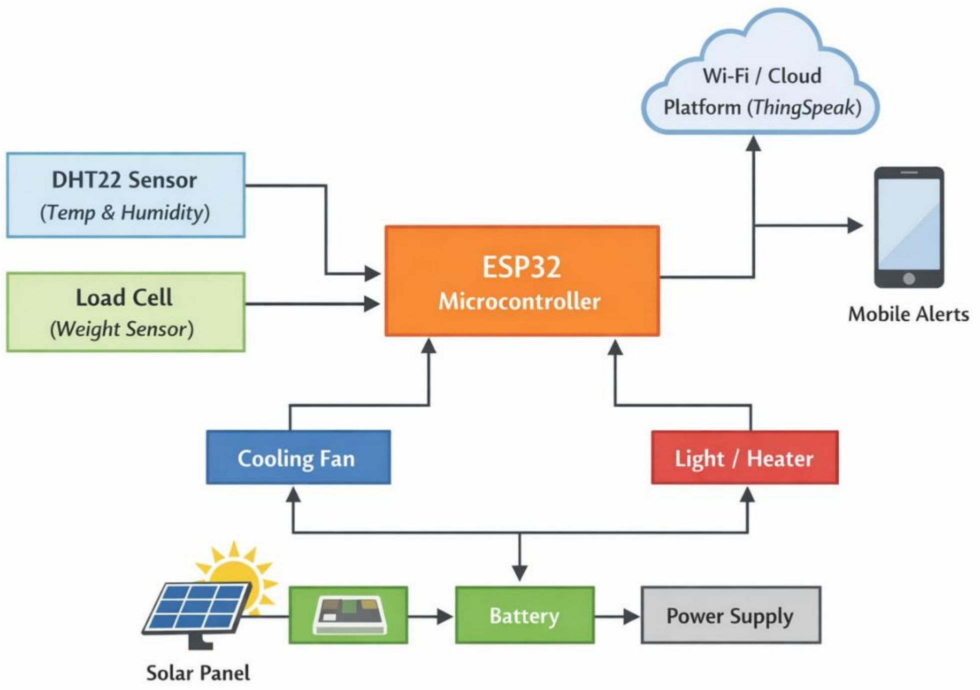

Fig.1 Block diagram of onion storage system

VII. WORKING

The proposed IoT-based smart onion storage system operates through continuous sensing, data processing, automated control, and real-time communication. The DHT22 sensor measures temperature and humidity, while the load cell with HX711 monitors the weight of stored onions. These sensor values are sent to the ESP32 microcontroller, which processes the data and compares it with predefined threshold values.

Based on the conditions, the ESP32 automatically controls the system. If temperature or humidity exceeds the limit, the cooling fan is activated through the relay module. If the temperature drops below the required level, the heating element or light is switched ON to maintain a stable environment. This ensures proper storage conditions without manual intervention.

The system also tracks weight continuously to detect moisture loss or spoilage. When abnormal weight changes are detected, an alert is sent to the user through Wi-Fi. All data is uploaded to a cloud platform for real-time monitoring and analysis. The system is powered by a solar panel with battery backup, ensuring continuous operation.

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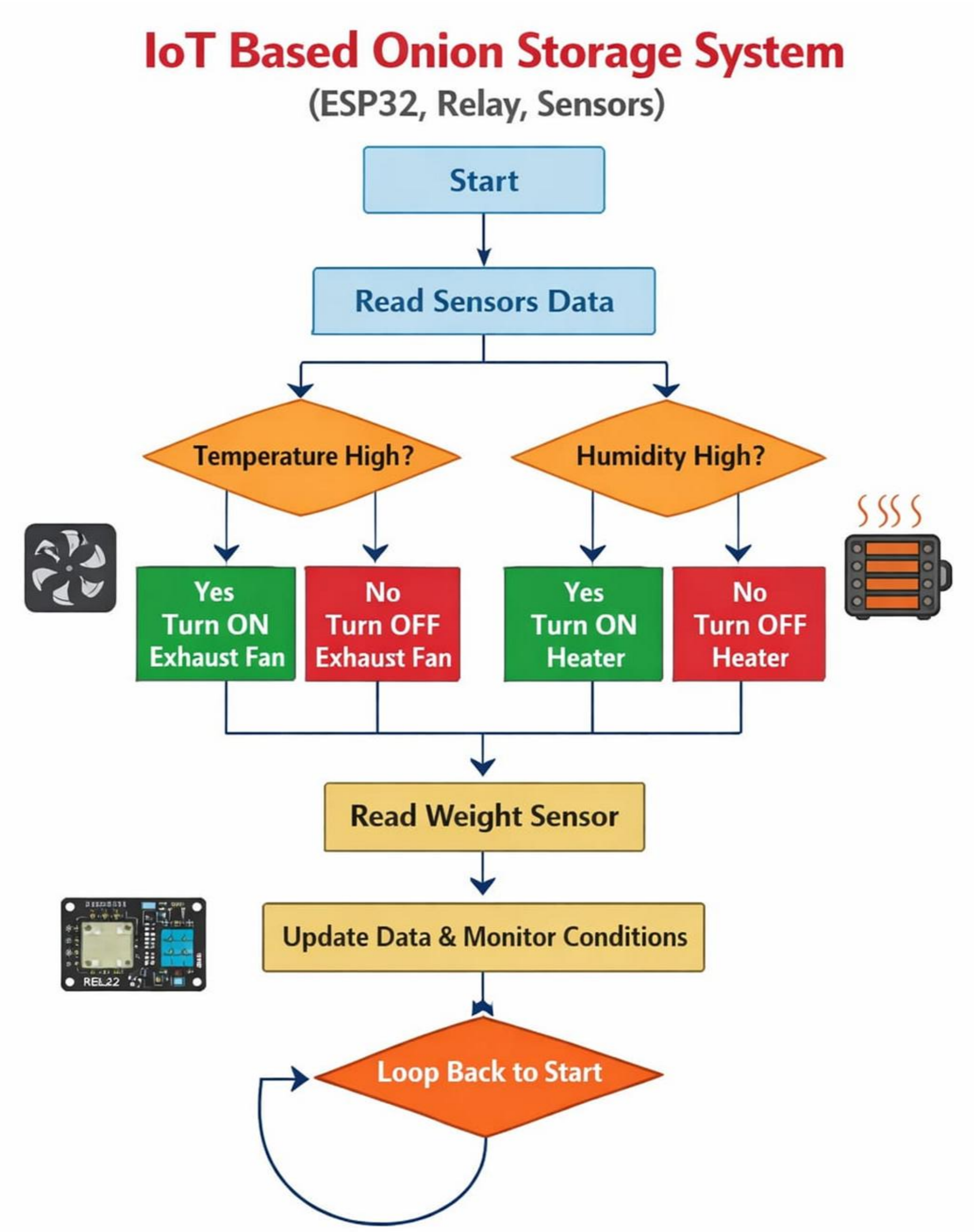
VIII. METHODOLOGY



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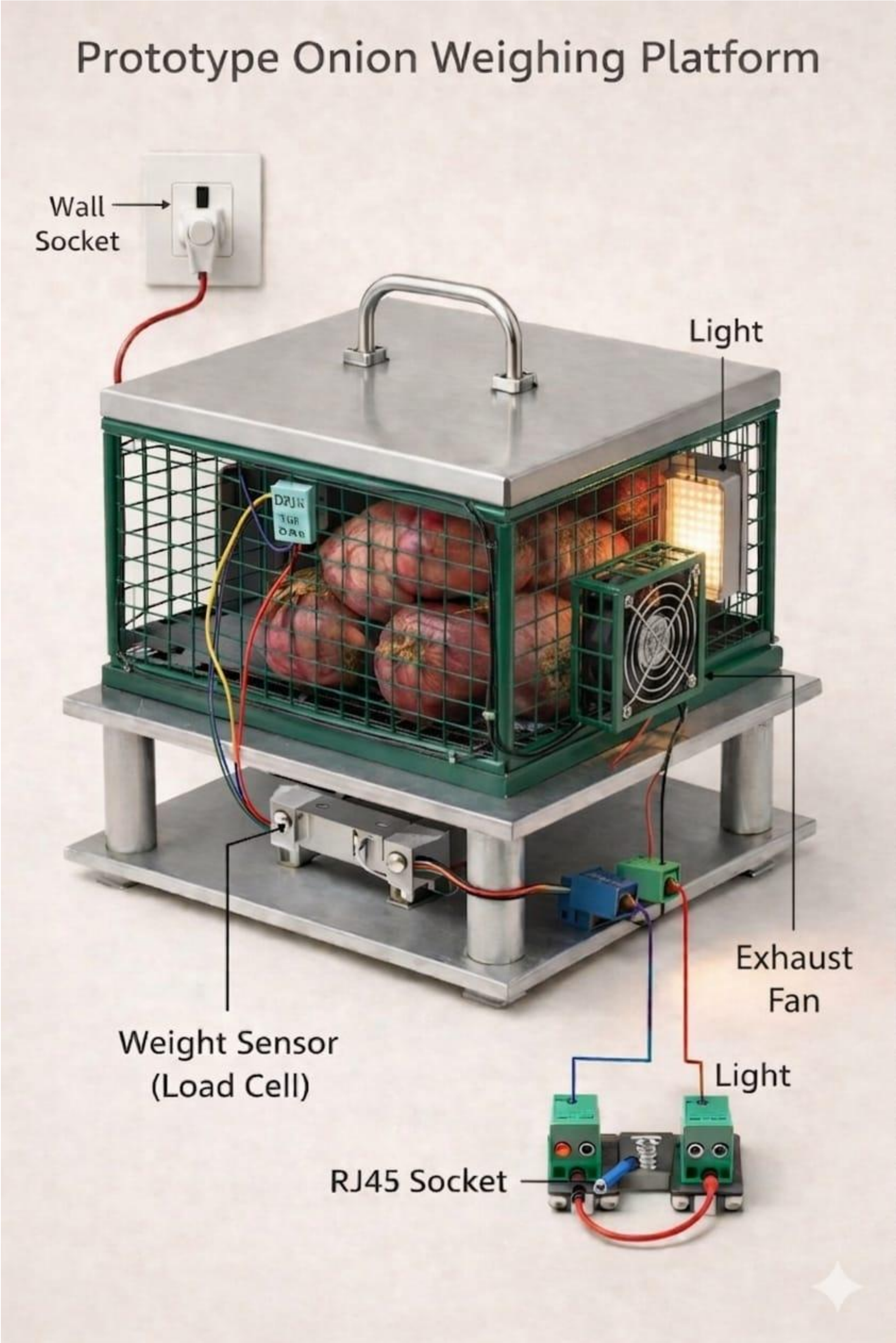
IX. PROPOSED WORK



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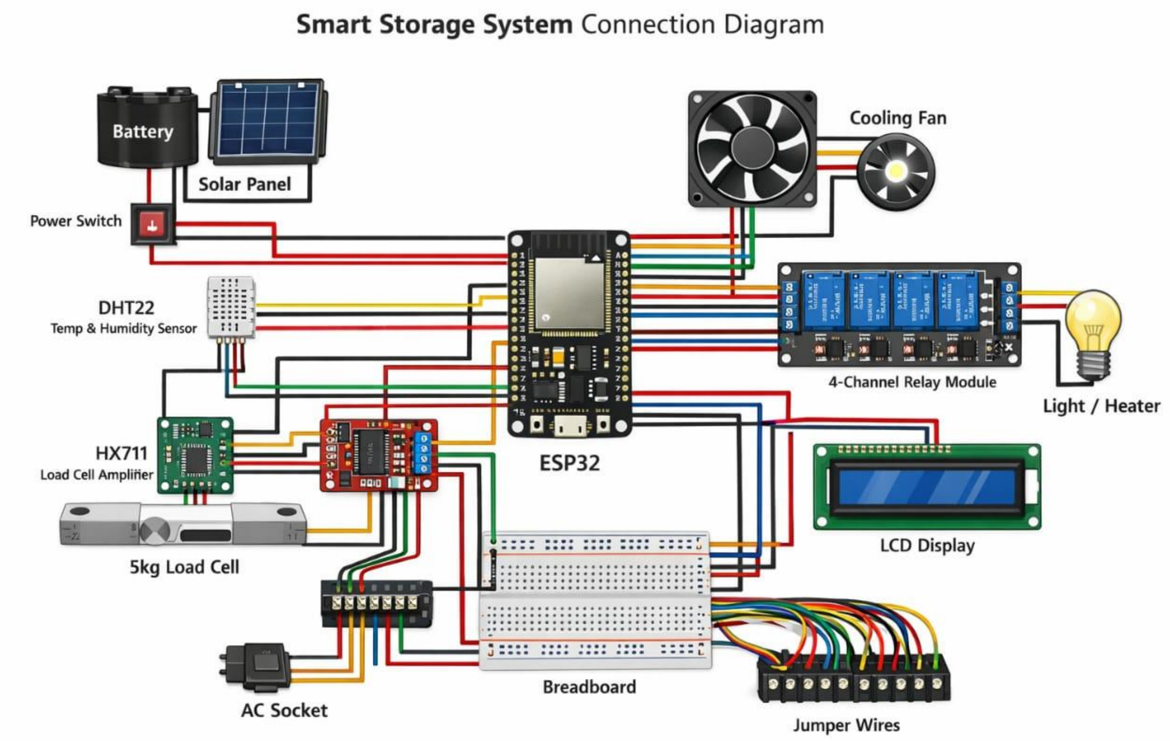
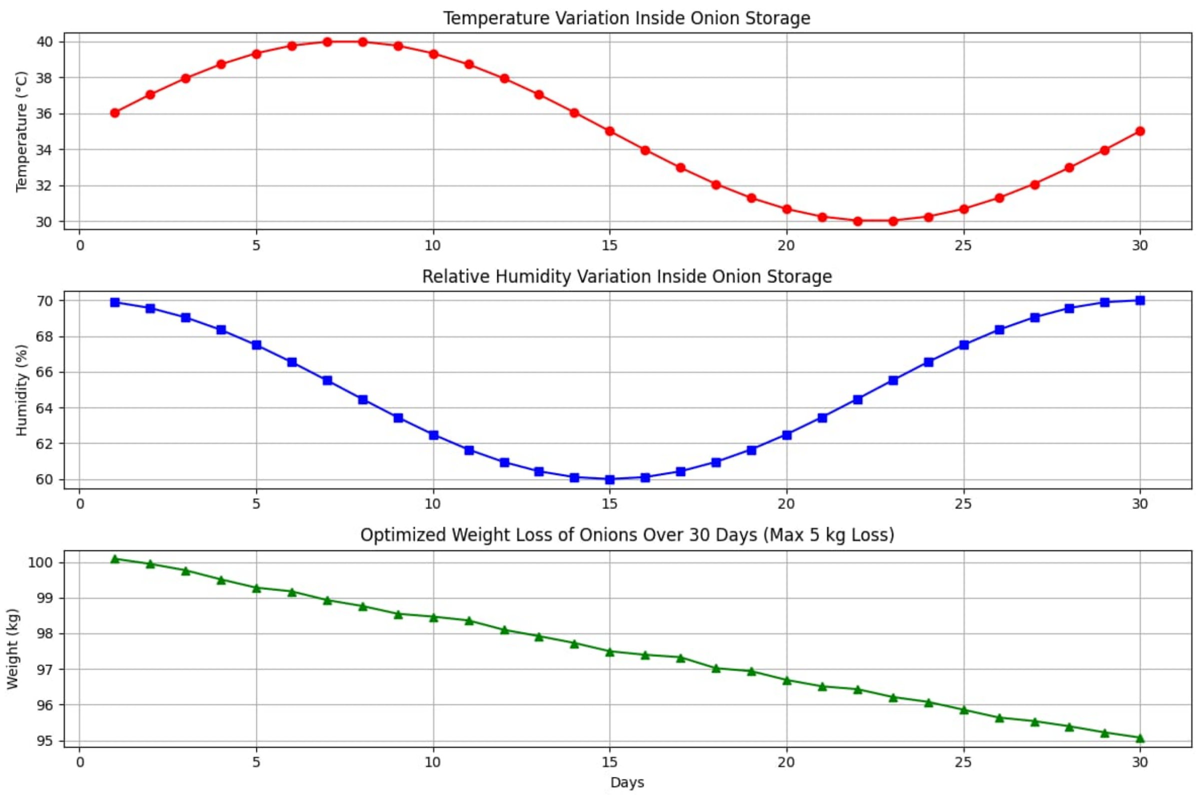
X. CIRCUIT DIAGRAM



XI. MODEL GRAPH



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XII. RESULTS AND DISCUSSION

The IoT-based onion storage system successfully maintained temperature and humidity within the optimal range, minimizing sprouting and microbial activity. Automated fan and light/heat units effectively regulated the internal environment, ensuring consistency and reducing post-harvest losses. The load cell accurately monitored weight, detecting gradual moisture loss, and triggered mobile alerts when weight reduction exceeded acceptable limits. Predictive analysis of weight trends allowed farmers to anticipate spoilage and take timely corrective action. The solar-powered operation ensured continuous monitoring and automation, making the system practical for rural areas with limited electricity. Overall, the system demonstrated significant improvements over traditional storage methods by extending storage duration, maintaining quality, and providing real-time actionable information to farmers.

XIII. ADVANTAGES

The proposed IoT-based smart onion storage system offers several advantages in improving storage efficiency and reducing post-harvest losses. It provides continuous monitoring of temperature, humidity, and weight, ensuring optimal storage conditions at all times. The automated control of fan and heating elements reduces the need for manual intervention, making the system easy to use for farmers. The integration of a load cell helps in detecting early weight loss, allowing timely action to prevent spoilage. The system is cost-effective and suitable for small and medium-scale farmers. The use of solar power ensures energy efficiency and makes it ideal for rural and off-grid areas. Additionally, real-time alerts and cloud monitoring improve decision-making and storage management.

XIV. CONCLUSION

This study presents an IoT-based smart onion storage system that integrates real-time environmental monitoring, automated climate control, weight tracking, mobile alerts, and predictive analysis. The system is affordable, scalable, and suitable for small and medium-scale farmers, particularly in rural areas. Solar-powered operation ensures sustainability and reliability. The combination of automated climate regulation, weight monitoring, and predictive analytics effectively reduces post-harvest losses and improves shelf life. Future work may include AI-based predictive models, automated refrigeration integration, and expansion of the system for larger-scale storage operations, further enhancing efficiency and farmer support.

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